Testosterone Administration in Women Increases the Peripersonal Space Boundary in the Face of a Stranger

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Abstract

Peripersonal space (PPS) is the sector of space immediately surrounding the body where body and environment are in dynamic relationship. Represented neurally by a specific network of multimodal frontoparietal neurons, multisensory information arising in PPS is processed in terms of possibilities for action, allowing for significantly faster reaction times to stimuli than in 'far' or extrapersonal space. Consequently, objects and interactions have heightened meaning here: this is a defensive space in which threats are monitored and objects of desire trigger approach behaviour. PPS is socially sensitive, purposefully extending or contracting its boundary in response to the presence of others, in this way revealing hidden social attitudes. The apportioning of space into self/other is predicated upon feelings of social power and territoriality—known to be biologically underpinned by the hormone testosterone. Testosterone has been found to promote threat vigilance and a motivated approach orientation, suggesting it may have an effect on the construction of PPS boundaries in a social context. This testosterone administration study investigated whether changes in testosterone levels reflect in changes in the mapping of PPS boundaries. In a double-blind, randomly assigned design, a within subjects group (N = 18) of participants performed a multisensory integration task in the presence of an unknown person to measure their PPS boundary in testosterone versus placebo conditions. Elevated testosterone was associated with a larger PPS boundary as well as globally accelerated multisensory processing, suggesting a determining role in PPS representation. It was not found to sharpen the gradient of the PPS boundary. Further investigation is needed as to whether the measurement of change in PPS boundary properties is a reliable tool for making explicit unseen social dynamics and attitudes.

Keywords: peripersonal space; personal space; space construction; shared action space; embodied cognition; body schema; self-other; social power; social dominance; interpersonal dynamics; territoriality; testosterone.

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Introduction

The embodied approach to cognition describes the mind arising out of a moving, feeling, sensate body in engagement with its world (Anderson, 2003; Gallagher, 2006; Mahon & Caramazza, 2008; Rizzolatti, Fadiga, Fogassi, & Gallese, 1997). Objects and interactions take on heightened meaning in the space immediately surrounding the body (Pezzulo, Iodice, Ferraina, & Kessler, 2013). This is peripersonal space (PPS)—flexible, neurally coded for action, and socially sensitive (Teneggi, Canzoneri, di Pellegrino, & Serino, 2013). An information monitoring defensive space, its form critically adapts to the presence of others (de Vignemont & Iannetti, 2015), suggesting that implicit social attitudes could be revealed through its measurement (Gallagher, 2006; Pezzulo et al., 2013). The conceptualisation of space and its interpersonal allocation are patently underscored by feelings of social power (Sambo & Iannetti, 2013). Studies have found social dominance and territoriality to be regulated by the hormone testosterone (Mazur & Booth, 1998; Schaal, Tremblay, Soussignan, & Susman, 1996). Given this relationship, investigating the effects of testosterone on PPS representation may offer useful insights into the mechanisms of socially dominant behaviour.

The Mind in Matter and the Body in Space

A growing number of cognitive theorists suggest that higher-level processing is critically shaped by the body and its interactions with the physical world (Anderson, 2003; Brozzoli, Makin, Cardinali, Holmes, & Farnè, 2012; di Pellegrino & Làdavas, 2015; Gallagher, 2006; Gallese & Sinigaglia, 2010; Graziano & Gross, 1995; Rizzolatti et al., 1997). Advancements in neurobiology and neuroimaging technologies have contributed to the emergence of theories of embodiment that ground cognition in the sensorimotor experiences of the organism (e Costa & Rocha, 2005; Mahon & Caramazza, 2008).

In this paradigm, cognition and emotion are seen to involve a process of ‘re-enactment’ called *embodied simulation*, where direct perceptual experiences are partially reproduced in the brain’s representations of the body, so as to aid reasoning, attitude formation, and other functions of cognitive processing (Gallagher, 2006; Gallese, 2007; Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015).

The experience of embodiment is thought to be represented with a body schema—or body-centred reference frame—in the somatosensory complex of the brain (Damásio, 1994; Holmes & Spence, 2004). Neural renderings of the body are informed by the way in which we conceptualise space and how our bodies negotiate its orientations and possibilities for action (Anderson, 2003). The area around the body is a space that it can reach into to use

tools or to interact; the body can even be seen to inhabit this space less tangibly, through planning subsequent actions into it (Gallese & Sinigaglia, 2010; Làdavas & Serino, 2008). This region of space becomes an extension of the body schema, an experiential space (Gallese, 2000; Rizzolatti et al., 1997)—this is the territory of PPS.

