Effect of Testosterone on Interoception in Women

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Abstract

Background and aims: Interoceptive accuracy (IA) refers to the ability to accurately detect internal visceral signals and appears to be involved in emotion regulation processes. Recent findings indicate that IA tends to decrease significantly following social ostracism, suggesting a link between interoception and social threat. Given that testosterone, is known to promote resilience and encourage status-seeking behavior in contexts that are socially threatening, the present study aimed to investigate whether its effects on social functioning are mediated, in part, by changes in IA.

Method: A randomised, double-blind, placebo-controlled trial was implemented using a sample (n = 39) of females aged 18 – 35. Testosterone was administered at a dosage of 0.5ml, sublingually. Participants performed a heartbeat-tracking task, a commonly employed measure of IA, before and after being ostracized in an online Cyberball game.

Results: When controlling for individual variability in heart rate, there was a significant effect of testosterone on baseline IA compared to the placebo group. Furthermore, a statistically significant difference in the change in IA following the Cyberball game emerged between the groups, with testosterone causing a drop from baseline while the placebo group exhibited an increase..

Discussion: Higher baseline IA scores in the testosterone group may reflect enhanced self-related processing, consistent with reports of concomitant activation of the insula cortex. Alternatively, the decrease in IA following exclusion in the Cyberball game may facilitate a coping response aimed at restoring group membership. These findings offer important new insights into the mechanisms via which testosterone influences social behaviour.

Key words: interoception; interoceptive accuracy; testosterone; social threat; ostracism

Effect of Testosterone on Interoception in Women

The idea that psychological experiences are intrinsically embodied is one that has gained traction within the past few years. The central tenet of this study is that mental experience is profoundly influenced by the fact that the brain resides within a body (Gallese & Sinigaglia, 2010). Within the brain, the body is represented in multiple ways, which together form a cohesive phenomenological experience that provides a basis for self-awareness (Ainely & Tsakiris, 2013). Importantly though, the different ways in which these representation are integrated may have important implications for the experience of selfhood. Interoception, which refers to the awareness of internal bodily states, is one such form of representation (Borghi & Cimatti, 2010; Craig, 2002; Tajadura-Jimenez & Tsakiris, 2014) and appears to be involved in the top-down modulation of emotional behavior (Seth, 2013; Tajadura-Jimenez & Tsakiris, 2014). Several lines of evidence have recently highlighted the role of interoception in *social* functioning (in paticular, Ainley & Tsakiris, 2013; Durlik & Tsakiris, 2015; Tajadura-Jimenez & Tsakiris, 2014). Social exclusion, a form of social threat, is known to reduce accuracy in the awareness of internal bodily states. Given that the hormone, testosterone, is known to play a major role in social emotions (Bos, Panskepp, Bluthe, & van Honk, 2012), an exploration into whether or not its effects are mediated in part at the sensory-motor level by modulating interoception, is warranted.

Definitions and Neurological Foundations

Interoception refers to the awareness of signals or feelings that arise from within the body, which may be derived from any of the internal organs or systems, as opposed to bodily sensations that are perceived exteroceptively, such as touch, vision and smell (Ainley & Tsakiris, 2013; Craig, 2002; Fairclough & Goodwin, 2007). These signals or feelings are generally linked to activity of the autonomic nervous system and may potentially alter the thoughts and behaviours of an organism, regardless of whether the organism is fully conscious of them or not (Cameron, 2001).

Neuroimaging studies have highlighted two possible interoceptive pathways. The first involves the afferent projections to the right anterior insula cortex, while the second pathway involves the afferent projections from the skin to the somatosensory cortex. This second pathway differs from that of discriminatory touch as the interoceptive tactile pathway is more involved with pleasant sensation (Craig, 2002; Khalsa, Rudrauf, Feinstein, & Tranel, 2009). Both of the above pathways are believed to work in unison to process incoming interoceptive signals. The dorsal cingulate gyrus, and the dorsomedial prefrontal cortex have also been

implicated in the processing of interoceptive signals (Pollatos, Schandry, Auer, & Kaufman, 2007). Along similar lines of research, Fairclough and Goodwin (2007) reported a positive correlation between the accuracy in detecting interoceptive signals and the size of the right anterior insula, which suggests that this structure is heavily involved in interoception. However, the chemical modulation of these brain structures still remains to be established.

Interoception is usually studied by contrasting the interoceptive awareness of an individual, with their interoceptive accuracy (IA; Ainley & Tsakiris, 2013; Chentsova-Dutton & Dzokoto, 2014). Interoceptive awareness refers to the self-reported inclination of an individual to attend to their internal bodily signals, while IA refers to the ability of an individual to accurately detect their internal bodily signals (Chentsova-Dutton & Dzokoto, 2014). There are several ways to measure IA. One method that has generated a lot of research is a task involving the perception of one's own heartbeat, one of the few internal bodily signals that can be readily detected. This method has also been shown to be the most accurate measure of IA, and as such, IA is typically measured using a heartbeat perception task (Ainley & Tsakiris, 2013; Ferri, Ardizzi, Ambrosecchia, & Gallese, 2013; Garfinkel, Seth, Barret, Suzuki, & Critchley, 2015; Tajadura-Jimenez & Tsakiris, 2014). This usually takes the form of a participant counting one's own heartbeat without touching a pulse site, and comparing one's count to that of an objective heart rate monitor (Ainley & Tsakiris, 2013; Tajadura-Jimenez & Tsakiris, 2014). These experiments often show that women perform less well than men in terms of IA, which indicates a possible gender difference in interoception (Ainley & Tsakiris, 2013).

The Function of IA

There is still debate as to the exact function of interoceptive awareness, however several theories have been proposed. Damasio, in his book *Self Come to Mind* (2012), argues that the primitive feeling state that interoception provides is foundational in the development of self-consciousness as it gives rise to a basic sense of selfhood by focusing the mind on the material body in which it resides. This provides a relatively stable representation within the organism, from which an organism is able to interpret changes in neural information. Specifically, interoceptive signals converging in the insula region of the cortex have been proposed to underpin this rudimentary form of self-consciousness by mapping representations of the body in the brain, which in turn enables the conscious detection of physiological change.

The fact that interoception enables the detection of physiological change suggests that it functions as a key process linking bodily states to externally triggered affective reactions.

Corroborating this, the insula is well known for its role in integrating emotional experience and physiological states (Eisenberger, 2012). This idea is best articulated by the somatic marker hypothesis, developed by Damasio, Everitt, and Bishop (1996). This hypothesis states that bodily responses elicited by environmental stimuli play an integral role in influencing emotional decision-making. While early work emphasised a link with anxiety in particular (Fairclough & Goodwin, 2007; Fukushima, Terasawa, & Umeda, 2011), more recent findings suggest that interoceptive processes are brought to consciousness as a function of emotional *intensity* (Herbert, Pollatos, Flor, Enck, & Schandry, 2010) and not by way of any one specific emotional response. For instance, accuracy in the detection of interoceptive signals has been associated not only with the apprehension of public speaking (Durlik, Cardini, & Tsakiris, 2014), but is also related to positive emotional reactions such the anticipation of a social reward (Ferri et al., 2013), feelings of body competence (Ainley & Tsakiris, 2013), self-regulation and physical exercise (Herbert et al., 2010). These findings underscore a role for interoception in optimal behavioral regulation in emotional contexts.

Accumulating evidence converges on the hypothesis that IA may have important implications for coping with threat, specifically social threat. In line with the findings reporting robust insula activation in response to social exclusion (Eisenberger, 2012), a recent study by Pollatos, Matthias, and Keller (2015) reported a negative correlation between IA and levels of perceived distress following social rejection. Moreover, Pollatos et al. (2015) found that higher IA was associated with lower levels of perceived distress, as well as, behavioural affiliation following social exclusion. In line with these findings, Durlik and Tsakiris (2015) showed that on average, IA tends to drop significantly in response to the negative experience of social ostracism in an online ball-tossing game, in which the participant throws a virtual ball between pre-programmed avatars, which keep the ball away from the participant. Those with superior interoceptive abilities appear to be better able to successfully down-regulate negative emotions during unpleasant social interactions (Fustos, Gramann, Herbert, & Pollatos, 2012), possibly through the use of implicit suppression strategies (Kever, Pollatos, Vermeulen, & Grynberg, 2015). For instance higher level of IA is seen in individuals who make greater use of suppression strategies (Kever et al., 2015). These findings suggest that the integrity of internal bodily representations may constitute a critical mechanism of emotional regulation in threatening situations.

Durlik and Tsakiris (2015) have proposed that the modulation of interoception during stressful situations may inform the style of attentional processing in controlling behavior. Specifically, the ability to accurately perceive bodily signals may help to direct attention

away from the exteroceptive domain, which takes precedence when the brain's purported *reactive control* system is in operation (Tops, Boksem, Luu, & Tucker, 2010). This may allow behavior to be controlled to a greater extent by top-down factors such as prior cognitive schemas, referred to as the *predictive control* system. This shift causes a behavioural style that is less attentive to the immediate, external world of the individual and may serve as an adaptive mechanism that immobilises the individual for adaptive coping, and is informed by previous learning when coping with stress.

