The Effects of Testosterone on Susceptibility to the Rubber Hand Illusion

Teneille A. Page (PGXTEN001)

Supervisors: Donné van der Westhuizen & Prof. Mark Solms

Department of Psychology

University of Cape Town

Word Count: 9538

PLAGIARISM

DECLARATION

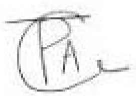
1. I know that plagiarism is wrong. Plagiarism is to use another's work and to pretend it is one's own.

2. I have used the *American Psychological Association (APA)* convention for the citation and referencing. Each significant contribution to, and quotation in, this essay/ report/ project/ from the work, or works, of other people has been attributed and has been cited and referenced.

3. This essay/ report/ project / is my own work

4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

5. I acknowledge that copying someone else's assignment or essay, or part of it, is wrong, and declare that this is my own work.



SIGNATURE: ______________________

Teneille Ashleigh Page

Abstract

The Rubber Hand Illusion (RHI), a novel paradigm for investigating the sense of body ownership, demonstrates that neural representations of the self are not rigid schemas but are malleable, altered not only by external perceptions of the body but also by emotional factors such as trait empathy. Specifically, it is thought that flexibility of the body schema may play an important role in social perspective-taking, enabling one to mentally simulate and experience another's action. Given that the steroid hormone, testosterone, has been shown to impair one's ability to experience certain forms of empathy, it is hypothesised that the hormone will modulate susceptibility to the RHI. This idea is supported by findings that sex hormones may have an effect on several bodily processes involved in the induction of the illusion (e.g. proprioception; interoception). As such the present study sought to investigate the effects of testosterone in women on bodily self-representations by determining its influence on the RHI, which was operationalised in terms of proprioceptive drift, skin temperature change and a self-report questionnaire. A double blind, randomised, placebo controlled trial was carried out in a culturally diverse sample of students from the University of Cape Town. Results indicate that testosterone does not appear to influence the subjective phenomenological experience of ownership over a fake limb. However, participants who received testosterone showed an increase in temperature in their own limb rather than exhibiting a drop in limb temperature as was seen in the control group. This finding reflects maintenance of homeostatic regulation over the experimental hand in the testosterone group and suggests that the thermodynamic response of the illusion can be dissociated from other measures. Finally, testosterone appeared to have an effect on proprioceptive drift toward the rubber limb, suggesting enhanced sensitivity for interoceptive input. Such findings help shed light on the embodied mechanisms through which testosterone exerts its influence on social-emotional functioning.

Body Ownership; Testosterone; Rubber Hand Illusion (RHI); Bodily Self-Representations; Social-Emotional Functioning; Empathy.

The Effects of Testosterone on Susceptibility to the Rubber Hand Illusion

Bodily self-awareness plays a crucial role in social interactions and social-emotional functioning (Tsakiris, 2007, 2010). For instance, the mirror neuron theory of empathy states that the ability to appropriately infer another's mind state emerges from the capacity to simulate their actions and consequently their intentions (Bastiaansen, Thioux, & Keysers, 2009). Such simulations occur within the same brain areas that represent motor regions of one's own body (Bastiaansen et al., 2009; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). Research on the Rubber Hand Illusion (RHI), a novel paradigm for investigating the sense of body ownership, demonstrates that representations of the self are not rigid schemas but are malleable, altered not only by bodily processes but also by the social context and other dispositional variables (Botvinick, 1998; Tsakiris, 2010). Specifically, it is thought that flexibility of the body schema may play a role in social perspective-taking, enabling one to perform mental simulations of another's behavioural patterns (Pezzulo & Iodice, 2013; Teneggi, 2013). In line with this, recent evidence suggests that individuals high in trait empathy are more susceptible to the RHI (Durgin, Evans, Dunphy, Klostermann, & Simmons, 2007). Given that testosterone has been shown to impair one's ability to experience certain forms of empathy (e.g. cognitive, affective, somatic; Montoya, 2013; van Honk et al., 2011), it is hypothesised that the hormone will modulate susceptibility to the RHI. Specifically, if testosterone is shown to interfere with the process of embodiment over an external limb, this would provide some indication as to the mechanisms via which the hormone influences the ability to effectively infer the emotional states of others.

Body Awareness

Tsakiris (2010) describes how the body negotiates exchanges between the world and the mind. Stimuli are perceived by sensory receptors distributed throughout the body's surface; subsequently our experience as mindful beings is inherently embodied since different bodily processes are used to mediate our interaction with worldly objects. Embodiment, or body ownership, is a concept whereby a person experiences, on a perceptual level, the body and its movements as their own (Tsakiris & Haggard, 2005). This experience is something one tends to take for granted. However, body ownership is a feat accomplished during development as the infant interacts with the social and physical world around it, developing a sense of agency over the body and attributing their actions to their own wilful volition (Rochat, 2011). Once acquired, an individual experiences their body *subjectively* and as something distinctly different from external objects or another person's body. This implies a phenomenological aspect to somatosensory perception, which is argued by Tsakiris (2007) and Longo (2008) to be integral in self-consciousness.

Due to this phenomenological nature, appropriate operationalisation of embodiment is challenging. It is difficult to study body ownership experimentally as no way of producing a condition where the body is absent exists. Although the phenomenological tradition has richly described the characteristics of embodiment (Ehrsson, 2012; Gallagher, 2000; Tsakiris, 2007) and neuropsychological studies have elucidated these processes from dissociations between lesion sites and subsequent changes in body representations (Aspell & Blanke, 2009; Gallagher & Cole, 1995; Schwoebel & Coslett, 2005), systematic methodologies are still needed to experimentally manipulate variables that might lead to changes in the subjective sense of the bodily self (Longo, 2008).

The Rubber Hand Illusion

A well-established experimental paradigm for exploring alternations in the sense of body ownership is the RHI (Botvinick, 1998; Ferri, 2013; Tsakiris, 2010). It is an experimental procedure during which a participant is induced to experience a artificial limb as belonging to their own body as a result of the integration of multisensory information (Botvinick, 1998; Tsakiris, 2010) as well as other affective processes (Lloyd, Gillis, Lewis, & Farrell, 2013). This demonstrates the plasticity of bodily representations. The RHI is typically induced by applying synchronous stroking to both a participant's own hand, concealed from view, and a rubber hand placed next to it, as the participant fixes their gaze onto the fake limb (Botvinick, 1998; Tsakiris, 2010). The illusion is more likely to occur if the rubber hand is aligned with the real hand; is of a similar skin tone and handedness to the real hand and when synchronous brushing of the rubber and real hand occur (Botvinick, 1998; Tsakiris & Haggard, 2005; Tsakiris, 2007).

The extent of the illusion is typically measured using questionnaires, proprioceptive drift measurements and skin temperature changes (Botvinick, 1998; Moseley et al., 2008; Tsakiris & Haggard, 2005; Tsakiris, 2007). Questionnaires assess explicit, subjective changes of the extent to which the rubber limb is thought to feel like one's own. Increased proprioceptive drift, a shift in the perceived location of the real hand towards the rubber limb, also assesses induction of the illusion (merged). Rohde, Di Luca and Ernst (2011), caution however that different mechanisms of multisensory integration may operate within proprioceptive drift and subjective feelings of ownership, respectively. It is suggested that proprioceptive drift relies on visuoproprioceptive integration whilst subjective feelings of ownership requires correlated visual and tactile stimulation (i.e. synchronous stroking; Rohde et al., 2011). As such one should be weary of using any single method exclusively as a measure of the intensity of the experience of ownership in the RHI. Lastly, changes in skin temperature can be used as another implicit assessment of the illusion. Moseley et al (2008) demonstrated that skin temperature of the real hand tends to decrease once the participant takes ownership of the rubber hand, which the authors have understood to reflect homeostatic dysregulation of the real hand.

The RHI and Multisensory Integration

Based on findings from the RHI, it is argued that body ownership is regulated by both bottom-up and top-down processes. Bottom-up processes involve integration of visual and tactile afferent signals. However, these afferent signals are not sufficient to induce the experience of body ownership. For instance, Tsakiris and Haggard (2005) found that when the rubber is replaced with a neutral object or is of an incongruent posture/identity to the participant's real hand, the induction of the RHI does not occur. Such demonstrates that mere synchronous visual – tactile stimulation is not sufficient to induce the illusion. Thus a top-down process, whereby a person's preconceived body schema influences one's tendency to accept something as belonging to their body, also contributes to the process of embodiment (Tsakiris & Haggard, 2005; Tsakiris, 2007). This could be attributed to the neural integration of the temporoparietal junction, which assesses the incorpreability of external objects, the ventral premotor cortices and posterior parietal areas, which not only control actions but build integrated representations of actions, objects and relevant locations, and the right posterior insula, whose activation is associated with subjective experiences of ownership (Gallese, 2005; Tsakiris, 2010). Therefore, the integration of interoceptive (perception of physiological processes within the body), exteroceptive (perception of stimuli outside of the body) and proprioceptive signals (orientation of the body in 3D space) are thought to influence embodiment (Tajadura Jiménez, 2014; Walsh, 2011).

Evidence suggests that different weightings in the contributions of sensory and top-down information alter the extent to which the illusion occurs. For instance, unusually robust proprioception appears to foster resistance to the RHI (Cascio, Foss Feig, Burnette, Heacock, & Cosby, 2012), while mere expectation of the rubber hand getting stroked has been shown to induce it (Ferri, 2013; Fotopoulou, 2009). In general, it is thought that the RHI occurs because of the human bias toward visual processing, meaning that the visual sensory evidence of the rubber limb, which corresponds with top-down representations of the body, dominates over other bodily signals. In support of this, Tajadura-Jaminez (2014) found that people with high interoceptive sensitivity are less likely to experience changes in their body schema. However, the significance of individual biases in the variety of bodily processes that contribute toward the experience of the illusion have not yet been clarified.

Malleable body schemas are thought to enable the representation and simulation of another’s action so as to facilitate successful perspective-taking during social interaction. This process relies heavily on exteroceptive processing to enable the efficient processing of another’s automatic signals (Quattrocki, 2014). A bias toward this visual modality might therefore be apparent during the integration of signals involved in the sense of body ownership. Decety (2003) further points out that one’s own and another’s behavioural goals are represented in the same neural system, namely, the right inferior parietal lobule, and contribute toward a conceptual understanding of action sequences. Thus, failure to form representations of another’s behaviour or distinguish the self from the other in these neural maps may impoverish the ability to understand and recognise the mental states of others. Consequently, malleability of the body schema, as measured by the RHI, may influence the cultivation of self-other awareness, which is foundational for effective empathic functioning (Tajadura Jiménez, 2014).

RHI and Social Processes

Evidence suggests that the RHI is modulated by levels of empathy (Durgin et al., 2007), though the type of empathy (e.g. affective, cognitive, somatic) remains uncertain. Asai et al. (2011) proved that there is a positive correlation between empathic personality types and susceptibility to the illusion, indicating a diminished sense of self-body representation. Moreover, individuals with Autism Spectrum Disorder (ASD), a condition characterised by several socio-emotional deficits, are less responsive to the RHI (Palmer, 2013; Paton, 2012). Cascio et al. (2012) demonstrated that autistic children took, on average, three minutes longer to succumb to the illusion than typically developing children and those with low empathy scores, measured by the Autism Diagnostic Observation Schedule (ADOS), showed significantly impaired proprioceptive drift toward the rubber hand. These findings suggest that the ability to understand and assimilate other’s emotional states interacts with embodiment mechanisms.

Testosterone’s Relationship to Empathy:

There is substantial evidence that the hormone testosterone, the main male sex hormone, significantly influences social-emotional functioning, especially empathy and aggression (Baron Cohen, 2002; Lutchmaya, 2002; Manning, 2001; Montoya, 2013; van Honk et al., 2011). Testosterone decreases cognitive empathy, the ability to recognise and understand another’s emotion, subsequently impoverishing one’s ability to interact affiliatively with the social world (Montoya, 2013; van Honk et al., 2011). A study performed by van Honk et al. (2011) showed that testosterone administration to females significantly impaired their ability to infer emotional and mental states of other people by examination of eye facial regions. Interestingly though, this effect is mediated by fetal testosterone exposure in the womb, which subsequently influences the development of androgenic neural pathways (Montoya, 2013; van Honk et al., 2011). Greater exposure appears to reflect in lower ratios between sizes of the second and fourth finger digits (2D:4D). Lutchmaya (2002) showed that higher concentrations of fetal testosterone are inversely correlated with the amount of eye contact, an important characteristic in social development, made at 12 months.

Furthermore, Autistic children tend to have lower 2D:4D ratios (Baron Cohen, 2002; Manning, 2001; Voracek, 2006) and Ingudomnukul (2007) found that women with ASD are more likely to suffer from testosterone related medical conditions thus suggesting a possible link between fetal testosterone and autism.

Finally, Tibi-Elhanany and Shamay-Tsoory (2011) showed that people who experience elevated levels of social anxiety have greater cognitive empathic tendencies with enhanced precision in attributing affective mental states. Supposedly, people with Social Phobia tend to have increased mentalising abilities and consequently are prone to engage in simulation thereby mimicking others thoughts and feelings. Given testosterone's ability to potentially attenuate social anxiety, it remains an intriguing possibility that the hormone's effect on these feelings may influence the inclination to represent other bodies in mind.