Defining PPS

PPS is the sector of space surrounding the body that is neurally primed for action (di Pellegrino & Làdavas, 2015). It was first proposed by Rizzolatti and colleagues in 1981, following studies on a class of multisensory frontoparietal neurons that represent the zone where body and environment are in dynamic relationship (di Pellegrino & Làdavas, 2015; Rizzolatti, Scandolara, Matelli, & Gentilucci, 1981). These neurons integrate somatosensory information with visual and auditory stimuli arising from objects in PPS and represent this in an egocentric frame of reference in terms of possibilities for action (de Vignemont & Iannetti, 2015; di Pellegrino & Làdavas, 2015; Gallese, 2000; Rizzolatti et al., 1981; Teneggi et al., 2013). This information is routed in the brain via the dorsal stream, the visual pathway responsible for processing action-related information (Chinellato, Grzyb, Fattori, & del Pobil, 2009). This stream represents the visuospatial qualities of objects in PPS relative to the body (Kravitz, Saleem, Baker, & Mishkin, 2011; Valdés-Conroy, Román, Hinojosa, & Shorkey, 2012).

PPS is a responsive and malleable medium (Graziano & Gross, 1995; Valdés-Conroy et al., 2012), modifying its shape through a property called action-dependent plasticity: action—or the possibility for it—dynamically shapes how this space is represented (Gallese, 2000; Làdavas & Serino, 2008; Valdés-Conroy et al., 2012). Here, objects are within reach; consequently, they are represented differently than in ‘far’ (or extrapersonal) space (Holmes & Spence, 2004; Valdés-Conroy et al., 2012).

In this multisensory-motor zone, low level processing is executed significantly faster than in extrapersonal space (Noel, Pfeiffer, Blanke, & Serino, 2015b). Stimulation of the major exteroceptive senses, namely vision and audition, has been found to speed up reaction time (RT) to somatosensory stimuli; consequently, a subject will respond significantly faster to the touch of their skin if this sensation coincides with a visual or auditory stimulus within their PPS (Noel, Cascio, Wallace, & Park, 2017; Serino et al., 2015b). This distinguishing, quantifiable characteristic of PPS makes the plotting of its boundaries possible via the measurement of RT to bimodal stimuli at sequential distance intervals from the subject (Serino et al., 2015b; Teneggi et al., 2013). The distance at which these RTs significantly speed up serves as a proxy for the PPS boundary (Serino et al., 2015b; Teneggi et al., 2013).

In this way, the expansion or retraction of PPS boundaries can be detected, as can the degree of gradualness of the transition between PPS and extrapersonal space (Teneggi et al., 2013).

The PPS boundary can vary in the angle of its slope or gradient (Noel et al., 2017). A softer gradient is thought to mean a more gradual distinction between the space of the 'self' and that of the 'other'—associated with an extended sense of self or a blurring of the self-other boundary (Noel et al., 2017). It has been suggested along the same lines that a sharp or severe gradient corresponds to difficulties with interpersonal relatedness, an inflexibility with placing oneself in the position of another (Noel et al., 2017).

Studies have shown the dimensions of PPS to vary inter-individually depending on factors such as body shape (Borghi & Cimatti, 2010) and even personality traits, such as claustrophobia and anxiety (Noel et al., 2015b). PPS serves as a defensive space to monitor potential threats, so as to co-ordinate a protective response, while objects of desire trigger approach behaviour here (de Vignemont & Iannetti, 2015; Iachini, Coello, Frassinetti, & Ruggiero, 2014; Valdés-Conroy et al., 2012). This space also critically adapts to others, accommodating similarly along approach-avoidance lines to their presence (Teneggi et al., 2013). This points to a determining role for social contexts in the formulation of PPS boundaries.

The Social Body

Although the existence of *personal space*, i.e. an individual's sensitive-to-intrusion 'comfort bubble', is acknowledged in social psychology as a valid interpersonal construct, it is only now beginning to find empirical support as a distinct, neurally-based process through the link between PPS as an action space and social representation (Iachini et al., 2014; Pellencin, Paladino, Herbelin, & Serino, 2017).