It is widely acknowledged that social-emotional behaviours in mammals are under the influence of steroid hormones (Bos et al., 2012). In particular, the steroid hormone, testosterone, has been linked in many instances of active coping efforts, characterised by aggressive approach-oriented behavior. In men testosterone is produced in the testes while in women this occurs in the placenta and ovaries. It is also produced in the adrenal cortex of both sexes (Arnold & Gorski, 1984). Testosterone is mainly associated with behavioral states that promote social resilience and dominance in competition, contexts that are inherently socially threatening (Eisenegger, Haushofer, & Fehr, 2011; Kouri, Lukas, Pope, & Oliva, 1995; van Honk et al., 2001). This suggests that there may be a link between IA and testosterone, as IA has been shown to be linked to social threat (Durlik & Tsakiris, 2015).

In situations of social threat, such as viewing angry faces, women have been found to secrete testosterone, which increases the amygdala response, a brain structure known to be closely linked to threat (Bos, van Honk, Ramsey, Stein, & Hermans, 2013). Likewise, significant positive correlations have been found between testosterone levels and amygdala activity in men after viewing angry male and female faces (Derntl et al., 2009). Importantly, recent research has demonstrated that the experience of social rejection, a common form of social threat, corresponds with reduced baseline testosterone levels (Eisenegger et al., 2011), suggesting that testosterone may exert its effects on social functioning via its effect on interoceptive processing. This idea is supported by the reported sex difference in IA in which males tend to exhibit more accurate judgments of IA (Ainley & Tsakiris, 2013). Additionally, Bos and colleagues (2012) found that in humans, the administration of testosterone strongly influences several limbic regions, including the insula, while also reducing fearfulness to threatening faces, as highlighted above (Bos et al., 2013; Derntl et al., 2009). Specifically, the effect of testosterone on amygdala activity and subsequent behavioural responses to threat-related stimuli may enable the preferential processing of specific stimuli that are relevant to a competitive style of coping, while simultaneously down-regulating those which are not (Bos et al., 2013; Derntl et al., 2009).

Changes in the processing of emotional stimuli have significant effects on behaviour in social settings. For instance, several studies have reported declines in empathic abilities following testosterone administration, such as the ability to infer emotional state based on images of facial expressions (Eisenegger et al., 2011). Notably, it has been argued that inference about the emotional state or thoughts of another individual requires *attenuation* of interoceptive signals, so that these sensations do not interfere with the interpretation of the autonomic signals of the 'other', which are perceived by the exteroceptive domain and subsequently represented in the brain (Quattrocki & Friston, 2014). As such, interoception could interfere with the capacity to act altruistically in social situations.

Together, these findings suggest that the modulation of interoception may depend partly on testosterone functioning as an embodied mechanism that influences responding in social interactions in ways that promotes a competitive attitude. Supporting this, Lyons and Hughes (2015) recently found a relationship between IA and narcissism, a character trait that has been linked to dominant behavior and testosterone (Sellers, Mehl, & Josephs, 2007) and which the authors believe underpins the reduced empathy found in these individuals.

Therefore we see that there is a multitude of overlap between interoception and testosterone. Despite the overlap, there is insufficient literature on the interaction between testosterone and interoception, probably because literature on the embodied modulation of social emotions is only now beginning to gain wider interest. Thus, it is worth investigating whether or not the effects of testosterone on social behavior are due to an influence on interoception, especially in social situations that call for proactive coping.

Aim and Hypotheses

This study aimed to investigate the effects of testosterone on IA in females, as measured by a heartbeat-tracking task, as well as the relationship between IA and several personality variables. It further sought to investigate whether or not testosterone modulates the dampening effect of social threat on IA.

The hypotheses for the study were as follows:

1. Testosterone will significantly increase baseline IA relative to placebo.
2. Testosterone will attenuate the drop in IA, which has been shown to occur as a result of social rejection in a virtual-reality setting.
3. Baseline IA will positively correlate with personality traits related to social resilience.

Method

Design

The study constituted a mixed variables double-blind placebo-controlled experiment, with additional correlational variables. This study contained aspects of between group elements, as well as within-group variables.

Independent variable 1. Testosterone (2 levels; between-groups). Participants were randomly allocated to either a group that received testosterone or one that received a placebo.

Independent variable 2. Time (2 levels; within-groups). Participants within both the placebo and testosterone groups completed the IA task before and after completing the Cyberball social exclusion task (described in measures).

Dependent variable. Interoceptive Aaccuracy. The IA of the participants was measured using a heartbeat perception task (described in measures and procedures).

Setting. The study took place in a controlled room in the Department of Psychiatry at the University of Cape Town (UCT).

Participants

A total of 58 female participants were recruited using convenience-sampling techniques. This was done through the Student Research Invitation Initiative at the University of Cape Town, as well as on the classifieds website Gumtree.co.za (Appendix A). All participants were compensated for their time with R250.

Body mass index (BMI) interferes with IA (Herbert & Pollatos, 2014), therefore six participants were excluded as their BMI was over 30. Five participants were excluded due to technical difficulties with the heart rate device. Two participants were excluded for being left-handed, and a further six participants were excluded as they were dishonest about their menstrual cycles.

Participants in the final sample (N = 39) were randomly assigned to either the placebo group (n = 20), or the testosterone group (n = 19).

Inclusion criteria. Right-handed women, of any race and culture, between the ages of 18-35 years old, who were not on any type of hormonal medication, such as the oral contraceptive or hormonal replacement therapy. Participants must have been in the first 10 days following the end of their last menstruation.

Only women were used in this study as the effects of 0.5mg of testosterone have been reliably reported in women four hours after sublingual (under the tongue) administration of the hormone (Tuiten et al., 2000). No such studies have been conducted on men using the specific dosage of 0.5mg of testosterone. Women were also only used as they have

significantly lower levels of endogenous testosterone than men, and as such exogenous testosterone would have a greater effect on women (Tuiten et al., 2000). The participants were not on any hormonal medication to prevent any confounding interactions that may arise with testosterone. Participants were in the first 10 days following the end of their last menstruation in order to control for any hormonal fluctuations that occur during the menstrual cycle that may affect the cognitive abilities of the participants (Hampson, 1990). All participants were right-handed in order to control for hemispheric lateralisation of the insular regions involved in interoception (Lake & Bryden, 1976).

Exclusion criteria. Participants were excluded from the study if they were pregnant, as there are major hormonal changes that occur in pregnancy that could confound the results (O'Leary, Boyne, Flett, Beilby, & James, 1991). Participants were also excluded if they had been diagnosed previously with a psychiatric disorder and/or were taking any psychiatric medication, in order to prevent any interaction effects. Participants were also excluded if their BMI was over 30.

Materials

Self-report measures.

***The Affective Neuroscience Personality Scales (ANPS*).** The ANPS provide a description of personality in terms of one's general tendency to experience several basic emotions (Davis, Panksepp & Normansell, 2003; Davis & Panksepp, 2011). Research has demonstrated that these emotion traits load reliably onto the Five-Factor Model of personality (Davis et al., 2003), which consistently describes variation in personality across both age and culture in terms of five core variables. Dominance and lust items developed in a recent study by van der Westhuizen and Solms (2015), and which have been shown to correlate uniquely with circulating testosterone, were also administered alongside the original ANPS (ANPS-DL; Appendix B). The questionnaire consists of 118 3-point Likert-like scale items, which measures the extent to which the participant agrees or disagrees with a statement about themselves (0 = strongly disagree, 3 = strongly agree; Davis et al., 2003; Davis & Panksepp, 2011; van der Westhuizen & Solms, 2015). This measure was included in order to investigate whether there is any correlation between certain personality traits and IA.

The Post Ostracism Cyberball Questionnaire. The Post Ostracism Cyberball Questionnaire (Appendix C) provides an illustration of the extent to which the participants felt the effects of the Cyberball social ostracism task (Williams et al., 2002). The questionnaire consists of 24 5-point Likert-like items. These items measure the extent of how ostracised the participant felt at the completion of the Cyberball task (1 = not a at all, 5 = very

much) and has shown to be a valid and reliable measure (Williams et al., 2002).

Physiological materials.

Testosterone. In line with standard practice, testosterone, with a hydroxypropyl-β-cyclodextrin liquid carrier, was administered sublingually (under the tongue) in a single administration dosage of 0.5mg. This dosage is capable of markedly altering emotional and cognitive functioning four hours after administration in women (Tuiten et al., 2000).

***Heart rate monitoring device*.** The heart rate of the participant was measured using a custom-made (developed by Dr Lester John, Biomedical Engineering Department, UCT) optical heart rate sensor placed on the index finger of the left hand. The sensor was connected to a physiological data unit (NI-USB 6000, National Instruments) that sampled at 1 kHz. Recording was controlled by a computer program, which provided the participant with audio and visual prompts.

***Digit ratio*.** A Cannon document scanner was used to scan the right hand of the participants. The ratio of the second and fourth digits was compared, as this is an indicator of baseline testosterone (Tuiten et al., 2000).

Social exclusion task.

Cyberball social exclusion task. The Cyberball task is a simple computerised game that was developed by Williams, Cheung and Choi (2000). The game is played by the participant and two avatars, and consists of 30 ball tosses between the three players. It includes a socially included condition, where all players receive the ball equally, and a socially excluded condition, where the participant only receives the ball twice at the very beginning of the game. This game has been shown to accurately induce the feeling of ostracisation in participants, and as such will serve as the social threat stimulus of the study (Williams, Cheung & Choi, 2000). This is because ostracising an individual causes them to feel socially threatened (Williams et al., 2000).

Procedure

Before the study commenced, ethical approval was granted from the Health Sciences Human Research Ethics Committee of UCT (Appendix D) as well as the Department of Psychology at UCT. Prior to commencement of the hormone trials, a pilot study was conducted to assess the soundness of the experimental procedures. No hormones were used in the pilot study and none of the data collected was used in the final analysis.