Overview:

The recent interest in the RHI as a novel paradigm for studying social-emotional processes suggests that testosterone may exert some of its effect on behaviour via embodiment mechanisms. Specifically, it is thought that flexibility of the body schema may play an important a role in social perspective-taking, enabling one to mentally simulate and experience another's action. Given that testosterone has been shown to impair one's ability to experience certain forms of empathy, it is hypothesised that the hormone will modulate susceptibility to the RHI. Supporting this hypothesis, several studies tentatively suggest that testosterone may modulate bodily signals relevant to the induction of the RHI, such as proprioception (Aydog, 2005; Fridén, 2006) and interoception (Roberts & Pennebaker, 1995). Specifically, men are thought to rely more heavily on internal cues to understand emotional states whilst women are suspected to rely more on external cues (Roberts & Pennebaker, 1995). It remains unclear why this difference exists but biological factors are assumed to play a role.

Aims and Objectives

Consequently, the proposed research sought to investigate the effects of testosterone in women on bodily self-representations by determining its influence on the RHI, which was operationalised in terms of a self-report questionnaire, proprioceptive drift and skin temperature change. By using the RHI, a person's sense of body ownership could be manipulated, allowing the unique opportunity to assess individual differences in the extent to which a person was able to modify their pre-existing bodily schema. The relevance of such objectives provides a greater understanding concerning the influence of the body on social emotional functioning, which, until recently, has been neglected by models of social emotions.

Hypotheses

1. Testosterone will attenuate susceptibility to subjectively experiencing the rubber limb as one's own, relative to placebo.
2. Testosterone will attenuate proprioceptive drift of the experimental hand relative to placebo.
3. Testosterone will attenuate a temperature drop in the experimental hand relative to placebo.

Methods

Design

The study was a double blinded, randomised, placebo controlled trial which tested the extent to which testosterone modulated the susceptibility to the RHI. It utilised a 3-way ANOVA design and used paired comparisons to investigate other variables. The independent variables under investigation were Testosterone administration and Placebo administration. Susceptibility to the RHI, which was the dependent variable, was measured in three ways, namely:

- Self-report questionnaire
- Proprioceptive drift
- Skin temperature of hand

Data collection took place at Groote Schuur Hospital in the Cognitive Training Offices of the University of Cape Town's (UCT) Psychiatry Department.

Participants

Participants were recruited using a convenience sampling technique. Once permission was granted, email advertisements inviting candidates to participate in a study about testosterone, interoception and body ownership were sent out to UCT's student body (See

Appendix A). Additionally, the advert was placed in the 'Temporary Jobs' section on Gumtree and flyers were distributed to the local community. Random assignment of participants was utilised to control for any possible sampling biases. Participants were assigned a code which was used throughout the study.

A power analysis was conducted to determine the sample size needed to find an effect. Figures were taken from Morgan et al. (2011) who investigated Ketamine's impact on the RHI, utilising a similar research method to the current study. Taking SD = .91, mu(0) = 2.21 (known mean of population), mu(1)=2.84 (expected mean of sample), α = .05 and β = .80 a suggested sample size of n=13 was needed (Morgan et al., 2011). However, the placebo and testosterone conditions had 23 and 21 right-handed female participants respectively to accommodate for possible outliers.

Inclusion criteria. Only females aged between 18 – 35 years not taking any kind of hormonal contraception (including Mirena/implant/injection) were deemed eligible to participate. This age bracket is indicative of women's reproductive age and controls for the later onset of menopause. Participants were required to partake within the first 10 days following the end of their last menstruation. This was to control for hormone fluctuations which could confound the results. Participants were right-handed and representative of all racial and cultural groups.

Exclusion criteria. Women who were pregnant, had been diagnosed with a psychiatric disorder or were taking psychiatric, hormone or other chronic medication were excluded from the sample. Men were excluded from the study as parameters concerning the dosage (0.5mg) and neurophysiological effects of testosterone have only been determined for women (Tuiten et al., 2000). Furthermore, participants with a Body Mass Index (BMI) of 30 or above were excluded from the analysis as it is evidenced that obese individuals (BMI $\geq$ 30) have reduced interoceptive sensitivity (Herbert & Pollatos, 2014).

Following completion of the experiment, participants were remunerated with R250 in cash or three Student Research Participation Points (SRPP) in accordance with larger testosterone studies being performed at UCT.

Measures

Testosterone. A liquid form of testosterone containing a hydroxylpropyl-β-cylcodextrine carrier was administered to participants sublingually.

Furthermore, in order to measure fetal testosterone priming, scans of the participants' hands were taken. This allowed for accurate measurements of the second and fourth fingers and permitted the calculation of the 2D:4D ratio.

Baseline testosterone levels and post-hoc hormonal analyses may be determined/ conducted, if necessary for future research, on 5 m*l* saliva samples collected from participants upon arrival.

Self-report Questionnaire. A 9-item Self-Report Questionnaire which provides a measure of the subjective experience of the induction of the illusion, i.e. the experience that the rubber limb is one's own, was administered (See Appendix B). The first eight questions of the 9-item questionnaire were taken from Tsakaris, Tajadura Jiménez and Costantini (2011) who abridged and validated Longo's (2008) original 27-item self-report questionnaire. Longo (2008) developed the questionnaire schedule based on a qualitative study where five participants were encouraged to freely report their experiences of the RHI. The ninth question was added to assess one's sense of power over their limb. This questionnaire covered themes relating to body ownership and location of the real hand in relation to the rubber hand. It made use of a Likert scale where scores ranged from 1 (strongly disagree) to 7 (strongly agree) with 4 being (neither agree nor disagree).

Proprioceptive Drift. This measure determined the change in perceived location of the real hand to the rubber hand following the illusion and is considered valid and reliable based on previous research (see Botvinick, 1998; Kaya, 2014; Mosely et al, 2008; Paton, 2012; Tsakiris & Haggard, 2005; Tsakiris, 2007).

Temperature. Skin temperature of the participants' hidden hand was measured using an MT964 Non-Contact Infrared Thermometer which provided a highly accurate and precise temperature reading of the participants' hand. This measure is considered valid and reliable based on previous research (see Botvinick, 1998; Kaya, 2014; Mosely et al, 2008; Paton, 2012; Tsakiris & Haggard, 2005; Tsakiris, 2007).

Procedures

A pilot study (n=7) was performed prior to the commencement of the finalised study. This was done without hormone administration in order to assess the soundness and practicality of the experimental procedure.

The procedure followed here was similar to that provided in Tsakiris (2011) and Tuiten (2000). Interested participants were directed to an online survey where they filled in their details. Individuals who met the inclusion criteria were contacted to book a session to come into the lab.

Upon arrival, between 9:00 – 13:00, the researcher provided a brief overview of the day's activities and asked the participant to sign the consent form (Appendix C). The participant provided more personal details in another questionnaire and was then shown to the bathroom, allowing them to give a 5m*l* saliva sample in private. Participants were asked to rinse their mouths and, using a straw, employ a passive drool technique to catch their saliva in a vial.

Once completed, participants were given a plastic vial containing either .5mg of testosterone or a placebo (consisting of only cyclodextrines). The participant was asked to place the liquid under their tongue and refrain from swallowing for 60 seconds. The testosterone and placebo conditions were coded by an independent researcher such that neither the participant nor the present researcher were aware of which condition had been administered. This code was revealed to the present researcher upon completion of all data collection.

Afterwards, the participant was allowed to leave but had to return promptly following four hours after the administration of the testosterone/ placebo. Researchers informed participants that they needed to refrain from excessive exercise or the intake of alcohol or caffeine during that time as it would have a physiological impact on the experimental variables.

The second testing sessions were done in the afternoon, between 14:00 – 17:00 to control for daily fluctuations in hormone levels. Upon return the RHI was then administered (see Figure 1). The researcher and participant sat opposite one another at a table which held a unique rectangular wooden box constructed specifically for the experiment. The box was open at the sides facing the researcher and the participant. The rim of the top surface of the box had a ruler on the side facing the experimenter, which assisted in proprioceptive drift measurements. A left-handed rubber hand was placed in the same orientation as the participant's real left hand, which rested inside the box at a distance of approximately 30cm away. A dark smock was draped over the participant's shoulder so as to hide the position of their arm whilst leaving only the rubber hand visible (see Figure 1.a.).

Baseline measure of the participant's sense of ownership over the limb was assessed prior to the commencement of the illusion-induction procedure. The participant's filled out the 9-item Self-Report Questionnaire of One's Subjective Experience of the RHI, provided an estimation of where in space they felt the nail of their left index finger to be (Figure 1.b.) and had the temperature of the top knuckle of their left index finger recorded (Figure 1.c.).

Upon commencement of the RHI, the researcher proceeded by simultaneously stroking the rubber and real hand with identical, soft paintbrushes at a frequency of 1 Hz in a synchronous fashion while the participant fixed their gaze upon the fake limb (Figure 1.d.). This was performed for 120s in silence, at which point the participant's hand temperature was measured again and they were required to indicate where they perceived the nail of their left index finger to be in the box below. Subsequently, participants were asked to complete the 9-item Self-Report Questionnaire again. Following that and after a short opportunity to move out and back in to the experimental position, the illusion and the respective pre-test and post-test measurements were repeated, however, that time with asynchronous stroking of the rubber and real hands. The order of Synchronous and Asynchronous stroking was counterbalanced and before the illusion was repeated the participant's height was recorded so as to prevent carry over effects.

Of note, the administration of the RHI was counterbalanced with a heart-beat tracking exercise which formed part of another investigation, so as not to confound the results. See Nicholas Reid's Research Study for more information. The participants were then thanked, debriefed and reimbursed with R250 cash.

Fig 1. Flow diagram demonstrating the procedures of the Rubber Hand Illusion

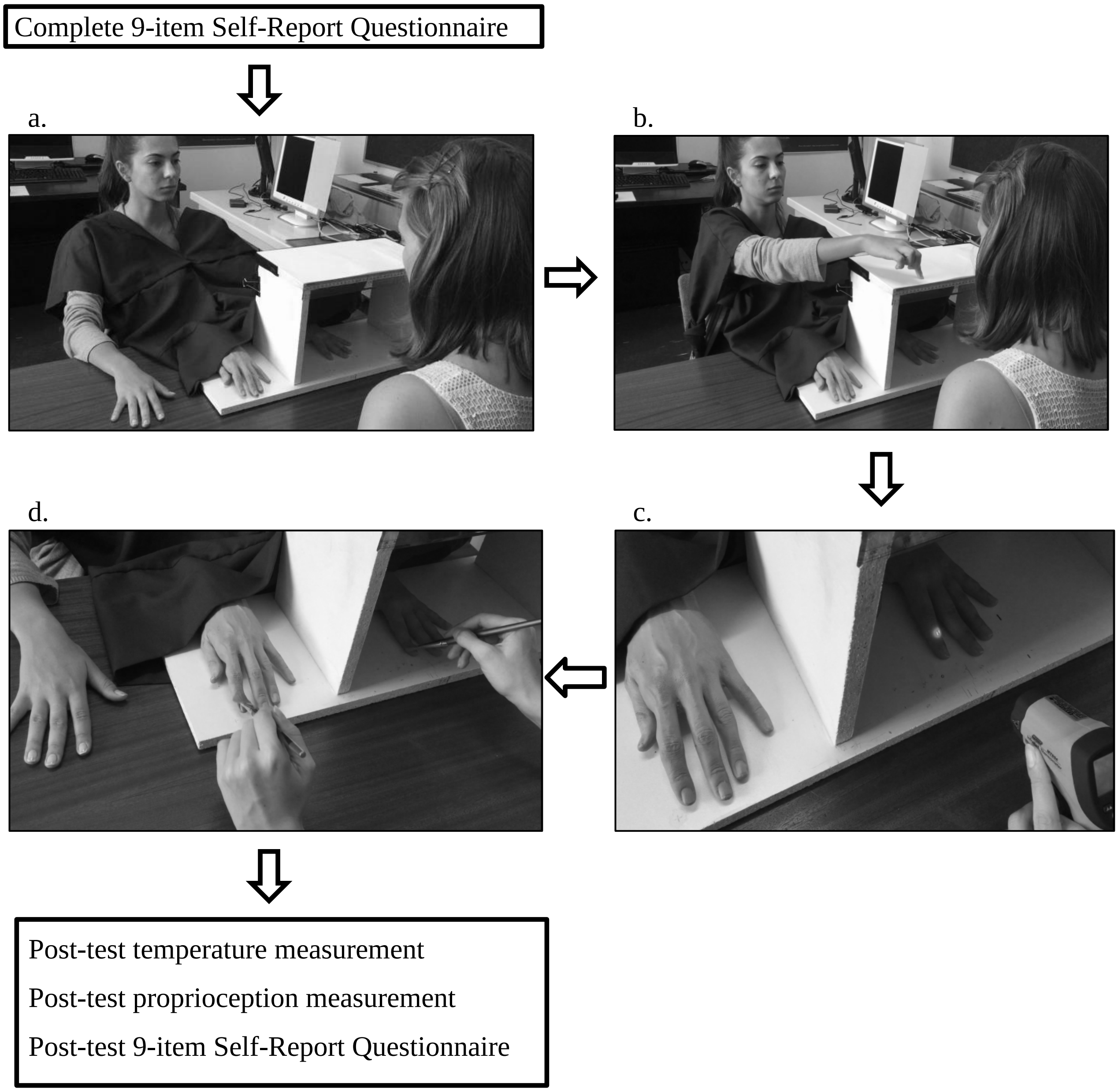


Figure 1. Flow diagram illustrating the order in which each task of the Rubber Hand Illusion was completed. Following the completion of the questionnaire the participant was set up for the commencement of the illusion (a), estimated where they perceived the nail of their left index finger to be (b) and had the temperature of their top knuckle of their left index finger taken (c). Both the rubber hand and the participant's real hand were then stroked for 120s with either a synchronous (d) or asynchronous mode of stroking, depending on which stroking condition was being administered. Following this, post-test temperature, proprioception and self-report measures were taken.