Studies show that PPS representation is socially modulatable—it is responsive to social interaction in general, as well as the specific quality of that interaction (de Bruijn, Miedl, & Bekkering, 2008; di Pellegrino & Làdavas, 2015; Gallese, 2000; Georgiou, Becchio, Glover, & Castiello, 2007; Pezzulo et al., 2013; Teneggi et al., 2013). Whether action goals are congruent, complementary, or competitive appears to directly influence how information about another's action space is integrated (Ambrosini, Blomberg, Mandrigin, & Costantini, 2013; Georgiou et al., 2007).

Cooperation or friendliness between parties seems to encourage the inclusion of the mapped body space of the other in PPS through a process of social re-calibration (Ambrosini et al., 2013; Pezzulo et al., 2013; Teneggi et al., 2013). Individual boundaries merge to form a neurally represented shared action space, a space which can be used for planning one's own

actions as well as predicting those of the other (Pezzulo et al., 2013; Ruys & Aarts, 2010). Conversely, distrust can prevent the sharing of action spaces in competitive situations (Pezzulo et al., 2013). Ruys and Aarts (2010) have further shown that although motivational valence plays a strong role in the social construction of space, the intra-individual disposition to attend to the intentions of the other is equally determining. Individuals with a strong tendency to take the other into account are more likely to form shared representations with them, regardless of the context (Ruys & Aarts, 2010).

PPS has been shown to recede in response to the appearance of an unknown 'other', as demonstrated by Teneggi and colleagues (2013), who found PPS boundaries to be significantly contracted in the presence of another person, as compared to a mannequin. The researchers interpreted this contraction to be in accommodation of the other (Teneggi et al., 2013). This accommodation can also be seen in strongly hierarchical social structures, where PPS is found to be asymmetrically represented. In military interactions, high ranking agents are allocated greater PPS to their low-ranking counterparts (Pezzulo et al., 2013), while both males and persons judged to be of high status tend to be given larger PPS margins by others (Iachini et al., 2016; Pezzulo et al., 2013). These findings suggest that underlying social dynamics may be a key determinant of PPS boundaries and, importantly—that interpersonal dominance orientations may strongly pattern PPS representations (Georgiou et al., 2007; Iachini et al., 2014; Pezzulo et al., 2013).

Dominance, Testosterone and PPS

Socially dominant behaviour is driven by the intention to gain or maintain high status in the form of power, influence or valued prerogatives over a rival (Mazur & Booth, 1998). An intrinsic dominance drive is thought to be common to most mammalian species (van der Westhuizen & Solms, 2015), regulated in large part by the activity of the hormone testosterone (Heany, van Honk, Stein, & Brooks, 2015; Mazur & Booth, 1998). In animals, testosterone is known to enhance territorial behaviour, while human studies have shown that it increases vigilance to social threat (Terburg, Aarts, & van Honk, 2012), promotes aggressive behaviour aimed at increasing social status (Eisenegger, Haushofer, & Fehr, 2011; Mazur & Booth, 1998) and generally facilitates the motivation to approach social challenge (Terburg & van Honk, 2013).

The association between testosterone and dominance motivation (Mazur & Booth, 1998) suggests that testosterone may have an effect on PPS during social interaction. Pharmacological research has shown that norepinephrine, which appears to be the major neurotransmitter system underlying the moment-to-moment mapping of PPS (Previc, 1998),

is related to testosterone activity (Heany et al., 2015; Mazur & Booth, 1998; Mehta & Josephs, 2010). The role of testosterone in coordinating defensive behaviour and increasing an approach orientation further suggests that its effects on the brain may be revealed in the representation of action space. However, no studies to date have directly investigated whether changes in testosterone levels reflect in changes in the mapping of PPS boundaries.

Given that changes in PPS appear to reveal important aspects of interpersonal relationships (Pezzulo et al., 2013), these may serve as an implicit measure of basic social attitudes, such as the motivation for dominance (Georgiou et al., 2007; Iachini et al., 2014; Pezzulo et al., 2013). Methods that are able to bypass human introspection are increasingly valued in psychology, because they are able to overcome a variety of cognitive biases, such as the self-serving bias or even expectation effects (Pronin & Kugler, 2007).

Research Aim, Question and Hypotheses

This research study aimed to contribute to the existing body of literature on the social modulation of PPS boundaries. The broader question underlying the study was whether the measurement of change in the properties of PPS boundaries could serve as a neural indicator of hidden power differentials.