Participants who met the inclusion criteria were invited to complete an online sign-up form on the Sogo.com platform, which included the ANPS-DL. Once this was completed and it was verified that the participants met the inclusion criteria, they were invited to sign-up for

an experimental slot of their choosing using an online scheduling service, Doodle.com. Participants were required to select a slot that had two experimental sessions on the same day.

Testosterone administration session. On arrival for session 1 at the testing venue, participants were given a brief overview as to what was required from them, and given a written consent form to sign (Appendix E), which stressed that all information and data will remain confidential and anonymous. A passive 5ml salivary sample was then taken in case deemed necessary to examine baseline testosterone levels in the future. Participants were asked to rinse their mouth out with water and then, using a straw, deposit saliva into a vial until it reached the 5ml mark. The vials were placed into a Ziploc bag and stored in a freezer. Participants were then given a vial, containing either liquid testosterone or a placebo, and instructed to place it underneath their tongue and wait 60 seconds before swallowing. Participants were requested to not eat during the hour preceding the second session and to refrain from engaging in any strenuous activity or ingesting excessive amounts of caffeine and/or nicotine in the time between testing sessions so as to avoid natural fluctuations in hormone levels and interoceptive abilities (Herbert, Muth, Pollatos, & Herbert, 2012).

Data collection session. The second session commenced four hours after the first. A female researcher collected all the data in this session. This was done in order to prevent any gender-based influences on power relations. The IA task was administered by connecting the heart rate monitor to the participants' left index finger, who was seated in front of a computer screen. Participants were asked to concentrate and try and count their heart beat, without touching any part of their body. Instructions on when to start and stop counting were presented audio-visually, with each counting trial being commenced and ceased with the words "go" and "stop". There was a single training interval, followed by three test intervals. The three intervals added up to 110 seconds, specifically they were 45, 35 and 30 seconds respectively, and the order of the intervals was randomly assigned, using a random number generator. The participant reported their heartbeat count at the end of each interval to the researcher, which was compared to the objective count derived from the heart rate monitor. No feedback on the participant's performance was given. Participants then performed the Cyberball task. Once the task was completed they performed the IA task again. Results of the second IA task were recorded and compared to the earlier results. The participant then completed the Post Cyberball Social Ostracism Questionnaire.

Administration of the IA task was counter-balanced across sessions with the Rubber Hand Illusion (Appendix F), which formed the basis of a separate investigation undertaken

by Teneille Page.

Finally, the height and weight of the participant was recorded at the completion of the IA task since BMI (Ainley & Tsakiris, 2013) has been reported to influence IA. The right hand of the participant was then scanned. Participants then had the opportunity to ask any questions, while they filled out a receipt and received R250 before leaving.

The data was recorded into excel, and later coded into SPSS version 22.0 (SPSS, IBM. Corporation, 2013, Chicago, IL.) for analysis.

In order to prevent disclosure of the study from occurring between participants, a debriefing email (Appendix G) was sent to all participants at the conclusion of the data collection process.

Results

Prior to the analyses, the data was screened for outliers and tested for violations of the assumptions required for the use of standard parametric analyses. As the data did not uphold the assumption of normal distribution (Appendix H), non-parametric statistical tests were conducted. The effect of testosterone on IA variables was investigated using a Mann-Whitney U-test for the between subjects variable (testosterone group versus placebo group) and a Wilcoxon matched pairs test for the within subjects variable (baseline IA versus post-Cyberball IA).

Note that “IA-change” refers to the difference between baseline IA scores and post-Cyberball IA score. This variable was created as it produces a value that is directly interpretable regarding the response the Cyberball social ostracism task.

Post Ostracism Cyberball Questionnaire

Table 1 highlights the descriptive statistics of the Post Ostracism Cyberball Questionnaire. An answer of 1 indicates that the statement did not at all reflect that participant’s reaction, while an answer of 5 indicates that the participant completely agreed with the statement. A comparison of the means for the negative items compared to the positive items indicates that the Cyberball task was successful in its manipulation. The most prominent item that indicates this is the last item of the questionnaire; “I was excluded”. The placebo group had a mean score of 4.62 ($\pm$ .87) for this item, and the testosterone group had a mean score of 4.29 ($\pm$ 1.21) out of a total of 5. This indicates that the exclusion manipulation was successful. The sub-totals for the positive and negative items of the scale (see Table 2) further prove the manipulation was effective. The positive items had a mean score of 1.94 ($\pm$ 1.13) while the negative items had a mean score of 3.13 ($\pm$ 1.47) out of a

possible score of 5. This indicates that the participants identified more with the negative feelings than the positive ones.

Table 1.

A Summary of the Descriptive Statistics of the Post Ostracism Cyberball Questionnaire

	Placebo *n* = 13	Testosterone *n* = 17
	M (SD)	*M* (SD)
I Felt Disconnected	3.846 (1.068)	4.118 (.781)
I Felt Rejected	4.000 (1.225)	4.176 (.883)
I Felt Like an Outsider	4.077 (1.188)	4.294 (.772)
My Feelings were Hurt	2.769 (1.691)	2.882 (1.409)
I Felt Good About Myself	2.538 (1.198)	1.824 (.809)
My Self-esteem was High	2.308 (1.032)	2.235 (1.033)
I Felt Liked	1.385 (.650)	1.294 (.470)
I Felt Invisible	3.538 (1.391)	3.588 (1.661)
I Felt Meaningless	3.308 (1.377)	2.118 (1.269)
I Felt non-existent	3.462 (1.713)	2.765 (1.437)
I Felt Powerful	1.385 (.768)	1.353 (.996)
I Felt I had Control	1.385 (1.121)	1.059 (.243)
I Felt Superior	1.462 (.877)	1.176 (.728)
I Felt Angry	2.308 (1.316)	2.353 (1.498)
My Mood was Good	2.154 (.987)	2.118 (1.111)
My Mood was Bad	2.769 (1.363)	3.000 (1.275)
My Mood was Happy	2.000 (1.000)	1.706 (.920)
My Mood was Sad	2.615 (1.446)	2.294 (1.312)
My Mood was Friendly	2.462 (1.198)	2.294 (1.263)
My Mood was Unfriendly	2.692 (1.377)	2.647(1.222)
My Mood was tense	3.154 (.987)	2.647 (1.222)
My Mood was Relaxed	2.154 (1.068)	2.765 (1.300)
I was Ignored	4.692 (.630)	4.353 (1.169)
I was Excluded	4.615 (.878)	4.294 (1.213)

Note. Data presented are mean values and standard deviations in parenthesis.

An analysis of variance (ANOVA) was conducted to ascertain whether there were any significant differences between the testosterone group and the placebo group regarding specific items of the questionnaire. All assumptions were upheld.

Table 2.

Summary of the Sub-Totals of the Positive and Negative items of the Post Ostracisim Cyberball Questionnaire

	Placebo	
	n	*M* (SD)
Negative items	360	3.125 (1.471)
Positive items	330	1.939 (1.128)

Note. SD = Standard Deviation

The ANOVA (Table 3) indicated that only the item, "I felt meaningless," reflected a significant difference in scores between the placebo and testosterone groups, $F(1, 28) = 6.019$, $p = .021$, $r^2 = .806$, with the placebo group ($M = 3.31$) scoring higher than the testosterone group ($M = 2.12$).

Table 3.

Summary of the ANOVA Analysis of the Post Ostracism Cyberball Questionnaire

Item		Sum of Squares	*df*	Mean Square	*F*	*p*
I Felt Disconnected	Between Groups	.313	1	.313	.345	.562
	Within Groups	22.650	25	.906		
	Total	22.963	26			
I Felt Rejected	Between Groups	.002	1	.002	.002	.961
	Within Groups	19.183	25	.767		
	Total	19.185	26			
I Felt Like an Outsider	Between Groups	.030	1	.030	.052	.822
	Within Groups	14.267	25	.571		
	Total	14.296	26			
My Feelings were Hurt	Between Groups	.046	1	.046	.019	.891
	Within Groups	60.917	25	2.437		
	Total	60.963	26			
I Felt Good About Myself	Between Groups	3.113	1	3.113	3.263	.083
	Within Groups	23.850	25	.954		
	Total	26.963	26			
My Self-esteem was High	Between Groups	.119	1	.119	.102	.752
	Within Groups	29.067	25	1.163		
	Total	29.185	26			
I Felt Liked	Between Groups	.313	1	.313	1.069	.311
	Within Groups	7.317	25	.293		
	Total	7.630	26			
I Felt Invisible	Between Groups	.046	1	.046	.018	.894
	Within Groups	64.250	25	2.570		
	Total	64.296	26			
I Felt Meaningless	Between Groups	12.452	1	12.452	7.285	.012*
	Within Groups	42.733	25	1.709		
	Total	55.185	26			
I Felt non-existent	Between Groups	5.007	1	5.007	2.050	.165
	Within Groups	61.067	25	2.443		
	Total	66.074	26			
I Felt Powerful	Between Groups	.002	1	.002	.002	.964
	Within Groups	22.517	25	.901		