Ethical considerations

The procedures described here fall under a larger investigation, formally titled *Neuropsychological Mechanisms of Social* Power, which has been approved by the UCT Human Research Ethics Committee (868/2014) and the UCT Psychology Department (See Appendix D). The research outlined here was carried out in accordance with the Declaration of Helskinki (2014) as well as UCT's guidelines for research on human subjects.

Consent, voluntary participation and confidentiality. Participants were informed that participation was voluntary and that they could withdraw at any time without repercussions. Participants were assured anonymity and confidentiality of all information they provided throughout the study. All data was stored by code in a locked room or on password-protected computers. Participants were reminded that saliva samples will only be assessed for hormones and will be destroyed after a period of 18 months.

Furthermore, participants could request to have their data removed from the dataset at any time. Following the commencement of the data collection, participants were debriefed on the procedures and were allowed to ask questions relating to the aims and objectives of the study.

Risks and Benefits. 23 studies relating to 0.5m*l* testosterone administration demonstrate that the research procedures described above are safe, reliable and valid methods (See Appendix E). Consequently, the present study did not place the participants' mental and physical well-being at any risk. In very rare cases testosterone could cause nausea and headaches, whilst cyclodextrine carriers could cause diarrhoea, but such adverse drug reactions are seldom reported. If participants felt any discomfort during the period between sessions, they were encouraged to contact the researchers immediately, who had a medical doctor on call. The remuneration of R250 acted as a benefit for participating in the study. Additionally, students who participated in the study gained insight into the inner workings of postgraduate research. Furthermore, participants had the opportunity to learn more about the psychological effects of testosterone during debriefing and can take pride in knowing that their participation assisted in furthering scientific knowledge.

Results

The data was analysed using IBM SPSS Statistics 22.0. by employing an established method in the field (Tsakiris & Haggard, 2005) whereby "perceptual shift" variables were created to factor out the influence of the control condition (asynchronous stroking) on the multisensory integration condition (synchronous stroking). This analysis was then followed up with 3-way analyses of variance to test for any main effects of stroking.

Perceptual shifts

In order to directly compare the outcome of the RHI for the placebo and testosterone groups focus is placed on the change in self-report, proprioception and temperature owing to visual-tactile integration (see Table 1.). According to Tsakiris and Haggard (2005), this integration component, known as perceptual shifts, can be defined as the increase in ownership over the rubber hand when visual and tactile simulation are correlated (i.e. synchronous condition) over and above the ownership attributed to uncorrelated visual tactile simulation (i.e. asynchronous condition). Therefore, in order to obtain a more precise measure of the RHI, the pre-test results from the asynchronous condition are subtracted from the pre-test results of the synchronous condition for the self-report measures (sum of first eight questions), proprioception judgement errors and temperature measures, respectively (i.e. $\text{synchronous}_{\text{pre-test}}$ – $\text{asynchronous}_{\text{pre-test}}$ = pre-test perceptual shifts). The same is done for the post-test results of the asynchronous and synchronous conditions for each test ($\text{synchronous}_{\text{post-test}}$ – $\text{asynchronous}_{\text{post-test}}$ = post-test perceptual shift).

Independent-sample t tests were subsequently conducted on the overall perceptual shifts for each respective test (post-test perceptual shift – pre-test perceptual shift). Note the assumption of normality was violated thus Reverse score and Log Transformations were performed (i.e. log (X_i + 10); Field, 2013). Results indicate a statistically significant perceptual shift in temperature due to visual-tactile integration of the RHI (t (42) = 2.87, p= .003, one-tailed) with participants who received testosterone having a positive perceptual shift value (M= .21, SD= .71) and those of the placebo group having a negative perceptual shift value (M= - .47, SD= .82). Such results suggest that the testosterone group's temperature increased following the illusion whilst the placebo group's temperature decreased (see Figure 2.1. and 2.2.a.).

There were no statistically significant results for self-report measures (t (39) =.23, p=.41, one-tailed; see Figure 2.2.b.) and proprioceptive drift (t (42) =- .54, p=.30, one-tailed; see Figure 2.2.c.) when focusing on changes owing to visual-tactile integration.

Table 1.
Descriptive Statistics Table of Perceptual Shifts

	N	Mean	Std. Deviation
		Placebo	
8-item self-report	21	11.67	9.98
Proprioception judgement error	23	.97	3.08
Temperature	23	-.47	.84
		Testosterone	
8-item self-report	20	13.50	13.33
Proprioception judgement error	21	.71	3.14
Temperature	21	.21	.71

Figure 2.1. Bar Graph Illustrating the Average Perceptual Shift Scores for Temperature Measures in the Placebo and Testosterone Groups

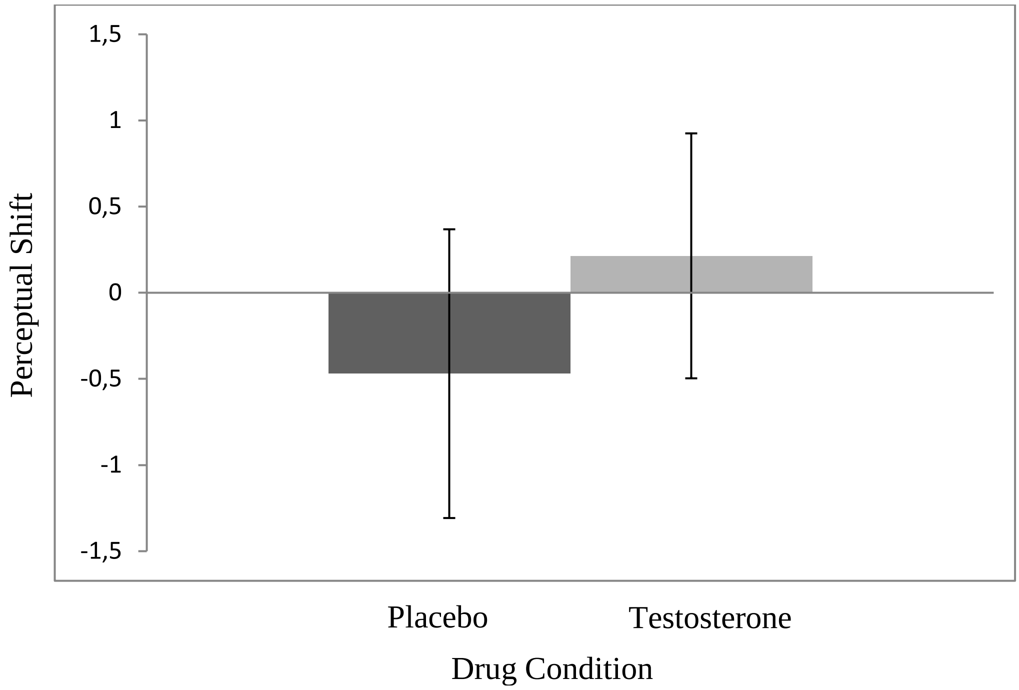
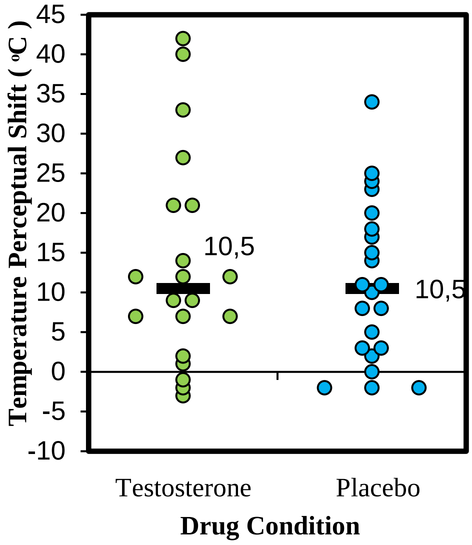


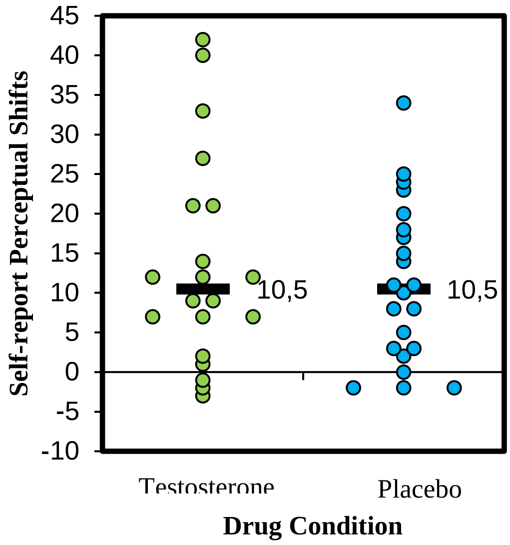
Figure 2.1. Bar graph displaying the average perceptual shift scores for temperature of the top knuckle of the left index finger. The Placebo group displays a significant decrease in temperature due to multisensory integration. The testosterone group displays a significant increase in temperature due to multisensory integration. Error bars represent standard deviations.

Figure 2.2. Univariate Scatterplots Displaying the Distribution of Perceptual Shift Scores for Temperature, Self-report and Proprioceptive Drift Measures

a. Univariate Scatterplot of Perceptual Shift Scores for Temperature Measures



b. Univariate Scatterplot of Perceptual Shifts Scores for Self-report Measures



c. Univariate Scatterplot of Perceptual Shift Scores for Proprioceptive Drift Measures

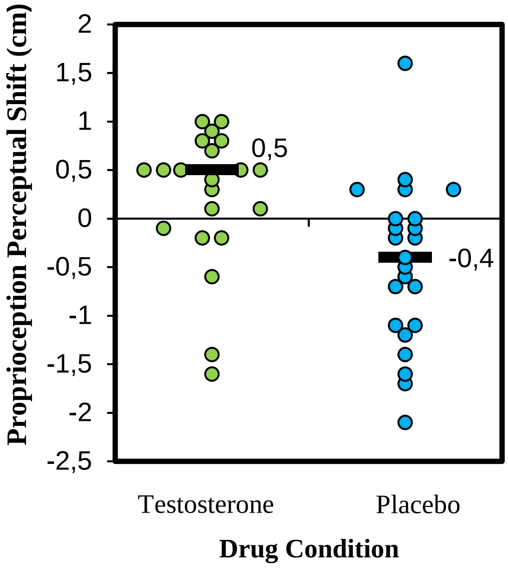


Figure 2.2. Univariate scatterplots displaying the distribution of perceptual shift scores for temperature (a), self-report measures (b) and proprioceptive drift (c) respectively. Perceptual shifts, can be defined as the increase in ownership over the rubber hand when visual and tactile simulation are correlated (i.e. synchronous condition) over and above the ownership attributed to uncorrelated visual tactile simulation (i.e. asynchronous condition). Scores are centred on the mean of each group. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Three different 2x2x2 Mixed Designs Analyses of Variances (ANOVA) were performed on the 9-item Self-Report Questionnaire, proprioceptive drift and skin temperature scores, respectively (See Table 2.1 and 2.2. for descriptive statistics). Such a design consisted of one between-subjects factor, namely, drug condition (testosterone vs. placebo) and two within-subject factors, namely, the mode of stroking (synchronous vs. asynchronous) and the time of measurement (pre-test vs. post-test). No outliers were detected using the three standard deviation rule and all parametric assumptions were upheld (Field, 2013).