This study explored whether social dominance motivation, known to be associated with testosterone, could be found to reflect in the subjective representation of personal space. Based on the established link between testosterone and social dominance (Heany et al., 2015; Mazur & Booth, 1998), we tested the effects of 0.5mg of testosterone versus placebo on the mapping of PPS boundaries, in the presence of an unknown person.

Teneggi and colleagues (2013) found that PPS contracts to accommodate another person as compared to a mannequin in extrapersonal space. We incorporated the presence of a confederate unknown to the participant to study the sensitivity of PPS to social information, with and without the effects of exogenous testosterone. Following Teneggi and colleagues' 2013 study, the size and gradient of the PPS boundary were determined via the measurement of RTs to tactile stimulation in the presence of incoming visual stimuli.

As a mechanism of 'territorial-type' behaviour, we hypothesised that raising testosterone levels would result in an increase in the size of the PPS boundary compared to placebo, establishing a larger defensive space; and a sharpening of its gradient—meaning a less gradual transition from self to other-space. In the presence of an unknown person, the PPS boundary was hypothesised to be smaller in the placebo condition because PPS has been found to contract in the presence of a neutral stranger, so as to accommodate the other party

(Teneggi et al., 2013). Under testosterone, we predicted that this accommodation effect would be mitigated so as to to maintain a larger defensive territory.

In brief, this study will test the following *a priori* hypotheses:

1. Elevated testosterone is associated with a larger PPS boundary, compared to placebo, in the presence of an unknown person.
2. Elevated testosterone is associated with a sharper PPS boundary gradient, compared to placebo, in the presence of an unknown person.

Methods

Design

This testosterone administration study is randomly assigned, double-blind and placebo controlled, with two within-group factors.

Independent variable. *Testosterone*—a within-group factor with two levels (testosterone, placebo). Each participant was tested under testosterone and placebo conditions across two experimental days, spaced two to three days apart.

Independent variable. *Distance*—a within-group factor with five levels (D1, D2, D3, D4, D5). This is the distance of the ball from the participant when the vibrotactile stimulus is experienced. These intervals are 20cm in depth, with D1 at zero distance to 20cm from the participant and D5 at 80cm to 1m from the participant.

Dependent variable. *RT*—The reaction time or speed at which the vibrotactile stimulus was registered, measured in seconds. This is described in greater detail in the 'Experimental task' section.

Setting. The study took place in a private laboratory in the Psychiatric Unit at Groote Schuur Hospital in Observatory, Cape Town.

Participants

Sample size. The total sample size was 18 participants.

A power analysis suggested that the sample size be set at N=32 to achieve a power of > 0.90 using a repeated-measures ANOVA investigating within-group differences (parameters: correlation among repeated measures = 0.5; effect size = medium; Cohen's f = 0.25; $\alpha = 0.05$). This effect size was averaged from the studies of Teneggi and colleagues (2013), which are most similar to this study. We elected to limit the sample size to N=18, although smaller than the suggested size, as, given the complexity and time-intensive nature of the design, this was better suited to our needs on a cost-benefit basis. This sample size generated sufficient statistical power of 0.74.

Sampling. We recruited students through the Students' Research Participation Program (SRPP) of the Psychology Department at the University of Cape Town (UCT), as well as from the general UCT student body through the Student Research Invitation Initiative (SRII). The sampling method used was convenience sampling.

Allocation to groups. The order in which testosterone and placebo conditions were allocated to participants was counterbalanced using a randomizer so as to avoid systematic variation in the form of practice or boredom effects and to achieve an effective treatment balance (Suresh, 2011). We used the online randomization software, randomizer.org.

Inclusion criteria. All participants were women between the ages of 18 and 35 years. These parameters were defined following previous studies that have reliably established the effects of the sublingual administration of a single dose of 0.5mg of testosterone in women (Tuiten et al., 2000).

Exclusion criteria. The decision was taken to limit the study to women as the effects of a 0.5mg dosage of testosterone had not been established in men, who have significantly higher levels of endogenous testosterone than women (Stein, n.d.). Candidates were excluded from the study if they had a history of neurological or psychiatric disorders. Subjects taking psychiatric or hormonal medication were excluded to avoid any possible confounding interactions with testosterone. Pregnant and menopausal women were excluded because the hormonal fluctuations related to these states could interfere with the results and as a safety measure, in the case of pregnant women.