	Total	22.519	26			
I Felt I had Control	Between Groups	.817	1	.817	1.288	.267
	Within Groups	15.850	25	.634		
	Total	16.667	26			
I Felt Superior	Between Groups	.600	1	.600	.862	.362
	Within Groups	17.400	25	.696		
	Total	18.000	26			
I Felt Angry	Between Groups	.091	1	.091	.045	.834
	Within Groups	50.650	25	2.026		
	Total	50.741	26			
My Mood was Good	Between Groups	.002	1	.002	.002	.969
	Within Groups	29.850	25	1.194		
	Total	29.852	26			
My Mood was Bad	Between Groups	.150	1	.150	.094	.762
	Within Groups	39.850	25	1.594		
	Total	40.00	26			
My Mood was Happy	Between Groups	.417	1	.417	.468	.500
	Within Groups	22.250	25	.890		
	Total	22.667	26			
My Mood was Sad	Between Groups	.817	1	.817	.427	.520
	Within Groups	47.850	25	1.914		
	Total	48.667	26			
My Mood was Friendly	Between Groups	.046	1	.046	.029	.867
	Within Groups	40.250	25	1.610		
	Total	40.296	26			
My Mood was Unfriendly	Between Groups	.067	1	.067	.039	.845
	Within Groups	42.600	25	1.704		
	Total	42.667	26			
My Mood was tense	Between Groups	1.780	1	1.780	1.341	.258
	Within Groups	33.183	25	1.327		
	Total	34.963	26			
My Mood was Relaxed	Between Groups	2.963	1	2.963	2.096	.160
	Within Groups	35.333	25	1.413		
	Total	38.296	26			
I was Ignored	Between Groups	.535	1	.535	.670	.421
	Within Groups	35.333	25	.799		

	Total	38.296	26			
I was Excluded	Between Groups	.474	1	.474	.451	.508
	Within Groups	26.267	25	1.051		
	Total	26.741	26			

Note. * Significant at α = .05.

Analysis of interoceptive data

Refer to table 4 for a summary of descriptive statistics for the IA scores of the placebo and testosterone groups.

Table 4.

Summary of the Descriptive Statistics of the Placebo and Testosterone Groups

	Placebo			Testosterone		
Measure	*n*	*M*(SD)	*Mdn*	*n*	*M*(SD)	*Mdn*
Baseline IA	20	.635 (.212)	.690	19	.766 (.187)	.769
Post-Cyberball IA	20	.671 (.160)	.652	19	.670 (.280)	.634
IA Change	20	.035 (.160)	.024	19	-.097 (.191)	-.033

Note. Mdn = median.

The Mann-Whitney U-test 9 (Table 5) indicated that there was no significant difference between the placebo and the testosterone group's baseline IA scores, U = 252, p = .084, r = .280, r^2 = .078, suggesting that both groups performed equally even though this statistic approached significance. There was also no significant difference between the placebo group's post-cyberball score and the testosterone group's post-Cyberball score, U = 189, p = .989, r = -.004, r^2 < .001.

Hence, despite both groups demonstrating small changes in response to the social manipulation, an analysis of the means suggests that these changes are in opposite directions, suggesting the possibility of distinct mechanisms, and as such the IA change variable was included in the Mann-Whitney U-test to see whether this change was statistically significant between testosterone and placebo groups. This test revealed that the IA-change of the testosterone group was significantly greater than that of the placebo group, U = 117, p = .041, r = -.328, r^2 = .108. This indicates that the testosterone group was affected by the Cyberball task while there is little evidence to suggest that the placebo group experienced any meaningful response.

Table 5.

Summary of the Mann-Whitney U-test

Placebo vs. Testosterone	*n*	*U*	*Z*	*p*	*r*
Baseline IA	39	252	1.742	.084	.280
Post-Cyberball IA	39	189	-.028	.989	-.004
IA Change	39	117	-2.051	.041*	-.328

Note. Significance set at α = .05.

It was found that objective heart rate of the participants is significantly correlated with baseline IA (Table 6).

Table 6.

Summary of the Pearson Correlation Analysis between Objective Heart Rate and Baseline IA

	Baseline	
	Pearson Correlation	*p*
Heart Rate	-.316	.050*

Note. Significance set at α = .05.

To further investigate this, an analysis of covariance (ANCOVA) was conducted (Table 7) on the baseline IA scores using objective heart rates of the participants as a covariate. Physical fitness of an individual has also been found to have an effect on IA (Georgiou et al., 2015), and objective heart rate is one measure of physical fitness. ANCOVA is robust enough to account for the non-parametric distribution of the data. All other assumptions were upheld by the data.

Controlling for participant's heart rates and digit ratios, it was found that there was a significant difference between the placebo and testosterone groups' baseline IA scores, $F(1, 36) = 5.056$, $p = .031$, $r^2 = .123$. By looking at the adjusted means (Table 8) the testosterone group ($M = .769$) scored significantly higher than the placebo group ($M = .632$) on baseline IA.

Table 7.

Summary of the ANCOVA Conducted on Baseline IA with Digit Ratio as a Covariate

	Baseline				
	Sum of Squares	*df*	Mean Square	*F*	*p*
Corrected Model	.348	2	.174	4.809	.014*
Intercept	1.076	1	1.076	29.768	.000*
Heart Rate	.182	1	.182	5.048	.031*
Group	.183	1	.183	5.056	.031*
Error	1.301	36	.036		
Total	20.692	39			

Note. Significance set at α = .05.

Table 8.

Summary of the adjusted baseline IA descriptive statistics after the ANCOVA analysis

	Placebo			Testosterone		
	n	*M*	*SD*	*n*	*M*	*SD*
Baseline	20	.632	.043	19	.769	.044

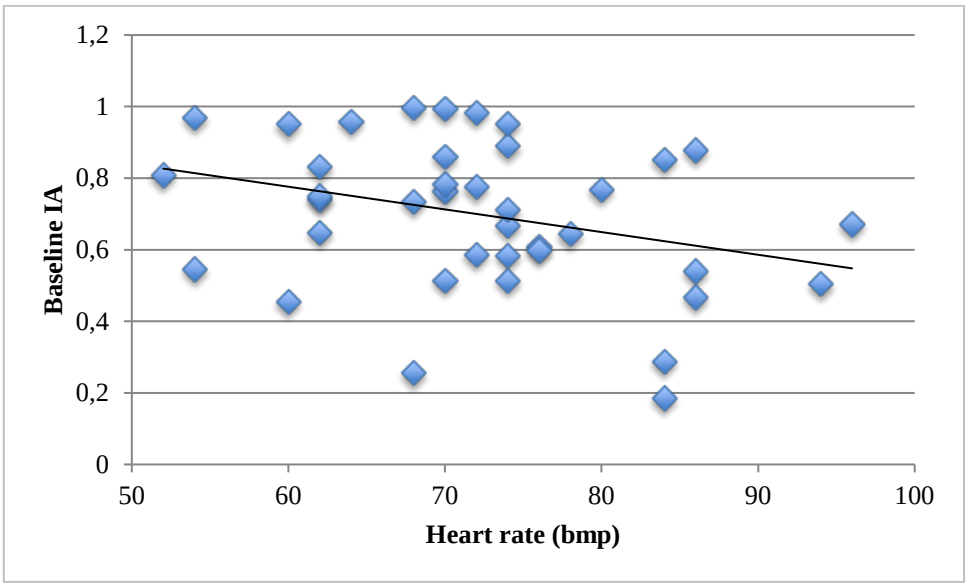

Figure 1. Scatter plot depicting the relationship between baseline IA and objective heart rate

Figure 1 indicates the direction of the Baseline IA x Heart Rate interaction, which is that heart rate predicts a decrease in baseline IA, r = -.316, p = .050. This model is statistically significant.

A Wilcoxon matched pairs test (Table 9) was then applied to investigate whether or not there was a significant within-groups difference in IA scores before and after the Cyberball social ostracism task. There was, however, no significant difference between the baseline IA scores (*Mdn* = .690) and the post-cyberball IA scores (*Mdn* = .652) of the placebo group, Z = .749, p = .455, r = .167, r^2 = .028, nor was there a significant difference between the baseline IA scores (*Mdn* = .769) and the post-cyberball IA scores (*Mdn* = .634) of the testosterone group, however this approached a significant result, Z = -1.851, p = .064, r = -.425, r^2 = .180. Importantly though, a comparison of the means indicates that the IA scores of the testosterone group dropped from .766 ($\pm$ .187) at baseline to .670 ($\pm$ .280) post-Cyberball, while the placebo group's IA score increased from .635 ($\pm$ .212) at baseline to .671 ($\pm$ .160) post-Cyberball.

Table 9.

Summary of the Wilcoxon Matched Pairs Test

Group	*n*	*Z*	*p*	*r*
Placebo	20	.749	.455	.167
Testosterone	19	-.1.851	.064	-.425

Note. Significance set at α = .05.

Pearson's correlations (Table 10) were run on the combined sample of women (n = 39) to investigate possible relationships between personality variables and baseline IA. Out of the eight personality traits measured on the ANPS-DL, only two produced significant correlations. A moderately strong, negative correlation between Anger and baseline IA emerged, $r(37)$ = -.443, p = .008. The trait associated with Lust was also found to be a moderately strong predictor of baseline IA, $r(37)$ = -.475, p = .004. Thus, the greater extent to which an individual possesses these traits, the lower their IA tended to be.

Table 10.

A Summary of the Pearson Correlation Coefficents between ANPS-DL Traits and Baseline IA

	Baseline IA	
ANPS-DL Traits	Pearson Correlation	*p*
Seeking	-.015	.934
Fear	-.128	.463
Caring	.093	.596
Anger	-.443	.008*
Play	-.142	.416
Sadness	-.135	.439
Lust	-.475	.004*
Dominance	-.166	.340

Note. * Significant at α = .05.

Figures 2 and 3 illustrate the significant, negative relationship between baseline IA and the personality traits of anger and lust.