Self-Report questionnaire. A 2x2x2 Mixed Designs ANOVA was conducted on the first eight questions, abridged and validated by Tsakiris et al. (2011). The first five questions assess ownership over the rubber hand while the remaining three gauge the location components associated with the RHI. Scores for each question were summed together giving a total for the phenomenal experience of the illusion; note, the higher one's score the more one experienced subjective ownership over the hand (See Figure 3.1). There appears to be a statistically significant difference in the degree to which participants succumb to the illusion based on the stroking condition they undergo (F (1) = 47.16, p< .001). Participants are more likely to report subjective ownership over the rubber hand following synchronous (M=32.07, SE= 1.22) rather than asynchronous stroking (M=25.77, SE=1.55). Additionally, a statistically significant main effect exists for the time of measurement (F = 86.493, p< .001) with greater subjective responses of ownership over the rubber hand being recorded at post-test (M=36.15, SE= 1.58) rather than pre-test measurements(M=21.69, SE= 1.47). Subsequently, a significant interaction effect on subjective responses of ownership over the rubber hand exists between the time of measurement and the mode of stroking (F=47.158, p< .001). Further investigation of this interaction illustrates a statistically significant difference from the pre-test to the post-test measurements of the subjective experience of ownership over the rubber hand following synchronous and asynchronous stroking in both the testosterone and placebo groups. Therefore, it is suggested that participants experience a greater sense of subjective ownership over the rubber hand after having undergone the illusion, regardless of the drug they receive.

Table 2.1.
Descriptive Statistics for Synchronous Stroking Condition

Measure	Pre-test n	Pre-test M	Pre-test SD	Post-test n	Post-test M	Post-test SD
			Placebo			
8-item self-report	22	21.32	9.41	22	41.27	11.35
Proprioception judgement error	23	3.11	2.93	23	3.63	3.43
Temperature	23	28.47	3.72	23	28.01	3.68
			Testosterone			
8-item self-report	20	21.75	9.31	21	43.29	9.26
Proprioception judgement error	21	3.24	2.52	21	4.48	2.77
Temperature	21	27.23	4.10	21	27.26	4.43

Table 2.2.
Descriptive Statistics for Asynchronous Stroking Condition

Measure	Pre-test n	Pre-test M	Pre-test SD	Post-test n	Post-test M	Post-test SD
			Placebo			
8-item self-report	22	21.32	9.41	22	30.9	13.47
Proprioception judgement error	23	3.34	2.98	23	2.89	3.32
Temperature	23	27.9	3.52	23	27.92	3.72
			Testosterone			
8-item self-report	20	21.75	9.31	21	29.57	12.45
Proprioception judgement error	21	2.96	3.40	21	3.48	2.87
Temperature	21	27.52	3.95	21	27.34	4.25

Fig 3.1. Univariate Scatterplot of Results of the 8-item Self-Report Questionnaire from Each Condition

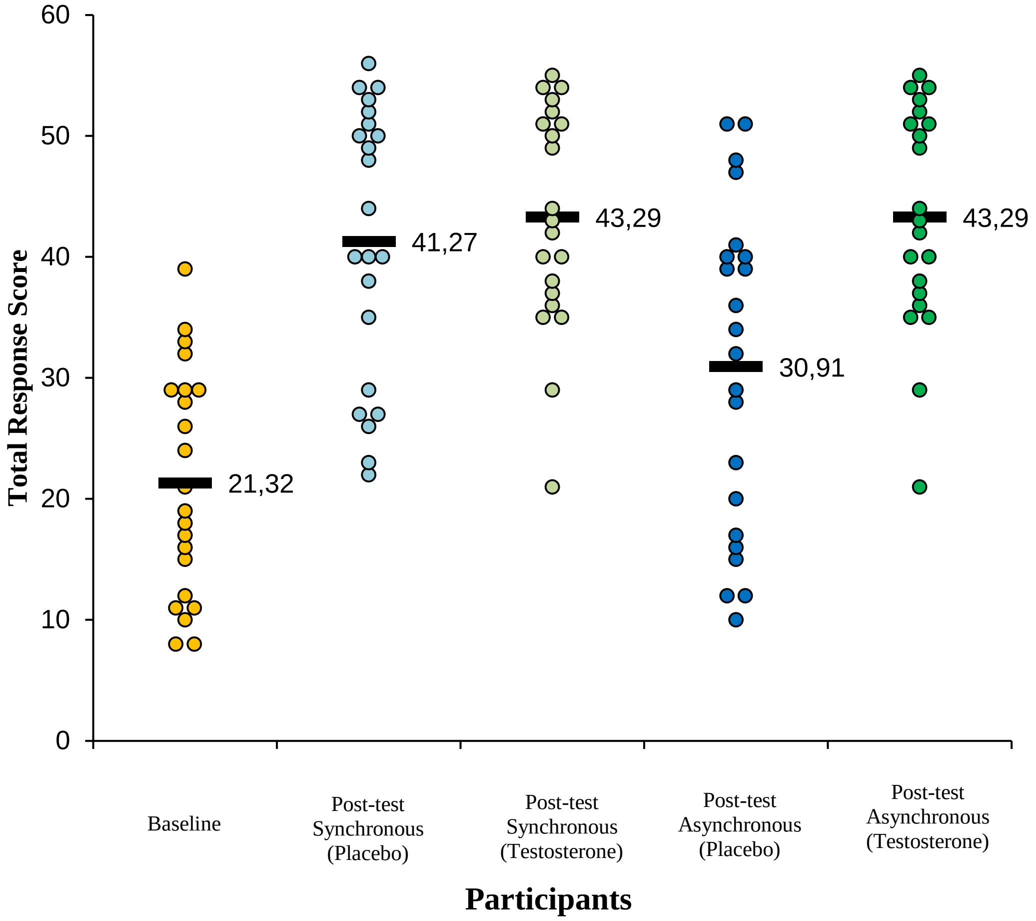


Figure 3.1. Univariate scatter plot displaying the distribution of participants' scores regarding their subjective experience of ownership over the rubber hand in each respective condition. Scores are centred on the mean of each group. The greater the score the more one experienced a phenomenal sense of ownership over the hand. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Proprioceptive Drift Pre-test and post-test proprioception judgements were recorded prior to and following stroking respectively. Considering we are interested in the participants' proprioceptive accuracy pertaining to their hand in space**,** judgement errors were calculated (Actual $_{\text{Location of left index finger's nail}}$ – Perceived $_{\text{Location of left index finger's nail}}$), where positive errors reveal mislocalisations in the direction of the rubber hand (Tsakiris & Haggard, 2005). Prior to the analysis such values were calculated for all pre-test and post-test measurements and used in the 2x2x2 Mixed Designs ANOVA to determine whether statistically significant proprioceptive drifts (Post-test $_{\text{judgement errors}}$ – Pre-test $_{\text{judgement errors}}$) occurred (See Figure 3.2. and 3.3.). A statistically significant main effect for the time of measurement exists (F (1) =5.00, p = .031) with a greater error in proprioception judgement being recorded at the post-test measurement (M = 3.62, SD = .42) compared to the pre-test measurement (M = 3.16, SD = .41). Such results reveal that participants perceive their hand to be closer to the rubber hand than it actually is following the illusion. Furthermore, the interaction between the type of drug one receives and the time at which the measurement is taken, has a statistically significant effect on proprioceptive drift (F (1) =4.35, p = .043). A pairwise comparison revealed a significant mean difference in the testosterone group between the pre-test (M =3.24, SE = .60) and post-test measurements (M =4.48, SE = .68) for the synchronous mode of stroking (*Mean Difference* $_{\textit{post-test – pre-test}}$ = 1.23, SE =.30, p < .001), indicating that these participants' proprioception shifted towards the rubber hand following the illusion, contrary to prediction.

Fig 3.2 Univariate Scatterplot of Results for Proprioceptive Drift in the Synchronous Stroking Condition

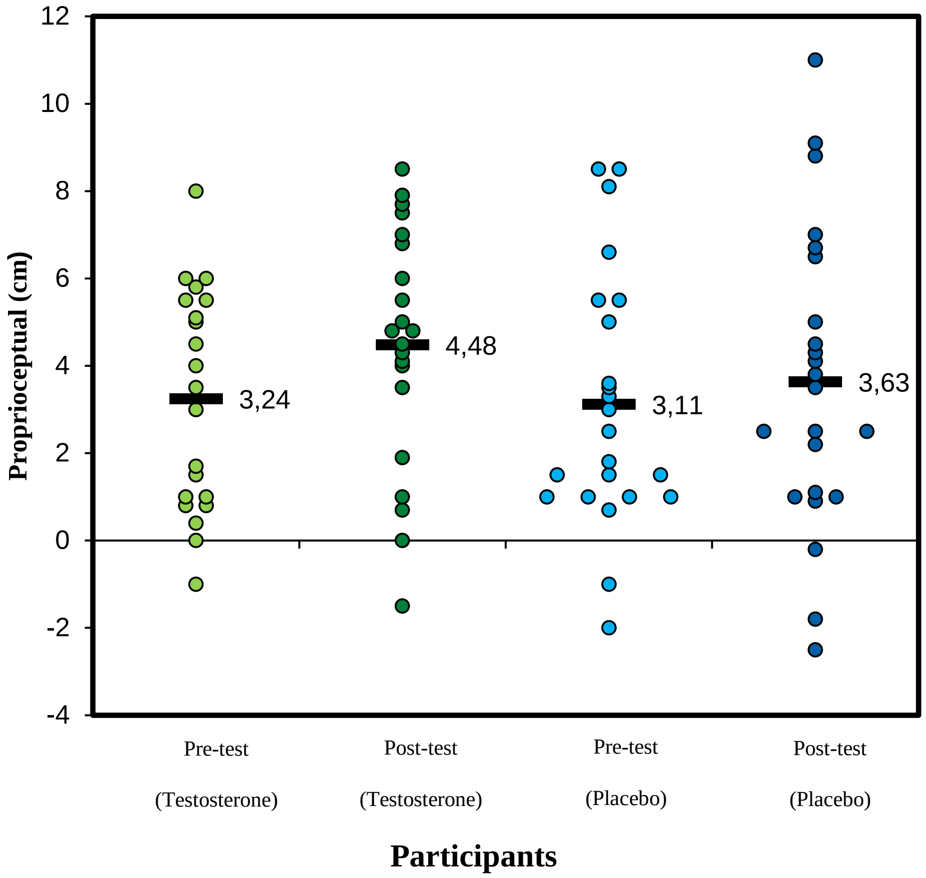


Figure 3.2. Univariate scatter plot displaying the distribution of participants' proprioceptive judgement error scores at pre-test and post-test measurement during the synchronous stroking condition. Scores are centred on the mean of each group. The closer the score to zero, the less error the participant made in perceiving the location of their limb. The more positive one's score, the closer to the rubber hand one perceived their hand to be. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Fig 3.3 Univariate Scatterplot of Results for Proprioceptive Drift in the Asynchronous Stroking Condition

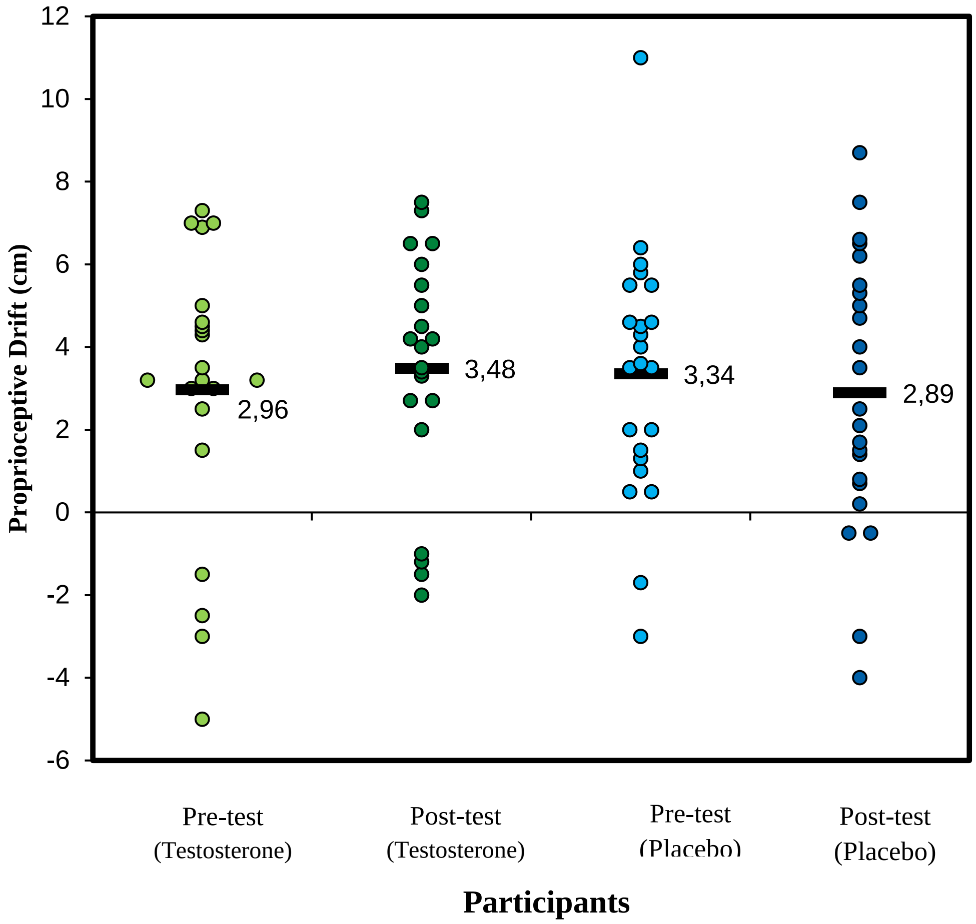


Figure 3.3. Univariate scatter plot displaying the distribution of participants' proprioceptive judgement error scores at pre-test and post-test measurement during the asynchronous stroking condition. Scores are centred on the mean of each group. The closer the score to zero, the less error the participant made in perceiving the location of their limb. The more positive one's score, the closer to the rubber hand one perceived their hand to be. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Temperature The interaction between the drug condition, mode of stroking and the time at which the measurement is taken has a statistically significant effect on the temperature of the top knuckle of the left index finger (*F* (1) =8.437, *p* = .006; see Figure 3.4. and 3.5.). A pairwise comparison indicates a significant decrease in temperature from the pre-test (*M*=28.47, *SE*=.82) to the post-test measurements (*M*=28.01, *SE*=.85) in the placebo group after experiencing the synchronous mode of stroking (*Mean Difference* $_{post\text{-}test\,–\,pre\text{-}test}$ = .46, *SE* =.16, *p* = .006). Furthermore, it is interesting to note that in the testosterone group there was an increase in temperature from pre-test (*M*=27.23, SE = .85) to post-test measurements (M=27.26, SE=.89) following synchronous stroking; however this observation is not statistically significant (*Mean Difference* $_{post\text{-}test\,–\,pre\text{-}test}$ = -.03, *SE* =.17, *p* =.86).