Confederates

Participants were assigned a different confederate at each of the two testing sessions, so as to avoid familiarity. Confederates were matched with participants for gender and race, as a control for threat. To promote neutrality, they were of average height (1.5–1.7m) and dressed in plain, dark clothing. All confederates were recruited from the UCT student body.

Materials

Physiological materials. A single administration dose of 0.5mg testosterone in a hydroxypropyl-β-cyclodextrin liquid carrier was administered sublingually to participants on one testing day. On the other day, the participants were issued with a placebo, made to taste the same as the testosterone and presented in identical format.

Measurement instrument. Following Teneggi and colleagues (2013), we undertook to measure the size and gradient of PPS boundaries using a visuotactile integration task conducted with specialized equipment and captured on software developed for this purpose. The software is the intellectual property of the Center for Neuroprosthetics at the Swiss

Federal Institute of Technology (Ecole Polytechnique Fédérale de Lausanne, EPFL). This task is described in detail in the 'Experimental task' section. Participants' RTs were stored for later analysis.

Measures.

Testosterone testing. Participants were asked to provide salivary samples for the purposes of establishing testosterone levels in future. This took place at the first session before testosterone/placebo administration and upon arrival at the second session, on both testing days. After rinsing their mouths with water, participants collected the 5ml sample in a vial, using a straw, in the privacy of a bathroom. The vials were sealed in labelled envelopes and stored frozen.

Procedures

Pilot study. A pilot study with a sample size of eight was carried out in the month of July to test the operating of the equipment and validate the task parameters. This involved running through the experimental task once with each participant, and excluded testosterone/placebo administration and salivary sample testing. No data gathered here was used in the final analysis.

Initial procedures. Form DSA 100 (Appendix A) was submitted to apply for permission to the university to advertise to the student body. Candidates responding to the recruitment appeal were invited to complete an online registration form providing key information pertaining to the inclusion and exclusion criteria. Those verified as being suitable candidates were emailed an invitation to book their appointments. They signed up for two testing days, two slots per day, scheduled three to four-and-a-half hours apart. Peak testosterone level is known to be maintained for this period after ingestion at this dosage (Tuiten et al., 2000). The testing took place within the first ten days following their period of menstruation to control for hormonal fluctuations, as testosterone is known to be most stable during this time (Tuiten et al., 2000). A few days before their appointments, participants were sent a reminder email, outlining important information.

Data collection day 1.

Session 1: Administration. Participants arriving at the testing venue were briefed with more detail regarding the procedure ahead. They were given a consent form (Appendix B), informing them of their rights and safety in this study, along with other study relevant information, that they could sign if in agreement to proceed.

Participants were then asked to provide a salivary sample, following which they were presented with a vial containing either testosterone or placebo in liquid form. Vials were pre-

coded and administered blind. Participants were asked to hold the liquid under their tongues for one minute before swallowing. They were verbally briefed on the guidelines for the interval between sessions, namely, to refrain from strenuous activity, to limit coffee and nicotine consumption, and to avoid eating in the hour before the second testing.

Session 2: Data collection 1. Upon arrival, participants were asked to provide a second salivary sample and given a general overview of what the session would involve. They were seated in a chair, a vibrotactile device was attached to their cheek using an adhesive plaster and the Oculus Rift virtual reality (VR) head-mounted display (HMD) was put on and adjusted to fit comfortably. The instructions for the execution of the task were explained, following which, the confederate entered the room and positioned themselves 1.25m ahead of the participant, facing them. The participant was directed to look ahead in the direction of the confederate for the duration of the task, but not to interact with them. The first testing then took place, as outlined in the 'Experimental task' section. There was a pause in the middle of the task where the participant could communicate whether they were ready to continue with the second half or could alternatively take a short break. The full duration of the task was 11 minutes.

Data collection day 2.

Session 3: Administration. Another salivary sample was taken on arrival. This was to establish that baseline testosterone levels were the same across days. Participants who were administered testosterone at the previous testing received placebo on this day and *vice versa.*

Session 4: Data collection 2. Participants arriving for the second testing were asked to provide a fourth and final salivary sample. On completion of the task, they were invited to ask any questions that they had about the study and were issued with a debriefing information sheet (Appendix C). They received R350 in compensation for their time and travel expenses and signed receipt of this before leaving.