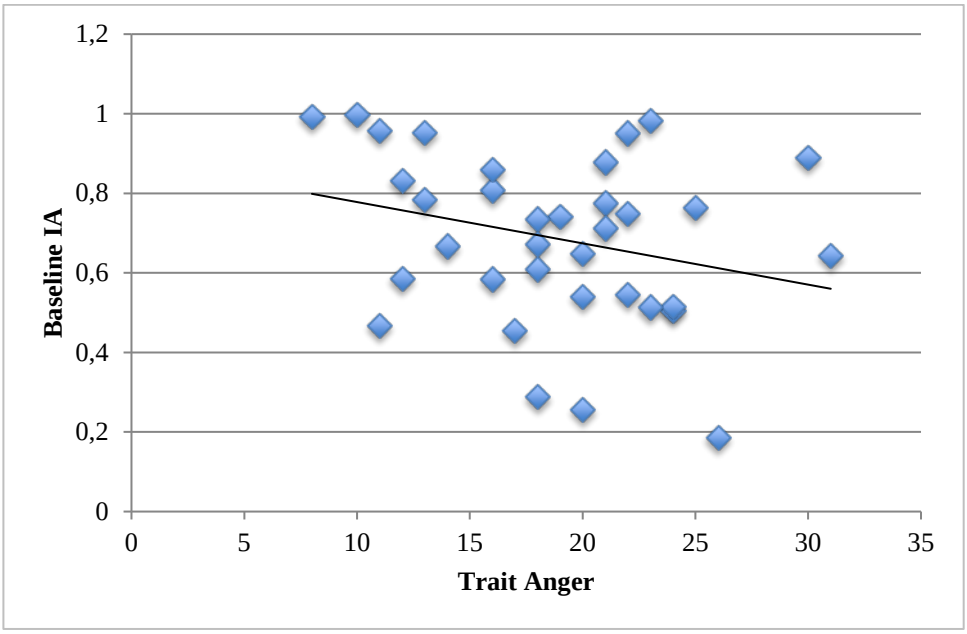

Figure 2. Scatter plot depicting the relationship between trait Anger and baseline IA.

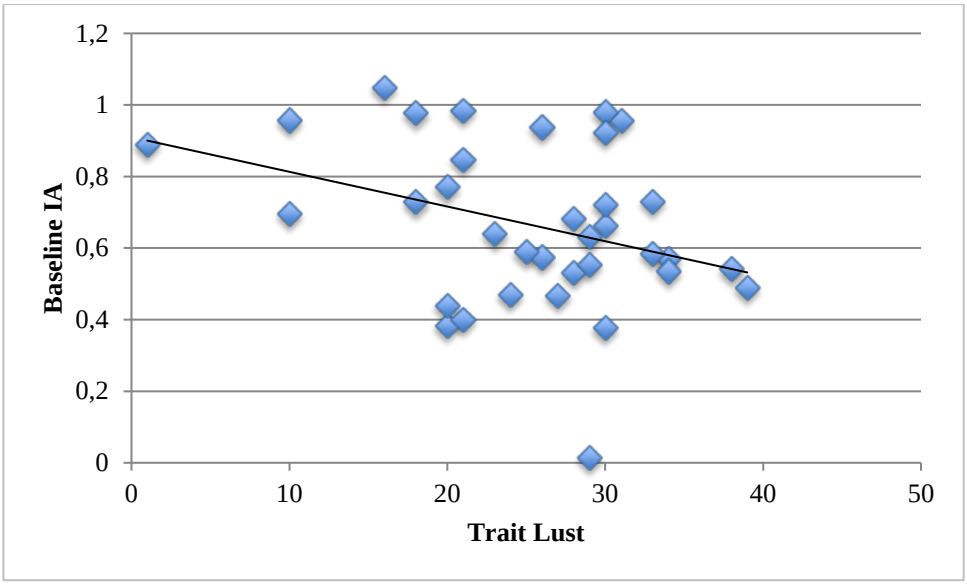

Figure 3. Scatter plot depicting the relationship between trait Lust and baseline IA.

Discussion

Previous research has demonstrated that changes in IA are associated with both positive and negative emotional reactions to social situations, especially those that involve an element of uncertainty (Durlik et al., 2014; Ferri et al., 2013). Specifically, there is accumulating evidence linking the modulation of IA to social threat. This is most notably reported by Durlik and Tsakiris (2015), who showed that IA significantly decreases after the Cyberball social ostracism task, as ostracism is thought to constitute a common form of social threat. While hormones are known to modulate social functioning, no studies to date have directly investigated the effects of hormones on embodied reactions following social exclusion. This study therefore aimed to explore the effects of testosterone on IA in female participants, both at baseline and in response to cyber-ostracism, given its integral role in fostering resilience in contexts that are inherently threatening (Bos et al., 2013; Derntl et al., 2009). The results reported here are the first to demonstrate that testosterone affects the interoceptive process. A single 0.5ml dosage of testosterone was effective in significantly increasing baseline IA scores when controlling for individual variation in heart rate. Furthermore, contrary to the second hypothesis, the testosterone group showed a small but significant reduction in IA following ostracism in the Cyberball task, a response opposite to that seen in the control group, where there was a slight, but not significant, increase in IA.

The effect of testosterone on the ability to accurately infer internal states at baseline may derive from its capacity to activate the insula cortex. Bos and colleagues (2012) found that a single 0.5ml administration of testosterone significantly increased activation of the

right anterior insula cortex. Activation of this structure has consistently been linked to interoceptive processing and may therefore facilitate processing of bodily signals.

The intensification of interoceptive signals in response to the administration of testosterone may occur via its activity on the autonomic system instead of its effects at the level of neural representations. However, no difference in heart rate was observed between placebo and testosterone groups suggesting that direct changes in the body are not accountable for the change in IA, Though, testosterone is regarded as a major underlying factor in hypertension in men (Kienitz & Quinkler, 2008), and increased blood pressure has been shown to transiently increase accuracy in detecting heart rate (Koroboki et al., 2010). While hypertension is seldom detected subjectively until at the critical stage, the administration of testosterone may have lead to an increase in blood pressure, explaining the elevation in baseline IA scores. Unfortunately, this mechanism cannot be verified as the current study did not assess blood pressure. Future research should investigate this process further.

Importantly, the different effects of testosterone on baseline and post-Cyberball IA scores suggest that the adaptive functions of interoceptive processing may be context-specific. According to Damasio's (2012) embodiment theory, interoception allows for the development of a basic sense of selfhood by focusing the mind onto the physical body. That is, embodiment constitutes the most primitive sense of self upon which higher aspects of consciousness are built and the rudimentary experience of being an agent in the world (Gallese & Sinigaglia, 2010). This allows for an individual to be able to interpret the changing neural information with reference to a stable embodied representation. The ability of testosterone to up-regulate interoceptive processesing at baseline may, as such, provide one with a more stable and fixed 'sense of self'. This rigidity may explain the link between testosterone and egocentric thinking (Wright et al., 2012). High interoceptive processing during social interactions may interfere with the process by which another individual's autonomic signals are represented in the brain. Consequently, social cognition, underpinned in large part by the brain's ability to represent the emotional and visceral conditions of another individual, may become compromised (Quattrocki & Friston, 2014). This idea is supported by findings demonstrating that individuals with higher IA scores at the trait-level tend to have less malleable body schemas (Tajadura-Jimenez & Tsakiris, 2014) and are more successful at regulating their emotions in response to stress. Testosterone's ability to intensify the interoceptive process may therefore facilitate feelings of being in *control* and promote a

decision-making process that is self-centered in nature, immune to the many discomforts and obligations that are impinged upon us by virtue of living in a social group.

Decision-making is not influenced solely by rational logic. Decisions are often made based on intuition, which is most notable in competitive situations where quick decisions about complex social interactions are required, or in situations where information is not readily available. This intuition takes the form of autonomic emotional judgments that are based largely on the interoceptive process (Dunn et al., 2010). Dunn and colleges (2010) found that high IA either helped or hindered the decision-making process depending on whether the interoceptive signals deemed the choices to be advantageous or disadvantageous. This indicates that interceptive awareness has a strong influence on decision-making. As such, the facilitation of IA by testosterone may aid the decision-making process to encourage proactive responding. Indeed, several studies have linked testosterone to successful outcomes in competitive disputes (Derntl et al., 2009; Dunn et al., 2010). However, the nature of the context may determine whether or not elevations in IA are adaptive or not.

The variable “IA change” was created to refer to the change between baseline IA scores and the post-Cyberball IA scores. The analyses indicated that there was a significant difference in IA change between the testosterone and placebo groups, with the testosterone group demonstrating a decline in accuracy after the social exclusion, while the placebo group’s IA scores improved, albeit very moderately. These findings at first may appear at odds with the idea of IA as facilitating proactive coping. However, it is possible that the decline in IA scores of the testosterone group represent an adaptive attempt at regaining lost social status as a result of ostracism. Corroborating this, several studies have provided support for the role of testosterone in status-seeking behavior (Cashdan, 1995; Eisenegger et al., 2011). This suggests that testosterone may differentially influence the processing of social threat, depending on the kind of behavioral response that is most effective at regaining control over social situations. For instance, testosterone is known to influence the preferential processing of social stimuli that are related to competitiveness, in which there is an opportunity to rise in status (Derntl et al., 2009). However, the Cyberball task is not competitive or overtly threatening in nature (Williams et al., 2000), and as such, a more effective response in this situation might be to re-affiliate. The drop in IA in the testosterone group may reflect this kind of response. Interestingly, though the testosterone group did drop in IA, unlike the placebo group, they did not express the subjective feeling of being “meaningless”, suggesting that while their physiological response was affected by ostracism, their self-esteem was less so. Eachus (2007) established a positive relationship between the

2D:4D digit ratio, which is an indication of fetal testosterone exposure, and self-efficacy on the Internet in men. This study defined Internet self-efficacy as the belief in one's ability to use the internet, as well as how an individual could handle social threats in a cyber-setting. "I felt meaningless" could be interpreted as a lack of self-efficacy. As such the relationship established by Eachus (2007) suggests that the testosterone group scored lower on this item because, unlike the placebo group, their sense of self-efficacy may not have been disturbed.