Overall, the results suggest three central findings. Firstly, testosterone does not appear to have an influence on the phenomenal mechanism elicited by the RHI. Secondly, the participants who received testosterone appear to retain homeostatic regulation of their hand following visual-tactile integration of the illusion, demonstrated by an increase in the temperature of their hidden limb. Comparatively, the placebo group demonstrated a drop in temperature owing to visual-tactile integration. Lastly, a larger drift in proprioception toward the rubber hand was seen in the testosterone group, suggesting that interoceptive input, by way of the mere effect of stroking, has a stronger, global effect in response to the administration of testosterone.

Fig 3.4. Univariate Scatterplot for Temperature Measures in the Synchronous Stroking Condition

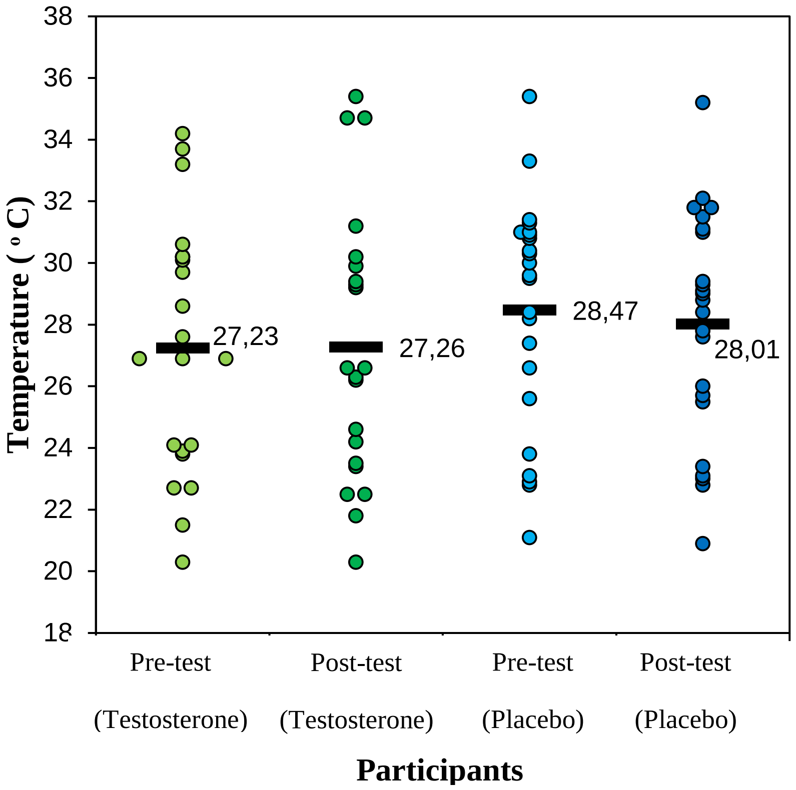


Figure 3.4. Univariate scatter plot displaying the distribution of participants' temperature scores at pre-test and post-test measurement during the synchronous stroking condition. Scores are centred on the mean of each group. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Fig3.5. Univariate Scatterplot for Temperature Measures in the Asynchronous Stroking Condition

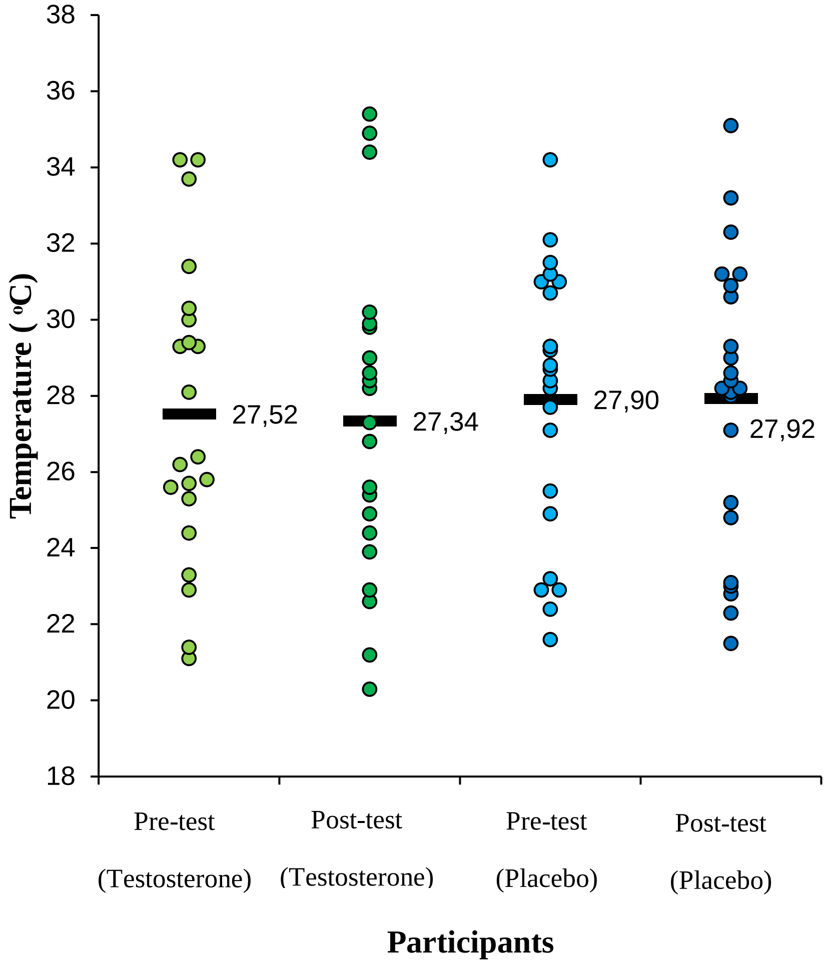


Figure 3.5. Univariate scatterplot displaying the distribution of participants' temperature scores at pre-test and post-test measurement during the asynchronous stroking condition. Scores are centred on the mean of each group. Univariate Scatterplot template taken from "Beyond bar and line graphs: time for a new data presentation paradigm" by Weissgerber, Milic, Winham and Garovic, 2015, PLOS Biology, 13(4), p. 7. Copyright 2015 by Weissgerber et al.

Discussion

The RHI provides an experimental procedure that enables the manipulation of a person's sense of body ownership, providing a unique opportunity to assess individual differences in the extent to which a person is able to modify their pre-existing bodily schema. This malleability appears to have important consequences for social interactions in light of accumulating evidence linking the susceptibility of the RHI to individual differences in emotional functioning (Asai, 2011; Cascio et al., 2012; Durgin et al., 2007; Palmer, 2013; Paton, 2012). Despite the considerable contribution of hormones to social behaviour, no studies to date have explored the possible link between the malleability of body schemas and hormonal processes. Moreover, several lines of research tentatively suggest that testosterone in particular may modulate bodily signals that are relevant to the induction of the RHI, such as proprioception (Aydog, 2005; Fridén, 2006) and interoception (Roberts & Pennebaker, 1995). Consequently, the proposed research sought to investigate the effects of testosterone on bodily self-representations by determining its influence on the RHI. The results reported here demonstrate that while testosterone does not appear to have any significant effect on subjective measures that reflect embodiment of an artificial limb under conditions of multisensory integration, it does appear to inhibit the temperature drop that is usually seen in the RHI. In fact, testosterone lead to an increase in the temperature of the participant's experimental limb. These findings provide the first evidence for a dissociation of the thermodynamic response to the illusion from self report and proprioceptive drift measures.

Dissociable mechanisms

Within all three measures, results indicated a disruption in body ownership in either the placebo or testosterone group or both. Such findings reveal that the RHI was successfully elicited. However, our results do not suggest that measures of proprioceptive drift and the subjective experience of ownership emerge from a unitary mechanism. While we observed significant findings in the both the control and testosterone group's data for subjective reports of ownership over the rubber hand following the illusion in both synchronous and asynchronous stroking conditions, the change in proprioceptive drift toward the rubber hand was only significant in the testosterone group following synchronous stroking. Thus if the measures of proprioceptive drift and the subjective experience of ownership operated via the same mechanism, we would have seen similar significance findings of ownership over the rubber hand for each measure.

Classic RHI studies have found the increase in proprioceptive drift towards the rubber hand to be a reliable behavioural measure of the illusion (Botvinick, 1998; Kaya, 2014;

Moseley et al., 2008; Paton, 2012; Tsakiris & Haggard, 2005; Tsakiris, 2007). Additionally, the self-report questionnaire, which covered themes relating to body ownership and location of the real hand in relation to the rubber hand, is seen to likewise measure the intensity of embodiment during the RHI (Longo, 2008; Tsakiris et al., 2011). However, it appears unfounded to assume that proprioceptive drift acts as a behavioural proxy for subjective experiences of ownership. Our findings are consistent with studies that show a dissociation between the subjective (i.e. 8-item self-report questionnaire) and objective (i.e. proprioceptive drift) measures of the illusion (M. Kammers, de Vignemont, Verhagen, & Dijkerman, 2009; Lloyd et al., 2013; Rohde et al., 2011; van Stralen et al., 2014). Such evidence suggests that although proprioceptive drift and feelings of ownership contribute to the overall experience of the illusion, different mechanisms are responsible for each measure.

Lloyd et al. (2013) have proposed different neural pathways upon which each measure acts. They suggest that the activation of the pathway travelling from the posterior to anterior insula is associated with the subjective awareness of the body and bodily emotions, whereas activation of the inferior parietal lobe followed by activation of the posterior insula is associated with proprioceptive drift. This neural mechanism is in agreement with Craig (2004) who suggests that the right anterior insular mediates the RHI by allowing the brain to distinguish between internal (i.e. phenomenal experiences) and external phenomena (i.e. proprioceptive drift). As such it is argued that the manipulation of body schemas during the RHI is negotiated by bottom-up multisensory inputs and regulated by top-down emotional responses.

Of significance, our results are the first to provide evidence that the thermodynamic response to the RHI is not only variable in direction (increase versus decrease), but also dissociable from proprioceptive drift and self-report measures. The change in temperature following induction of the illusion was the only operational measure in which the testosterone group demonstrated a significant difference from the control group. Specifically, those who received testosterone experienced a significant increase in limb temperature compared to the controls who, as reported in previous studies (Moseley et al., 2008; van Stralen et al., 2014), displayed a drop in limb temperature. Though testosterone has been linked to changes in body temperature (Hänssler & Prinzinger, 1979), the validity of this finding is confirmed by the observation that in the asynchronous condition, the experimental limb of the testosterone group actually dropped. Mosely et al. (2008) demonstrated a limb-specific drop in temperature following ownership over an artificial counterpart. Kammers, Rose and Haggard (2011) replicated findings that the RHI induced a decrease in limb temperature and further illustrated that the effect of the RHI was strengthened when the participant's real hand was artificially cooled yet was weakened when the participant's real hand was warmed. Our data challenges these findings and point to the fact that elicitation of the illusion doesn't necessarily correspond with a drop in temperature. Clearly then, the existing operational definitions for assessing susceptibility to the RHI need to be revised and the implications of these divergent mechanisms deserve more scrutiny in future research.

Testosterone and homeostatic "up"-regulation

Arguably, both the self-report questionnaire and proprioception estimates constitute *explicit* measures of the RHI. Both require mediation by brain structures that are involved in cortical processing, while physiological temperature changes do not. Considering that the analysis of perceptual shifts revealed that testosterone had a significant influence on temperature but no effect on subjective reports, it would appear that testosterone inhibits *implicit* ownership over the rubber hand. The explicit measures assess facets of the illusory experience that are available to conscious awareness while the temperature readings reflect a largely unconscious physiological process, even though it too is sometimes reported to be felt, though the change itself constitutes a physiological rather than psychological one. Mosley et al. (2008) argues that the drop in limb temperature that is seen in healthy participants reflects the homeostatic dysregulation of the own hand that occurs in the process of acquiring the sense of ownership over the fake one. This, the authors argue, signifies a *replacement* of the real limb with the artificial one. From this perspective, it appears, then, that the testosterone group in the present study, who experienced a rise in limb temperature, did not replace their own hand within their existing body schema with the rubber one, but instead 'gained' a third limb. Armel and Ramachandran (2003) have reported a similar finding, where they were able to demonstrate an increase in temperature in the distal residual limb (stump) of amputees when they began to feel a sense of ownership over a prosthetic. These authors suggest that the rise in temperature reflects the process of incorporating the prosthetic into the self-image. Our findings may therefore indicate a reluctance on the part of the testosterone group to relinquish homeostatic regulation over their own limb. The implication of this finding is not immediately apparent, however, the significance of retaining physiological processing of one's own limb for efficient action planning and execution is clear. Reduced tissue temperature has been associated with a reduction in the velocity of nerve conduction, which is known to interfere with both sensory and motor potential (Dhavalikar, Narkeesh, & Gupta, 2009). Motor control signifies the most rudimentary definition of power – the capacity to direct or exert influence. Hence, testosterone influences the malleability of body schemas, but in a very particular way, enabling the incorporation of foreign limbs without compromising the existing 'power potentialities' of the mind-brain interface.

Coping responses that are pro-active and assertive in nature, as well as the motivation to attain power in social groups, have been linked to brain systems regulated in large part by both testosterone and norepinephrine (Sapolsky, 1986; Stanton & Schultheiss, 2009; Tops, Boksem, Quirin, IJzerman, & Koole, 2014). Several studies indicate that testosterone induces the release of norepinephrine, especially in response to a social stressor or threat (Cardinali, Nagle, Gómez, & Rosner, 1975; Kumai, Tanaka, Watanabe, Matsumoto, & Kobayashi, 1994). Likewise, the thermoregulatory response that promotes heat gain is mediated in part by the release of norepinephrine controlled via the medial preoptic area of the anterior hypothalamus (Guyton, 1996). This brain structure is known to be extremely rich in testosterone receptors (Albert, Jonik, & Walsh, 1992; Ferris, Albers, Wesolowski, Goldman, & Luman, 1984; Kruk et al., 1983; Pan, Xu, Young, Wang, & Zhang, 2010), suggesting that the change in temperature as a result of the administration of testosterone occurs via its activation on the anterior hypothalamus (AH). Most interestingly, is that activation of the AH has been associated with dominance behaviours in several species (van der Westhuizen & Solms, 2015). Given that the RHI has been regarded as a proxy for measuring the ability to simulate other bodies in the service of effective social behaviour, the finding here that testosterone enables this ability, while simultaneously activating brain systems that facilitate dominant/approach responses, provides some clarity as to the mechanisms via which the hormone facilitates social ascendancy without the conscious awareness of wanting to achieve dominance (Eisenegger, Haushofer, & Fehr, 2011). Indeed, several studies to date have demonstrated that the hormone implicitly activates dominant approach behaviours (Cardinali et al., 1975; Kumai et al., 1994; van Honk et al., 2001). However, the current study employed a socially neutral paradigm and it therefore remains to be seen whether or not changes in RHI measures as a result of testosterone occur unanimously across social contexts.

Sensitisation to interoceptive input

Our analyses indicated that while the testosterone group did not exhibit a significant increase in proprioceptive drift when controlling for the change observed in the asynchronous conditions, we nonetheless were able to demonstrate a more global effect of stroking as shown by a significant difference in the synchronous condition between placebo group and testosterone group. This implies that the administration of testosterone may have sensitised the individual to interoceptive input. The skin forms the interface between the body and the external world and tactile processing of this organ is considered to be one of the major interoceptive pathways. Interoceptive processing, as a result of the stroking, occurs via the activation of mechanoreceptors in the skin and the subsequent relay of information to the primary somatosensory cortex of the contralateral hemisphere where tactile perception and body representation are integrated (Haggard, Taylor-Clarke, & Kennett, 2003). As such this interoceptive processing allows for the 'remapping' of one's body in relation to their environment (Damasio, 2010). Importantly, pleasant tactile stimulation, like the kind delivered to the hand during the RHI, is known to play a critical role in development, promoting the healthy development of the mind and minimising sensitivity to stress (Feldman, Singer, & Zagoory, 2010; Kida & Shinohara, 2013). Interestingly, studies on other mammals, such as rats demonstrate that males typically receive more physical contact from their mothers during infancy and this may account, in part, for the greater degree of social resilience exhibited by males compared to females in their adulthood (Moore, 1982). The current finding that the testosterone group responded in a more pronounced way to the interoceptive input that was delivered by the stroking, suggests that testosterone may lower the threshold at which an individual is able to benefit from pleasant sensory input. As such people with higher baseline levels of testosterone may be more susceptible to positive affective experiences. This idea is in line with literature that shows a link between testosterone and reward-sensitivity (van Honk et al., 2004). The better one's ability to be positively influenced by acts of nurturance, the better able one is able to flourish in the social environment. This proposed link between testosterone and dominance is consistent with the ideas put forward by van der Westhuizen and Solms (2015), in which the authors argue that the ability to acquire high social status in adulthood may emerge as a result of positive, nurturing experiences during the course of development.

Limitations

The current study has a few limitations that should be considered. The possibility that subjective self-report measures, proprioceptive drift and temperature changes are dissociable measures of the RHI may cause speculation over the meaning of the results and whether the measures actually operationalise the illusion. However, controls within the design (e.g. asynchronous stroking) illustrate that the respective measures did in fact operationalise the overall experience of the RHI. Thus despite the need for revised measures, such a limitation did not greatly affect our findings. More pertinently, though the RHI is thought to reflect the ability to simulate another's actions as part of the empathic process, future studies should address this issue more directly by employing neuroimaging methods to compare mirror neuron activity, empathic functioning and susceptibility to the RHI in a single design.

Another limitation may be that participants were potentially misleading with information regarding their menstrual cycle and whether they were on conceptives or not. Yet, we do not perceive such a limitation to have impeded on our findings as following the completion of data collection we cross-referenced various questionnaires participants had completed and excluded those who provided confounding information.

Additionally, van Stralen et al. (2014) took pre-test and post-test temperature measurements of the unstimulated hand (i.e. the right hand) to serve as a control for temperature fluctuations. We did not take such measurements; however, the observed temperature drop in the testosterone group during asynchronous stroking validates the findings of the increase in temperature during the synchronous condition. Additionally, considering we compared results across groups, the placebo group acted as our control. Therefore, such a limitation did not affect the validity of our results.

Lastly, a recent study found that the RHI seemed to be stronger with slow rather than fast stroking as manifested in the difference in subjective embodiment between synchronous and asynchronous stroking of a rubber hand (Crucianelli, Metcalf, Fotopoulou, & Jenkinson, 2013). While it is unlikely that the difference in stroking speeds between participants would differ to such an extent so as to cause a noticeable change, the strength of our research design and the large number of participants would control for such biases. Nevertheless, future studies will add important information regarding testosterone's effect on RHI measures by manipulating the degree of pleasantness of stroking**.**

Conclusion

Until recently, models of social emotions neglected, to a large extent, the influence of the body on social emotional functioning. However, accumulating evidence shows that many higher-order psychological experiences emerge from brain areas that are involved in more basic bodily processes. For instance, neural systems that are involved in thermoregulation also activate when appraising other people along dimensions of social warmth (Inagaki & Eisenberger, 2013; Zhong & Leonardelli, 2008). This study was able to contribute to the embodiment literature in two key ways. Firstly, it appears that the hormone, testosterone, plays an important role in representing the body in the brain. Our finding of an increase in temperature during multisensory integration in the limbs of participants who received testosterone demonstrates that the hormone strengthens mind-body representations and this may have important consequences for the self-concept. Additionally, following an embodied account of empathy, in which the simulation of others' bodies is integral for appropriately understanding their actions and intentions, our finding implies that the egocentric mind frame that is associated with high levels of testosterone (Wright et al., 2012), may occur via the hormone's effect on bodily representations. A robust body schema, especially in contexts that call for rapid updating of these neural maps, such as in a social challenge, may have important consequences for competitive success. Secondly, the present findings contribute to the existing literature that suggests a role for testosterone in sensitising the individual for social reward. In particular, this modulation appears to operate at the level of bodily mapping as well.

These findings may have significant implications for the way in which some psychological disorders are treated. The embodied approach places a focus on therapies that harness implicit changes in the brain as a result of physical interventions. For instance, mindfulness training which encourages the mind to attend in a detached manner to bodily signals, such as one's heartbeat, has shown to improve symptoms ranging from depression to anxiety (Finucane & Mercer, 2006; Hofmann, Sawyer, Witt, & Oh, 2010). The efficacy of these approaches may lie in upregulating interoceptive systems in the brain, thereby strengthening bodily representations (Tajadura Jiménez, 2014). These questions should form an integral part of future research initiatives. Models of psychological functioning that incorporate embodied accounts of social emotions may go a long way in helping to further understand the essential processes via which the mind emerges, as well as assist in developing effective treatments for emotional disorders.

References

Albert, D. J., Jonik, R. H., & Walsh, M. L. (1992). Hormone-dependent aggression in male and female rats: Experimental, hormonal, and neural foundations. . *Neuroscience and Biobehavioural Reviews, 16*(2), 177-192. doi:10.1016/S0149-7634(05)80179-4

Armel, K. C., & Ramachandran, V. S. (2003). Projecting sensations to external objects: Evidence from skin conductance response. *Proceedings of the Royal Society:Biological Sciences*, *270*(1523), 1499-1506. doi:10.1098/rspb.2003.2364

Asai, T. (2011). Rubber hand illusion, empathy, and schizotypal experiences in terms of self-other representations. *Consciousness and Cognition, 20*(4), 1744 - 1750. doi:10.1016/j.concog.2011.02.005

Aspell, J. E., & Blanke, O. (2009). Understanding the out-of-body experience from a neuroscientific perspective. In C. D. Murray (Ed.), *Psychological scientific perspectives on out of body and near death experiences* (pp. 73-88). New York, NY: Nova Science Publishers.

Aydog, S. T. (2005). The effects of menstrual cycle on the knee joint position sense: Preliminary study. *Knee Surgery, Sports Traumatology, Arthroscopy, 13*(8), 649-653. doi:10.1007/500167-004-0604-7

Baron Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Neurosciences, 6*(6), 248-254. doi:10.1016/S1364-6613(02)01904-6

Bastiaansen, J. A., Thioux, M., & Keysers, C. (2009). Evidence for mirror systems in emotions. *Philosophical Transactions of the Royal Society of London.Series B, Biological Sciences, 364*(1528), 2391-2404. doi:10.1098/rstb.2009.0058

Botvinick, M. (1998). Rubber hands 'feel'touch that eyes see. *Nature, 391*(6669), 756-756. doi:10.1038/35784

Cardinali, D. P., Nagle, C. A., Gómez, E., & Rosner, J. M. (1975). Norepinephrine turnover in the rat pineal gland. acceleration by estradiol and testosterone. *Life Sciences, 16*(11), 1717-1724. doi:10.1016/0024-3205(75)90056-9

Cascio, C., Foss Feig, J., Burnette, C., Heacock, J., & Cosby, A. (2012). The rubber hand illusion in children with autism spectrum disorders: Delayed influence of combined tactile and visual input on proprioception. *Autism, 16*(4), 406-419. doi:10.1177/1362361311430404

Craig, A. (2004). Human feelings: Why are some more aware than others? *Trends in Cognitive Sciences*, *8*(6), 239 - 241. doi:10.1016/j.tics.2004.04.004

Crucianelli, L., Metcalf, N. K., Fotopoulou, A. K., & Jenkinson, P. M. (2013). Bodily pleasure matters: Velocity of touch modulates body ownership during the rubber hand illusion. *Frontiers in Psychology*, *4*(703), 1-7. doi:10.3389/fpsyg.2013.00703

Damasio, A. (2010). *Self comes to mind: Constructing the conscious mind*. New York, NY: Pantheon Books.

Decety, J. (2003). Shared representations between self and other: A social cognitive neuroscience view. *Trends in Neurosciences, 7*(12), 527-533. doi:10.1016/j.tics.2003.10.004

Dhavalikar, M., Narkeesh, A., & Gupta, N. (2009). Effect of skin temperature on nerve conduction velocity and reliability of temperature correction formula in indian females. *Journal of Exercise Science and Physiotherapy, 5*(1), 24-29. Retrieved from http://search.informit.com.au/documentSummary;dn=857685483155150;res=IELHEA

Durgin, F., Evans, L., Dunphy, N., Klostermann, S., & Simmons, K. (2007). Rubber hands feel the touch of light. *Psychological Science, 18*(2), 152-157. doi:10.1111/j.1467-9280.2007.01865.x

Ehrsson, H. H. (2012). The concept of body ownership and its relation to multisensory integration. In B. D. Stein (Ed.), *The new handbook of multisensory processes* (pp. 775-792). Cambridge, MA: MIT Press.