The physiological sensitivity exhibited by the testosterone group in the Cyberball task was not seen in the placebo group. Durlik and Tsakiris (2015) propose that the drop in IA that they reported after the Cyberball task could be the result of one of two processes. The first is that the decrease in IA may reflect a numbing response to social exclusion. The numbing effect is thought to prevent excessive anxiety that may interfere with coping responses (Richards, Cooper, & Winkelman, 2003). If this is the case, then testosterone may be effective in reducing panic following social exclusion, which would be adaptive in socially benign contexts. Alternatively, the decrease in IA may be due to the allocation of cognitive resources away from the individual's current state and toward factors in the environment that can be acted upon to regain group membership (Durlik & Tsakiris, 2015). The ability to perceive interoceptive signals accurately may assist in directing an individual's attention away from the exteroceptive domain. The exteroceptive domain takes preference when the *reactive control system* is activated (Tops et al., 2010). This is a brain network activated by the stress response that causes an individual to become less attuned to context models that favour prior knowledge and more vigilant toward immediate surroundings. This can be advantageous when it is in the individual's interest to pay attention to cues in the environment that may enable reintegration into a social group. The findings reported here suggest that testosterone may influence social functioning via its effect on the embodiment process, which may function as a pivot in the allocation of cognitive resources toward the self versus the external world.

As stated above, the reactive control system is thought to reflect low interoceptive processing. One of the findings of this study was that trait anger was negatively linked to IA, which suggests that individuals high in trait anger tend to be reactive in nature, easily provoked by stimuli within their immediate environment. This of course is both intuitive but also supported by a literature demonstrating a link between personalities that score higher on measures of anger and impulsivity and intermittent explosive disorder (Coccaro, Lee & McCloskey, 2014). Another personality trait that was found to correlate negatively with IA was trait Lust. Lust is characterised by a longing for sexual gratification and is one of the

primary emotion systems required for reproduction (Fisher, Aron, Mashek, Li, & Brown, 2002). Feelings of Lust may similarly activate the reactive control system. Strong sexual desire has been shown to illicit an anticipatory stress response, which is similar to that exhibited in the anticipation of public speaking (Stefano, Stefano, & Esch, 2008). As mentioned above, IA is lowered by the anticipation of public speaking, a social threat. Thus, the frequent experience of lust could possibly elicit a similal effect on general levels of IA, possibly explaining the inverse relationship between trait Lust and baseline IA that is evident in this study. These negative correlations contradict the third hypothesis of the study, as it was originally expected that personality traits would be positively correlated with IA.

Finally, the current findings call into question the validity of using the Cyberball ostracism paradigm in the South African population. In their UK-based study, Durlik and Tsakiris (2015) reported a significant drop in IA following the Cyberball task. However, the current findings in the placebo group contradict this since no significant difference between baseline and post-Cyberball IA scores in this group were found. In fact, a comparison of the means shows that the placebo group improved slightly following the Cyberball task, even though this was not significant. One possible explanation for this disparity may be attributed to differences in the participant populations. South African crime statistics in recent years have consistently pointed to a rise in serious crime, creating a perception among South Africans of decreased security and perpetual threat (Lemanski, 2004). This perception is not limited to the South African population, but it is also reflected in the perception of tourists visiting the country. In a survey of tourists visiting Cape Town, South Africa, it was found that the country had a reputation for being an unsafe holiday destination. It was also found that these tourists routinely felt unsafe going out after dark, and when using public transport (George, 2003). Being exposed to repeated threatening stimuli may increase the threshold at which they are able to illicit an emotional response through the process of habituation (Dijksterhuis & Smith, 2002). As such, the Cyberball task may be less effective in eliciting a real reaction from members of the South African population compared to those from the UK as used in the study by Durlik and Tsakiris (2015).

Limitations

This study is not without its limitations, and one such limitation is that this study had a small sample size. Despite being in keeping with other studies that have administered testosterone to female participants, this small sample size affected the statistical power of the results obtained. A larger sample size would have allowed for a more accurate analysis and greater generalisability of the results.

Something that should also be considered is that as this was a hormone study, and hormone fluctuations in the female participants needed to be controlled for as much as possible. While all participants were required to be in the first 10 days following the cessation of their menstrual bleeding in an attempt to control for hormonal variation (Hampson, 1990), this study did not obtain basal temperature readings to confirm participants to basal temperature readings. Basal body temperature has been shown to be an accurate measure to ascertain the stage of the menstrual cycle a woman is in (Davis & Fugo, 1947). However this was largely controlled for by attaining self-report measures on several occasions to establish menstrual cycle phases.

It should also be noted that physical activity has been found to influence IA (Georgiou et al., 2015). This study did not take into account the levels of physical activity of the participants. However, this limitation was controlled for largely by taking into account the BMI of the participants, and excluding all participants with a BMI over 30.

As stated earlier, the heart rate monitoring device and program was created solely for this study. As such it is a pilot device that has had some technical issues, which resulted in the exclusion of several participants. However when compared to a manual stethoscope count, the device appeared to be reliable.

Another possible limitation of this study is that the salivary cortisol levels of the participants were not obtained. Cortisol and testosterone have an inverse relationship: the more cortisol in an individual's system, the less testosterone is present (Brownlee, Moore, & Hackney, 2005). The cortisol levels of the participants may have mediated the effect of the testosterone. Therefore, even though it is not standard practice in the testosterone administration field to control for cortisol (Tuiten et al., 2000), future studies will benefit from investigating its role as a possible mediating factor.

Conclusion

In recent years, there has been accumulating interest in the role of interoception in emotional functioning. This is a trend that falls within the field of embodied cognition, which argues for the interdependent role of bodily processes in psychological phenomena (Eisenegger et al., 2011). While the contribution of hormones to social behavior is well established (Bos et al., 2012), no study to date has examined the impact of testosterone on interoceptive processing. The findings reported here are as such the first to demonstrate a causal relationship between testosterone and interoceptive ability in women. Specifically, a 0.5ml dosage of the hormone appears to influence not only baseline measures of IA, but also changes in this ability in response to social ostracism. In the present study, the testosterone

group exhibited a higher degree of accuracy on a heartbeat-tracking task at baseline compared to the placebo group when controlling for individual variation in heart rate. In contrast, following exclusion in the Cyberball game, levels of accuracy in the testosterone group significantly dropped. We interpret these findings as being consistent with a duel model of interoceptive functioning, whereby trait and state level differences in IA may relate to different mechanisms of emotional funcitoning. In particular, high baseline IA appears to be associated with stability of the self-concept, while changes at the state level are context-specific, reacting to the immediate demands of the environment. Given testosterone's relationship to status-seeking behavior, the drop in IA observed in this group may reflect a coping response aimed at social re-integration.

Future studies will compliment these findings by investigating the unique role of specific brain regions that mediate the effects of testosterone on interoceptive processing. For instance, activation of the insula will be particularly noteworthy in this regard. Such an approach may help to overcome several shortcomings associated with using performance on behavioral tasks as proxies for IA. Furthermore, the influence of testosterone on IA in tasks that are competitive in nature may yield a finding that is opposite in effect to the finding reported here following the Cyberball task. It is clear that research in this field is still in its infancy but may provide promising avenues for the development of new models of emotional functioning that may have important implications for both the clinical and wider research spheres.

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Appendix A

Advertisement distributed through the email list of UCT students and on Gumtree.co.za

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

Copy of the ANPS-DL

Affective Neuroscience Personality Scale 2.4	**Strongly Disagree (0)**	**Disagree (1)**	**Agree (2)**	**Strongly Agree (3)**
1. Almost any little problem or puzzle stimulates my interest.				
2. People who know me well would say I am an anxious person.				
3. I often feel a strong need to take care of others.				
4. When I am frustrated, I usually get angry.				
5. I am a person who is easily amused and laughs a lot.				
6. I often feel sad.				
7. I would consider myself to be a sexually passionate person				
8. When I want something I usually go all-out to get it				
9. I do not get much pleasure out of looking forward to special events.				
10. I am not frequently jittery and nervous.				
11. I think it is ridiculous the way some people carry on around baby animals.				
12. I never stay irritated at anyone for very long.				
13. My friends would probably describe me as being too serious.				
14. I seem to be affected very little by personal rejection.				
15. I hardly ever fantasize about having sexual intercourse .				
16. I prefer to watch and observe than take the lead in group work				
17. I will gossip a little at times.				
18. I really enjoy looking forward to new experiences.				
19. I often think of what I should have done after the opportunity has passed.				
20. I like taking care of children.				
21. My friends would probably describe me as hotheaded.				
22. I am known as one who keeps work fun.				
23. I often have the feeling that I am going to cry.				
24. For me, being sexually intimate is a great source of pleasure.				
25. I go out of my way to get things I want				
26. I am usually not highly curious.				
27. I would not describe myself as a worrier.				
28. Caring for a sick person would be a burden for me.				
29. I cannot remember a time when I became so angry that I wanted to break something.				
30. I generally do not like vigorous games which require physical contact.				
31. I rarely become sad.				
32. I rarely have sexual thoughts.				
33. Striving to be better than my peers is not important to me				
34. I always tell the truth.				
35. Seeking an answer is as enjoyable as finding the solution.				
36. I often cannot fall right to sleep because something is troubling me.				
37. I love being around baby animals.				
38. When I get angry, I often feel like swearing.				
39. I like to joke around with other people.				