Eisenegger, C., Haushofer, J., & Fehr, E. (2011). The role of testosterone in social interaction. *Trends in Cognitive Sciences, 15*(6), 263-271. doi:10.1016/j.tics.2011.04.008

Feldman, R., Singer, M., & Zagoory, O. (2010). Touch attenuates infants' physiological reactivity to stress. *Developmental Science, 13*(2), 271-278. doi:10.1111/j.1467-7687.2009.00890.x

Ferri, F. (2013). The body beyond the body: expectation of a sensory event is enough to induce ownership over a fake hand. *Proccedings of the Royal Society, 280*(1765), 1140-1147. doi:10.1098/rspb.2013.1140

Ferris, C. F., Albers, H. E., Wesolowski, S. M., Goldman, B. D., & Luman, S. E. (1984). Vasopressin injected into the hypothalamus triggers a stereotypic behavior in golden hamsters. *Science*, *224*(4648), 521-523. doi:10.1126/science.6538700

Field, A. (2013). In Carmichael M. (Ed.), *Discovering statistics using IBM SPSS statistics* (4th ed.). Thousand Oaks, CA: Sage Publications Inc.

Finucane, A., & Mercer, S. W. (2006). An exploratory mixed methods study of the acceptability and effectiveness of mindfulness-based cognitive therapy for patients with active depression and anxiety in primary care. *BMC Psychiatry, 6*(14) doi:10.1186/1471-244X-6-14

Fotopoulou, A. (2009). Self-observation reinstates motor awareness in anosognosia for hemiplegia. *Neuropsychologia, 47*(5), 1256-1260. doi:10.1016/j.neuropsychologia.2009.01.018

Fridén, C. (2006). Knee joint kinaesthesia and neuromuscular coordination during three phases of the menstrual cycle in moderately active women. *Knee Surgery, Sports Traumatology, Arthroscopy, 14*(4), 383-389. doi:10.1007/s00167-005-0663-4

Gallagher, S. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Sciences, 4*(1), 14-21. doi:10.1016/S1364-6613(99)01417-5

Gallagher, S., & Cole, J. (1995). Body image and body schema in a deafferented subject. *Journal of Mind and Behavior, 16*(4), 369-389. Retrieved from http://psycnet.apa.org/psycinfo/1996-03068-001

Gallese, V. (2005). Embodied simulation: From neurons to phenomenal experience. *Phenomenology and the Cognitive Sciences, 4*(1), 23-48. doi:10.1007/s11097-005-4737-z

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119*(2), 593-610. doi:10.1093/brain/119.2.593

Guyton, A. C. (1996). Body temperature, temperature regulation and fever. *Textbook of medical physiology* (pp. 911-922). Philadelphia: W.B. Saunders Company.

Haggard, P., Taylor-Clarke, M., & Kennett, S. (2003). Tactile perception, cortical representation and the bodily self. *Current Biology, 13*(5), 170-173. doi:10.1016/S0960-9822(03)00115-5

Hänssler, I., & Prinzinger, R. (1979). The influence of the sex-hormone testosterone on body temperature and metabolism of the male japanese quail (coturnix coturnix japonica). *Cellular and Molecular Life Sciences, 35*(4), 509-510. doi:10.1007/BF01922736

Herbert, B. M., & Pollatos, O. (2014). Attenuated interoceptive sensitivity in overweight and obese individuals. *Eating Behaviors, 15*(3), 445-448. doi:10.1016/j.eatbeh.2014.06.002

Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting and Clinical Psychology, 78*(2), 169-183. doi:10.1037/a0018555

Inagaki, T. K., & Eisenberger, N. I. (2013). Shared neural mechanisms underlying social warmth and physical warmth. *Psychological Science, 24*(11), 2272-2280. doi:10.1177/0956797613492773

Ingudomnukul, E. (2007). Elevated rates of testosterone-related disorders in women with autism spectrum conditions. *Hormones and Behavior, 51*(5), 597-604. doi:10.1016/j.yhbeh.2007.02.001

Kammers, M. P., Rose, K., & Haggard, P. (2011). Feeling numb: Temperature, but not thermal pain, modulates feeling of body ownership. *Neuropsychologia, 49*(5), 1316-1321. doi:10.1016/j.neuropsychologia.2011.02.039

Kammers, M., de Vignemont, F., Verhagen, L., & Dijkerman, H. C. (2009). The rubber hand illusion in action. *Neuropsychologia, 47*(1), 204-211. doi:10.1016/j.neuropsychologia.2008.07.028

Kaya, D. (Ed.). (2014). *Proprioception, the forgotten sixth sense*. Foster City, CA: OMICS Group eBooks.

Kida, T., & Shinohara, K. (2013). Gentle touch activates the prefrontal cortex in infancy: An NIRS study. *Neuroscience Letters*, *541*, 63-66. doi:10.1016/j.neulet.2013.01.048

Kruk, M. R., van der Poel, A. M., Meelis, W., Hermans, J., Mos, P. G., & Lohman, A. M. H. (1983). Discriminant analysis of the localisation of aggressive inducing electrode placements in the hypothalamus of male rats. *Brain Research, 260*(1), 61-79. doi:10.1016/0006-8993(83)90764-3

Kumai, T., Tanaka, M., Watanabe, M., Matsumoto, C., & Kobayashi, S. (1994). Possible involvement of androgen in increased norepinephrine synthesis in blood vessels of spontaneously hypertensive rats. *The Japanese Journal of Pharmacology, 66*(4), 439-444. doi:10.1254/jjp.66.439

Lloyd, D. M., Gillis, V., Lewis, E., & Farrell, M. J. (2013). Pleasant touch moderates the subjective but not objective aspects of body perception. *Frontiers in Behavioral Neuroscience, 7*(207) doi:0.3389/fnbeh.2013.00207

Longo, M. R. (2008). What is embodiment? A psychometric approach. *Cognition, 107*(3), 978-998. doi:10.1016/j.cognition.2007.12.004

Lutchmaya, S. (2002). Foetal testosterone and eye contact in 12-month-old human infants. *Infant Behavior & Development, 25*(3), 327-335. doi:10.1016/S0163-6383(02)00094-2

Manning, J. T. (2001). The 2nd to 4th digit ratio and autism. *Developmental Medicine and Child Neurology, 43*(3), 160-164. doi:10.1111/j.1469-8749.2001.tb00181.x

Montoya, E. R. (2013). Testosterone administration modulates moral judgments depending on second-to-fourth digit ratio. *Psychoneuroendocrinology, 38*(8), 1362-1369. doi:10.1016/j.psyneuen.2012.12.001

Moore, C. (1982). Maternal behavior of rats is affected by hormonal condition of pups. *Journal of Comparative and Physiological Psychology, 96*(1), 123-129. doi:10.1037/h0077866

Morgan, H. L., Turner, D. C., Corlett, P. R., Absalom, A. R., Adapa, R., Arana, F. S., . . . Haggard, P. (2011). Exploring the impact of ketamine on the experience of illusory body ownership. *Biological Psychiatry, 69*(1), 35-41. doi:10.1016/j.biopsych.2010.07.032

Moseley, G. L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., & Spence, C. (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. *Proceedings of the National Academy of Sciences of the United States of America, 105*(35), 13169-13173. doi:10.1073/pnas.0803768105

Palmer, C. J. (2013). Movement under uncertainty: The effects of the rubber-hand illusion vary along the nonclinical autism spectrum. *Neuropsychologia*, *51*(10), 1942-1951. doi:10.1016/j.neuropsychologia.2013.06.020

Pan, Y., Xu, L., Young, K. A., Wang, Z., & Zhang, Z. (2010). Agonistic encounters and brain activation in dominant and subordinate male greater long-tailed hamsters. *Hormones and Behavior, 58*(3), 478-484. doi:10.1016/j.yhbeh.2010.05.001

Paton, B. (2012). The rubber hand illusion reveals proprioceptive and sensorimotor differences in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 42*(9), 1870-1883. doi:10.1007/s10803-011-1430-7

Pezzulo, G., & Iodice, P. (2013). Shared action spaces: A basis function framework for social re-calibration of sensorimotor representations supporting joint action. *Frontiers in Human Neuroscience, 7*(800) doi:10.3389/fnhum.2013.00800

Quattrocki, E. (2014). Autism, oxytocin and interoception. *Neuroscience & Biobehavioral Reviews, 47*, 410-430. doi:10.1016/j.neubiorev.2014.09.012

Roberts, T., & Pennebaker, J. (1995). Gender differences in perceiving internal state: Towards a his-and-hers model of perceptual cue use. *Advances in experimental social psychology* (27th ed., pp. 143-162). San Diego, CA: Academic Press, Inc.

Rochat, P. (2011). Possession and morality in early development. *New Directions for Child and Adolescent Development, 2011*(132), 23-38. doi:10.1002/cd.294

Rohde, M., Di Luca, M., & Ernst, M. O. (2011). The rubber hand illusion: Feeling of ownership and proprioceptive drift do not go hand in hand. *PloS One, 6*(6) doi:10.1371/journal.pone.0021659

Sapolsky, R. M. (1986). Stress-induced elevation of testosterone concentrations in high ranking baboons: Role of catecholamines*. *Endocrinology, 118*(4), 1630-1635. doi:10.1210/endo-118-4-1630

Schwoebel, J., & Coslett, H. B. (2005). Evidence for multiple, distinct representations of the human body. *Journal of Cognitive Neuroscience, 17*(4), 543-553. doi:10.1162/0898929053467587

Stanton, S. J., & Schultheiss, O. C. (2009). The hormonal correlates of implicit power motivation. *Journal of Research in Personality, 43*(5), 942-949. doi:10.1016/j.jrp.2009.04.001

Tajadura Jiménez, A. (2014). Balancing the “inner” and the “outer” self: Interoceptive sensitivity modulates self–other boundaries. *Journal of Experimental Psychology.General, 143*(2), 736-744. doi:10.1037/a0033171

Teneggi, C. (2013). Social modulation of peripersonal space boundaries. *Current Biology, 23*(5), 406-411. doi:10.1016/j.cub.2013.01.043

Tibi-Elhanany, Y. & Shamay-Tsoory, S.G. (2011). Social cognition in social anxiety: First evidence for increased empathic abilities. *Israel Journal of Psychiatry and Related Sciences, 48*(2), 98-106. doi:22120444

Tops, M., Boksem, M. A., Quirin, M., IJzerman, H., & Koole, S. L. (2014). Internally directed cognition and mindfulness: An integrative perspective derived from predictive and reactive control systems theory. *Frontiers in Psychology, 5*(429) doi:10.3389/fpsyg.2014.00429

Tsakiris, M., Tajadura Jiménez, A., & Costantini, M. (2011). Just a heartbeat away from one's body: Interoceptive sensitivity predicits malleability of body- representations. *Proceedings of the Royal Society, 278*(1717), 2470 - 2476. doi:10.1098/rspb.2010.2547

Tsakiris, M. (2007). On agency and body-ownership: Phenomenological and neurocognitive reflections. *Consciousness and Cognition, 16*(3), 645-660. doi:10.1016/j.concog.2007.05.012

Tsakiris, M. (2010). My body in the brain: A neurocognitive model of body-ownership. *Neuropsychologia, 48*(3), 703-712. doi:10.1016/j.neuropsychologia.2009.09.034

Tsakiris, M., & Haggard, P. (2005). The rubber hand illusion revisited: Visuotactile integration and self-attribution. *Journal of Experimental Psychology.Human Perception and Performance, 31*(1), 80-91. doi:10.1037/0096-1523.31.1.80

Tuiten, A., Van Honk, J., Koppeschaar, H., Bernaards, C., Thijssen, J., & Verbaten, R. (2000). Time course of effects of testosterone administration on sexual arousal in women. *Archives of General Psychiatry, 57*(2), 149 - 153. doi:10.1001/archpsyc.57.2.149.

van der Westhuizen, D., & Solms, M. (2015). Social dominance and the affective neuroscience personality scales. *Consciousness and Cognition, 33*, 90-111. doi:10.1016/j.concog.2014.12.005

van Honk, J., Schutter, D. J., Hermans, E. J., Putman, P., Tuiten, A., & Koppeschaar, H. (2004). Testosterone shifts the balance between sensitivity for punishment and reward in healthy young women. *Psychoneuroendocrinology, 29*(7), 937-943. doi:10.1016/j.psyneuen.2003.08.007

van Honk, J., Schutter, D., Bos, P., Kruijt, A., Lentjes, E., & Baron Cohen, S. (2011). Testosterone administration impairs cognitive empathy in women depending on second-to-fourth digit ratio. *Proceedings of the National Academy of Sciences of the United States of America, 108*(8), 3448-3452. doi:10.1073/pnas.1011891108

van Honk, J., Tuiten, A., Hermans, E., Putnam, P., Koppeschaar, H., Thijssen, J., . . . van Doornen, L. (2001). A single administration of testosterone induces cardiac accelerative responses to angry faces in healthy young women. *Behavioral Neuroscience, 115*(1), 238-242. doi:10.1037//0735-7044.115.1.238

van Stralen, H. E., van Zandvoort, M. J., Hoppenbrouwers, S. S., Vissers, L. M., Kappelle, L. J., & Dijkerman, H. C. (2014). Affective touch modulates the rubber hand illusion. *Cognition, 131*(1), 147-158. doi:10.1016/j.cognition.2013.11.020

Voracek, M. (2006). Lack of correlation between digit ratio (2D: 4D) and baron-cohen's "Reading the mind in the eyes" test, empathy, systemising, and autism-spectrum quotients in a general population sample. *Personality and Individual Differences, 41*(8), 1481-1491. doi:10.1016/j.paid.2006.06.009

Walsh, L. D. (2011). Proprioceptive signals contribute to the sense of body ownership. *Journal of Physiology, 589*(12), 3009-3021. doi:10.1113/jphysiol.2011.204941

Weissgerber, T. L., Milic, N. M., Winham, S. J., & Garovic, V. D. (2015). Beyond bar and line graphs: Time for a new data presentation paradigm. *PLOS Biology, 13*(4), 1-10. doi:10.1371/journal.pbio.1002128

Wright, N. D., Bahrami, B., Johnson, E., Di Malta, G., Rees, G., Frith, C. D., & Dolan, R. J. (2012). Testosterone disrupts human collaboration by increasing egocentric choices. *Proceedings.Biological Sciences / the Royal Society, 279*(1736), 2275-2280. doi:10.1098/rspb.2011.2523

Zhong, C. B., & Leonardelli, G. J. (2008). Cold and lonely: Does social exclusion literally feel cold? *Psychological Science, 19*(9), 838-842. doi:10.1111/j.1467-9280.2008.02165.x

Appendix A

Subject: Research Invitation - Females for Hormones and Cognition Study

Females are Invited to Participate in a Study on Hormones and Cognition in Exchange for R250.

Details about the study: Researchers at the Psychology department are running a study on the effects of testosterone on cognition.

Participation will involve coming into the lab twice on one day at the Psychiatry department. At 10:00 you will come in and receive either a placebo or a 0.5ml dosage of liquid testosterone to be taken orally. All women have naturally circulating testosterone in the body and the dosage is less than the total amount produced during one day. It will be out of your system within about 6 hours from the administration time and you will not experience any harmful side-effects. The second session of the day will be scheduled four hours later when you will return to the lab for 1 and a half hours where you will perform a variety of behavioral tasks. At the end you will be reimbursed with R250. This procedure has been approved by the Human Research Ethics Committee of the Health Sciences Faculty, and the South African Government's Department of Health and is part of a larger research protocol run by Professor Dan Stein, Head of Psychiatry.

Inclusion Criteria: Due to standardisation procedures, we are only recruiting females who are NOT taking any form of hormonal contraception (pill/ patch/ injection/ Mirena) or chronic medication. Note, you can only participate during the first 10 days following the end of a menstrual period.

How to participate: to sign up to participate, please follow the provided link below by cutting and pasting it in a new browser window and fill in your details on the online survey. Should you meet the criteria to participate you will be contacted directly via email.

http://www.sogosurvey.com/k/SsSTSVXsQTsPsPsP

Appendix B

9-item Self-Report Questionnaire of One's Subjective experience of the Rubber Hand Illusion

Rubber Hand Questionnaire

Please indicate on the scale below the extent of your agreement or disagreement with the following statements.

1. It seemed like I was looking at my own hand, rather than at a rubber hand

Disagree strongly	Disagree mostly	Disagree a bit	Neither agree Nor disagree	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

2. It seemed like the rubber hand was a part of my body

Disagree strongly	Disagree mostly	Disagree a bit	Neither agree Nor disagree	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

3. It seemed like the rubber hand was my hand

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

4. It seemed liked the rubber hand belonged to me

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly

5. It seemed like the rubber hand began to resemble my real hand

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

6. It seemed like the touch I felt was caused by the paintbrush touching the rubber

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

7. It seemed like the rubber hand was in the location where my hand was

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

8. It seemed like my hand was in the location where the rubber hand was

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

9. It seemed like I was unable to move my hand

Disagree strongly	Disagree mostly	Disagree a bit	Neither	Agree a bit	Agree mostly	Agree strongly
1	2	3	4	5	6	7

10. In the space below, enter the Participant Code that the experimenter will provide you with.

Characters Remaining: 100

Clear answers on page

Submit

Online Survey Software powered by SoGoSurvey

Appendix C

1.

PATIENT INFORMATION LEAFLET AND INFORMED CONSENT

Informed Consent Document

Instructions:

Please read through the following questions and their answers very carefully. After you have read through the document, please comment on whether you understood everything written in it, and sign where indicated.

If you have any further questions or concerns, please feel free to contact us:

Principal Investigator: Mark Solms
Department of Psychology **Tel: 021 650-3417**
University of Cape Town, Upper Campus
Rondebosch, Cape Town

Why is this research being done – what is it trying to find out?

This research is being done to find out more about how testosterone affects brain, the body and behaviour.

Why are you being invited to take part?

You are being invited to take part because you have expressed an interest to participate.

Will you need to take time off work?

During a research session, we will ask you to come in to the lab on two occasions on one day, which will be four hours apart. The first session will last 30 minutes and the second, 2 hours. Prior to signing up, you will be given an opportunity to select a research session that is most convenient for you.

What procedures, drugs or other treatments are involved in this research?

In this study you will be requested to take *either* 0.5mg of a testosterone or placebo solution under your tongue. This is a double-blind study, meaning that during the experiment, neither you nor the experimenter will know whether or not you will be receiving testosterone or placebo. You will also be requested to donate a 5ml vial of saliva, collected in a private bathroom cubicle. The saliva sample will be used to measure the natural level of testosterone in your body. We will NOT use the saliva sample to test for anything else and they will be stored in a security-controlled laboratory.

During this experiment you will be requested to fill in several questionnaires put to you by a researcher and then engage in several behavioural and computer tasks. Since we are interested in bodily processes, we will be measuring your ability to keep track of your heart beat, before and after a computer task. Finally, we will take measurements of your height, weight and scan your right hand.

What are the risks and discomforts of taking part in this research?

The testosterone is in liquid form with cyclodextrin as a carrier. Cylodextrin carriers can lead to diahorrea in *very* rare cases. Testosterone can lead to adverse drug reactions such as headache and nausea but these reactions are infrequently reported. All information you provide is kept strictly confidential. Your identity will remain anonymous throughout the research.

Are there any benefits to you if you take part in this research?

You will be compensated with R250 for taking part in this study.

What happens if you do not want to take part in this research?

Nothing. It is your right to not take part in the research, or to withdraw at any time during the research with no consequence to you, whatsoever. Furthermore you may request that your data be removed confidentially from the dataset.

What happens at the end of this research?

Debriefing will take place once all data is collected. This will allow you the opportunity to learn more about the aims and objectives of the study. You will not, however, be able to find out whether you received the testosterone or the placebo.

What happens at the end of this research?

Debriefing will take place once all data is collected. This will allow you the opportunity to learn more about the aims and objectives of the study. You will not, however, be able to find out whether you received the testosterone or the placebo.

Having read the above information, please sign below by typing your name and the date.

Characters Remaining: 100

Clear answers on page

Submit

Appendix D

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492 • Facsimile [021] 406 6411
Email: Sumayah.ariefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

11 December 2014

HREC/REF: 868/2014

Prof M Solms
Psychology
Room 2.07
PD Hahn Building
Upper Campus

Dear Prof Solms

Project Title: NEUROPSYCHOLOGICAL MECHANISMS OF SOCIAL POWER: THE ROLE OF SPATIAL REPRESENTATION AND COVERT ACTION SIMULATION PROCESSES (PhD-candidate- D van der Westhuizen) sub-study linked to 092/2011

Thank you for your response letter dated 28 November 2014, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above mentioned study.

Approval is granted for one year until the 30 December 2015.

Please submit a progress form, using the standardised Annual Report Form, if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

We acknowledge that the following student:-Donne van der Westhuizen is also involved in this project

Please note that the on-going ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.

Hrec/ref:868/2014

Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix E

The reliability, validity and safety of the methods for administering a single of dose of Testosterone have been shown by:

Aarts, H. &. (2009). Testosterone and unconscious positive priming increase human motivation separately. *Neuroreport*, *20*(14), 1300-1303. doi:10.1097/WNR.0b013e3283308cdd

Aleman, A. B. (2004). A single administration of testosterone improves visuospatial ability in young women. *Psychoneuroendocrinology, 29*(5), 612-617. doi:10.1016/S0306-4530(03)00089-1

Bos PA, T. D. (2010). Testosterone decreases trust in socially naive humans. *Proceedings of The National Academy of Sciences*, *107*(22), 9991-9995. doi:doi: 10.1073/pnas.0911700107

Bos, P. H. (2010). Testosterone administration modulates neural responses to crying infants in young females. *Psychoneuroendocrinology, 35*(1), 114-121. doi:10.1016/j.psyneuen.2009.09.013

Eisenegger, C. N. (2010). Prejudice and truth about the effects of testosterone on human bargaining behavious. *Nature, 463*(7279), 356-359. doi:10.1038/nature08711

Hermans, E. B. (2010). .Effects of exogenous testosterone on the ventral striatal BOLD response during reward anticipation in healthy women. *Neeuroimage, 52*(1), 277-283. doi:10.1016/j.neuroimage.2010.04.019

Hermans, E. P. (2006). A single administration of testosterone reduces fear-potentiated startle in humans. *Biological psychiatry*, *59*(9), 872-874. doi:10.1016/j.biopsych.2005.11.015

Hermans, E. P. (2006). Testosterone administration reduces empathetic behavior: a facial mimicry study. *Psychoneuroendocrinology*, *31*(7), 859-866. doi:10.1016/j.psyneuen.2006.04.002

Hermans, E. P. (2007). Exogenous Testsoterone attenuates the integrated central stress response in healthy women. *Psychoneuroendocrinology, 32*(8-10), 1052-1061. doi:10.1016/j.psyneuen.2007.08.006

Hermans, E. R. (2008). Exogenous testosterone enhances responsiveness to social threat in the neural circuitry of social aggression in humans. *Biological Psychiatry, 63*(3), 263-270. doi:10.1016/j.biopsych.2007.05.013

Postma, A. M. (2000). Effects of testosterone administration on selective aspects of object-location memory in healthy young women. *Psychoneuroendocrinology, 25*(6), 563-575. doi:10.1016/S0306-4530(00)00010-X

Schutter, D. &. (2004). Decoupling of midfrontal delta-beta oscillations after testosterone administration. *International JOurnal of Psychophysiology, 53*(1), 71-73. doi:10.1016/j.ijpsycho.2003.12.012

Schutter, D. P. (2005). Administration of testosterone increases functional connectivity in a cortico-cortical depression circuit. *The Journal of Neuropsychiatry and Clinical Neuroscience, 17*(3), 372-377. doi:10.1176/jnp.17.3.372

Tuiten, A. V. (2000). Time course of effects of testosterone administration on sexual arousal in women. *Archive of General Psychiatry, 57*(2), 149-152. doi:10.1001/archpsyc.57.2.149

Tuiten, A. v. (2002). Can sublingual testosterone increase subjective and physiological measures of laboratory-induced sexual arousal? *Archive of General Psychiatry Journal, 59*(5), 465-466. doi:10.1001/archpsyc.59.5.465

van der Made, F. B. (2009). Childhood sexual abuse, selective attention for sexual cues and the effects of testosterone with or without vardenafil on physiological sexual arousal in wom with sexual dysfunction. *The Journal of Sexual Medicine, 6*(2), 429-439. doi:10.1111/j.1743-6109.2008.01103.x van der Made, F. B. (2009). The influence of testosterone combined with a PDE5-inhibitor on cognitive, affective, and physiological sexual functioning in women suffering from sexual dysfunction. *The JOurnal of Sexual Medicine*, *6*(3), 777-790. doi:10.1111/j.1743-6109.2008.01142.x

van Honk, J. &. (2007). Testosterone reduces conscious detection of signals serving social correction: implications for antisocial behavior. *Psychological Science*, *18*(8), 663-667. doi:10.1111/j.1467-9280.2007.01955.x

van Honk, J. P. (2005). Testosterone reduces unconscious fear but not consciously experienced anxiety: implications for the disorders of fear and anxiety. *Biological Psychiatry*, *58*(3), 218-225. doi:10.1016/j.biopsych.2005.04.003

van Honk, J. S. (2004). Testosterone shifts the balance between sensitivity for punishment and reward in healthy young women. *Psychoneuroendocrinology, 29*(7), 937-943. doi:10.1016/j.psyneuen.2003.08.007

van Honk, J. S.-C. (2010). Testosterone administration impairs cognitive empathy in women depending on second/fourth digit ratio. *Proceedings of the National Academy of Sciences*, *108*(8), 3448-3452. doi:10.1073/pnas.1011891108

van Honk, J. T. (2000). Conscious and preconscious selective attention to social threat: different neuroendocrine response patterns. *Psychneuroendocrinology, 25*(6), 577-591. doi:10.1016/S0306-4530(00)00011-1

van Honk, J. T. (2001). A single administration of testosterone induces cardiac accelerative responses to angry faces in healthy young women. *Behavioural Neuroscience, 115*(1), 238-242. doi:10.1037/0735-7044.115.1.238