40. I often feel lonely.				
41. Some might consider me to be a flirtatious or seductive person.				
42. When I go after something I use a 'no holds barred' approach				
43. I usually feel little eagerness or anticipation.				
44. I have very few fears in my life.				
45. I do not especially like being around children.				
46. When I am frustrated, I rarely become angry.				
47. I dislike humor that gets really silly.				
48. I never become homesick.				
49. I have not been in the mood for sex in a long time.				
50. I usually avoid activities in which I would be the center of attention				
51. Sometimes I feel like swearing.				
52. I enjoy anticipating and working towards a goal almost as much as achieving it.				
53. I sometimes cannot stop worrying about my problems.				
54. I feel softhearted towards stray animals.				
55. When someone makes me angry, I tend to remain fired up for a long time.				
56. People who know me would say I am a very fun-loving person.				
57. I often think about people I have loved who are no longer with me.				
58. I do not like to deny myself pleasure.				
59. If I see a chance to get something I want I move on it right away				
60. I am usually not interested in solving problems and puzzles just for the sake of solving them.				
61. My friends would say that it takes a lot to frighten me.				
62. I would generally consider pets in my home to be more trouble than they are worth.				
63. People who know me well would say I almost never become angry.				
64. I do not particularly enjoy kidding around and exchanging "wisecracks."				
65. It does not particularly sadden me when friends or family members are disapproving of me.				
66. Sometimes I wonder if I am capable of feeling sexual desire.				
67. I seldom feel agitated when I do not win				
68. I have never "played sick" to get out of something.				
69. My curiosity often drives me to do things.				
70. I often worry about the future.				
71. I feel sorry for the homeless.				
72. I tend to get irritated if someone tries to stop me from doing what I want to do.				
73. I am very playful.				
74. I tend to think about losing loved ones often.				
75. I am very aware of my sexual desires.				
76. When I see an opportunity for something I like I get excited right away				
77. I rarely feel the need just to get out and explore things.				
78. There are very few things that make me anxious.				
79. I do not like to feel "needed" by other people.				
80. I rarely get angry enough to want to hit someone.				
81. I do not tend to see the humor in things many people consider funny.				
82. I rarely have the feeling that I am close to tears.				
83. It is unusual for me to experience genital arousal.				
84. I do not find it satisfying being in a position of leadership				

85. There have been times in my life when I was afraid of the dark.
86. Whenever I am in a new place, I like to explore the area and get a better feel for my surroundings.
87. I often worry about whether I am making the correct decision.
88. I am the kind of person that likes to touch and hug people.
89. When things do not work out the way I want, I sometimes feel like kicking or hitting something.
90. I like all kinds of games including those with physical contact.
91. I frequently feel downhearted when I cannot be with my friends or loved ones.
92. I enjoy sensual experiences.
93. When working on a project, I like having authority over others
94. I am not the kind of person that likes probing and investigating problems.
95. I rarely worry about my future.
96. I do not especially want people to be emotionally close to me.
97. I hardly ever become so angry at someone that I feel like yelling at them.
98. I do not frequently ask other people to join me for fun activities.
99. I rarely think about people or relationships I have lost.
100. I find sex a bit boring .
101. I do not like to be the one in a group making decision
102. I have never intentionally told a lie.
103. I often feel like I could accomplish almost anything.
104. I often feel nervous and have difficulty relaxing.
105. I am a person who strongly feels the pain of other people.
106. Sometimes little quirky things people do really annoy me.
107. I see life as being full of opportunities to have fun.
108. I am a person who strongly feels the pain from my personal losses.
109. I often find myself fantasizing about sexual foreplay.
110. People who know me well would say that I have a powerful character
111. I am not an extremely inquisitive person.
112. I almost never lose sleep worrying about things.
113. I am not particularly affectionate.
114. When people irritate me, I rarely feel the urge to say nasty things to them.
115. Playing games with other people is not especially enjoyable for me.
116. It would not bother me to spend the holidays away from family and friends.
117. I feel uncomfortable thinking about sex.
118. I do not compete in challenges to win
How to Score:
Strongly Disagree = 0
Disagree = 1
Agree = 2
Disagree = 3
Note: for all negative items, score in the opposite:
Strongly Disagree = 3
Disagree = 2
Agree = 1
Strongly Agree = 0

Appendix C

Copy of the Post Ostracism Cyberball Questionnaire

Please write down your participant id: _____

Below is a short questionnaire that asks you about your experience of the online ball-tossing game. Please answer the following items:

Question:	Not at all				*Very much*
I felt disconnected.	1	2	3	4	5
I felt rejected.	1	2	3	4	5
I felt like an outsider.	1	2	3	4	5
My feelings were hurt.	1	2	3	4	5
I felt good about myself.	1	2	3	4	5
My self-esteem was high.	1	2	3	4	5
I felt liked.	1	2	3	4	5
I felt invisible.	1	2	3	4	5
I felt meaningless.	1	2	3	4	5
I felt non-existent.	1	2	3	4	5
I felt powerful.	1	2	3	4	5
I felt I had control over the course of the interaction.	1	2	3	4	5
I felt superior.	1	2	3	4	5
I felt angry	1	2	3	4	5
My mood was….					
…good	1	2	3	4	5
…bad	1	2	3	4	5
…happy	1	2	3	4	5
…sad	1	2	3	4	5
…friendly	1	2	3	4	5
…unfriendly	1	2	3	4	5
…tense	1	2	3	4	5
…relaxed	1	2	3	4	5
I was ignored	1	2	3	4	5
I was excluded	1	2	3	4	5
Assuming 25% of the time you would receive the ball if everyone received it equally, what percent of the throws did you receive?	_____%				

Appendix D

Copy of the Health Sciences Board of Human Research ethical approval

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

Appendix E

Copy of the consent form

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 Investigators: Nicholas Reid, Teneille Page, & Donné van der Westhuizen
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 R200 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.

Having read through all the questions and answers, please comment on whether you understand everything written in it, if not then please comment on what you did not understand, or any concerns that you might have:

_____

Full names and surname (Please Print): _____

Signature: _____ Date:_____

Appendix F

Copy of the counter-balancing program

Session	RHI (Begin with)	IA	Synch (first)	Asynch	Testosterone or Placebo	
8	x		x		?	
9	x			x	x	
10		x	x		y	
11		x		x	x	
12	x		x		y	
13	x			x	y	
14		x	x		x	
15		x		x	x	
16	x		x		x	
17	x			x	y	
18		x	x		x	
19		x		x	y	
20	x		x		x	
21	x			x	x	
22		x	x		x	
23		x		x	x	
24	x		x		x	
25	x			x	x	
26		x	x		x	
27		x		x	y	
28	x		x		y	
29	x			x	y	
30		x	x		y	
31		x		x	y	
32	x		x		x	
33	x			x	y	
34		x	x		x	
35		x		x	x	
36	x		x		y	
37	x			x	x	
38		x	x		y	
39		x		x	y	
40	x		x		x	
41	x			x	y	
42		x	x		x	
43		x		x	y	
44	x		x		y	
45	x			x	y	
46		x	x		y	
47		x		x	x	

Appendix G

Copy of the debriefing email sent to participants

What if Something Goes Wrong?
Prof. Mark Solms, is covered under University of Cape Town no fault clause of the University of Cape Town Insurance. As per this: the University of Cape Town (UCT) undertakes that in the event of you suffering any significant deterioration in health or well-being, or from any unexpected sensitivity or toxicity, that is caused by your participation in the study, it will provide immediate medical care. UCT has appropriate insurance cover to provide prompt payment of compensation for any trial-related injury according to the guidelines outlined by the Association of the British Pharmaceutical Industry, ABPI 1991. Broadly-speaking, the ABPI guidelines recommend that the insured company (UCT), without legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

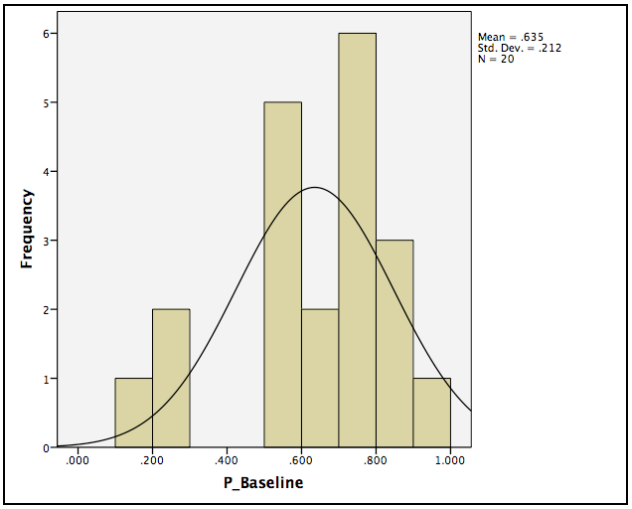
What if you have complaints about the study? If you want any information regarding your rights as a research participant, or have complaints regarding this research, you may contact Prof. Marc Blockman, the **Chairperson of the Research Ethics Committee** at the University of Cape Town. The contact information for the HREC is as follows:

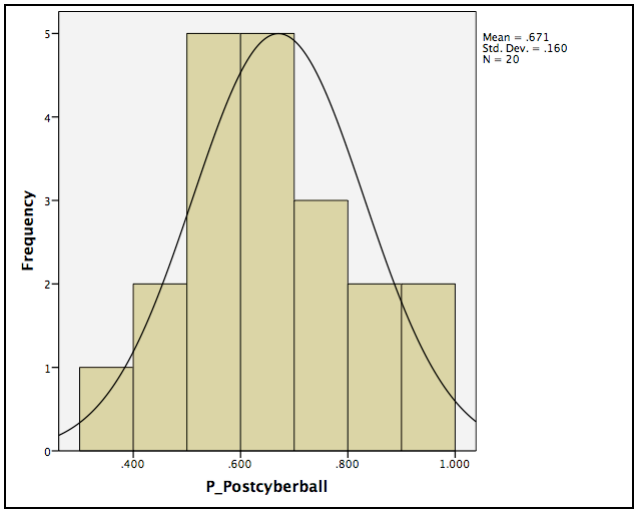
Human Research Ethics Committee
Faculty of Health Science
E-52-54 Groote Schuur Hospital Old Main Building
Observatory 7925
Tel: (021) 406 6626
Fax: (021) 406 6411
Email: lamees.emjedi@uct.ac.za

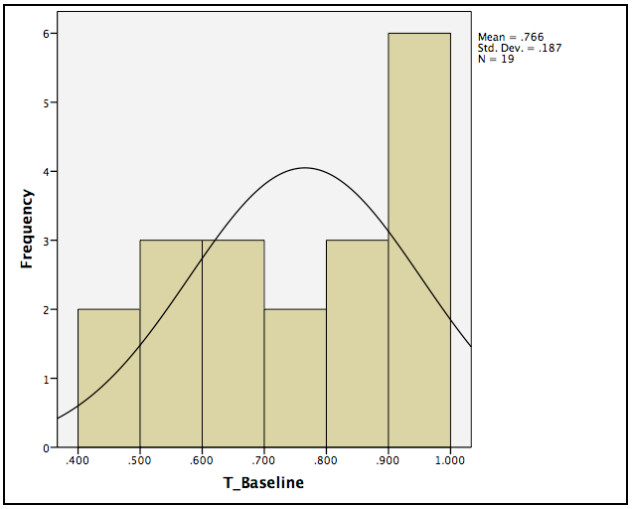
After you have consulted your doctor or the ethics committee and they have not provided you with answers to your satisfaction, you should write to: The Registrar, South African Medicines Control Council (MCC), Department of Health, Private Bag X 828, PRETORIA 0001.

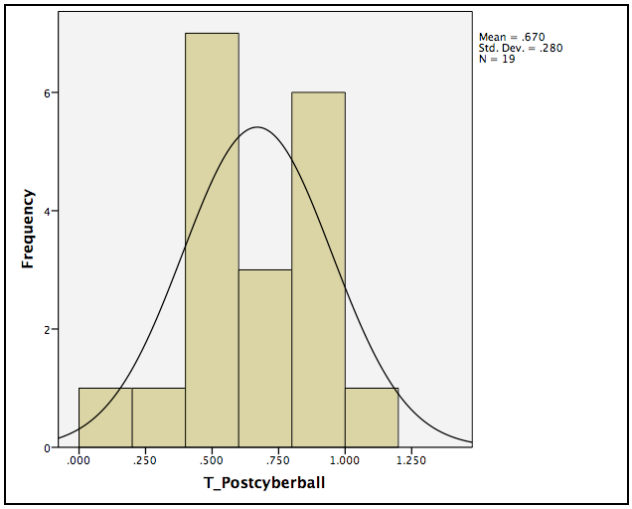
Appendix H

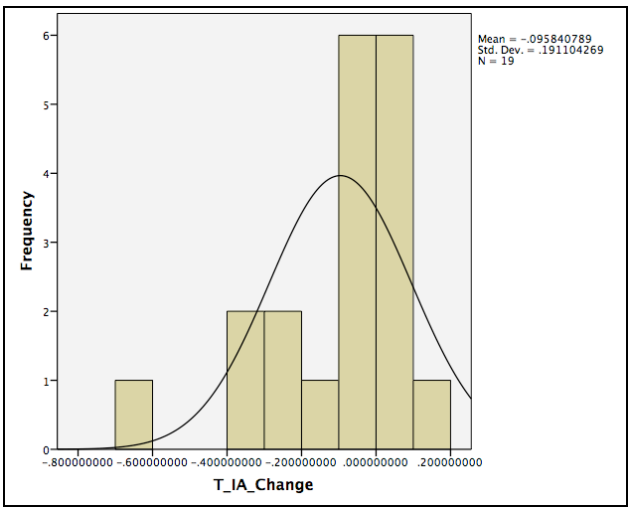
Histograms indicating the non-parametric distribution of the data

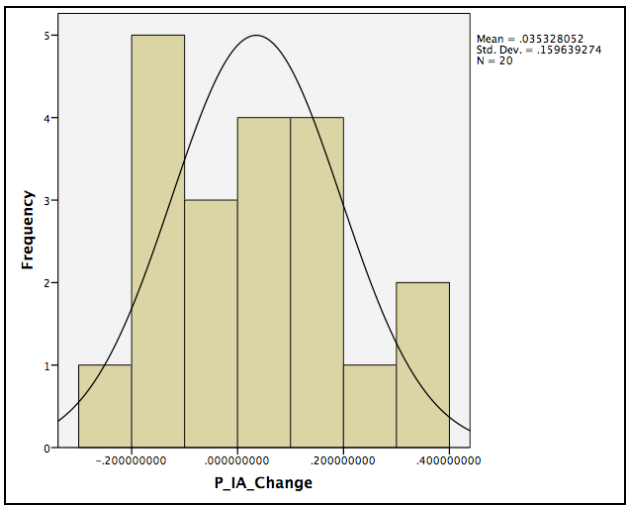


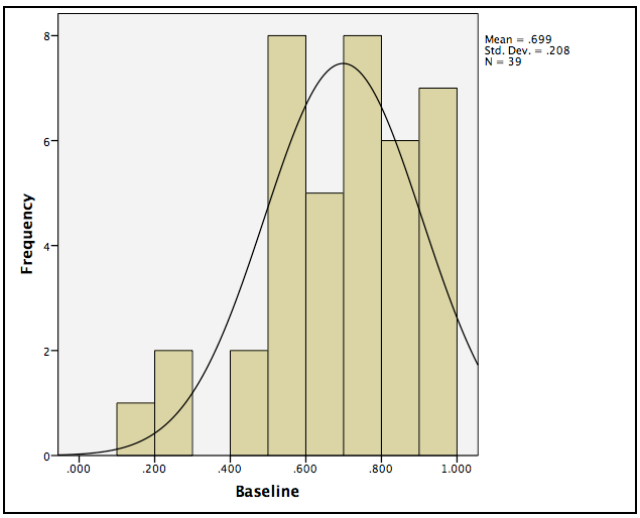


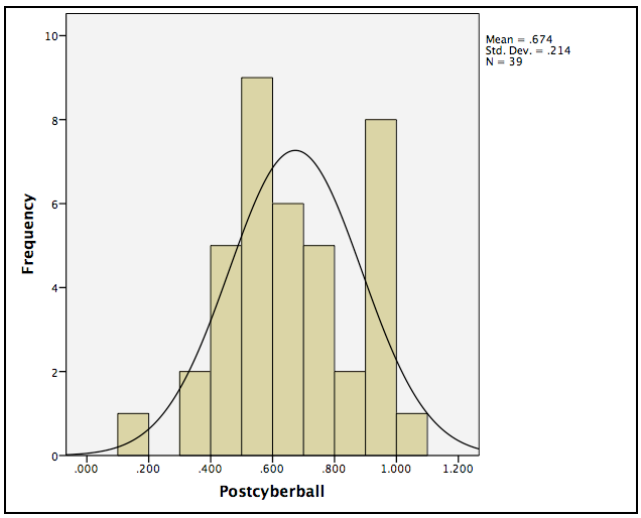









Mean = .699
Std. Dev. = .208
N = 39
Frequency
Baseline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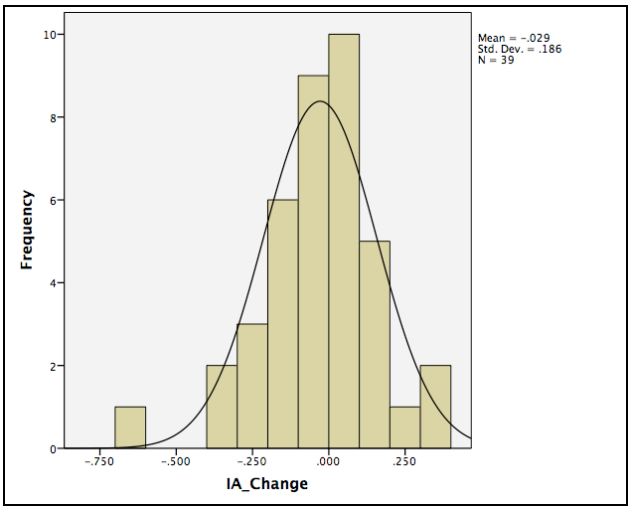
Std. Dev. = .214
N = 39
Frequency
Postcyberball


Mean = -.029
Std. Dev. = .186
N = 39
Frequency
IA_Change