Experimental task. This took the form of a visuotactile integration task, following Teneggi and colleagues' 2013 study. During the experimental procedure, the participant was seated in a chair next to a desk with a computer keyboard within easy reach. Through the HMD, they could see a VR ball moving towards them from the far to near distance at a medium speed. Concurrent to this, they experienced a tactile stimulus on their cheek (a soft buzzing sensation) at different intervals. Their task was to register this stimulus by pressing a key on the keyboard as quickly as possible.

The visual stimulus was task-irrelevant in the sense that the participant was not instructed to respond to what they saw in any way. However, this procedure was designed on

the principle that PPS is a space in which somatosensory information from the body is integrated with visual and auditory stimuli more rapidly than in extrapersonal space. Consequently, when the participant experienced the tactile stimulus *while* the visual stimulus (VR ball) was within their PPS, their RT would be speeded up (Teneggi et al., 2013). More simply put, the participant would press the key more quickly with the VR ball in their PPS compared to when it was in extrapersonal space.

In each trial, the tactile stimulus was delivered in different combinations with the spatial position of the VR ball at depth levels D1–D5. Otherwise stated, the synchronous experience of visuotactile stimuli was registered and processed when the visual stimulus was at five possible distance points from the participant (Teneggi et al., 2013). Participants also experienced the tactile stimulus *without* the presence of the ball at intervals distributed throughout the duration of the task. These tactile-only or unimodal RTs were taken to serve as a measure of participants' RTs without the facilitation—or PPS boosting effect, to be used later in the analysis to control for individual variation effects (Noel et al., 2015a).

Catch trials were included along with the experimental trials, in which the visual stimulus was presented without the tactile stimulus. These served to counteract participant expectancy and learning effects, promote attention, and so bolster the validity of the measurement task.

The captured RTs were then used to plot PPS and establish its size. A distance at which the synchronous visuotactile stimuli facilitated (i.e. significantly sped up) RTs was established to be within PPS. The RT data was also used for a gradient analysis, elaborated further in the 'Data Analysis' section.

Ethical considerations. Ethical approval for this study was granted in December 2014 from the Faculty of Health Sciences Human Research Ethics Committee of UCT. This was renewed in May 2017 (Appendix D).

Drug safety has been established at this testosterone dosage as no aversive effects have been found in over twenty-five studies (Stein, n.d.), with the exception of headaches in very rare cases (Nelson, 1978). This was explained clearly in the informed consent form.

Participants were informed of their rights to confidentiality, anonymity, to withdraw at any time and to the protection of the data in this document. On completion of the final task, they were issued with a debriefing information sheet addressing general post test questions and thanking them for their participation.

Data Analysis

The data was imported into Microsoft Excel to be processed and later coded into IBM SPSS (Version 24) for analysis.

Data Sorting

Calculating the RT scores. Participants' catch trial data was deleted and their RT scores for each trial calculated from the raw captured data. Each participant responded a total of 150 times under each condition (testosterone and placebo). Of these scores, 50 are organised into five tactile, or unimodal, categories (T1–5) and 100 scores constitute 5 visuotactile, or bimodal, categories (VT1–VT5), corresponding to the 5 distance points.

Mean scores were calculated for each of the 10 categories. Finally, accidental responses and significant outliers (detected using an SPSS analysis, explained under the assumptions for 'Analysis 1') were deleted and replaced with the mean for that category.

Baseline-correction of the RT scores. In line with previous studies (Noel et al., 2015a; Noel et al., 2015b; Pellencin et al., 2017; Serino, Canzoneri, Marzolla, Di Pellegrino, & Magosso, 2015a), the visuotactile scores were baseline-corrected to control for intra-individual variations in response speed. This was achieved by subtracting from each score the corresponding tactile category mean for that participant—functioning as a measure of their baseline response speed. The variability in the scores is due to natural fluctuations in individual response speed and this technique was designed to neutralise the impact of these differences in the analysis (Noel et al., 2015a). The resulting baseline-corrected bimodal RT scores were then coded into SPSS datasets and used for all analyses. From this point on, all references to RTs mean baseline-corrected bimodal (visuotactile) RT scores.

Statistical Analyses

We ran one-sample t-tests on each participant's placebo and testosterone data individually, so as to plot their PPS boundaries across conditions. RT scores at each level of *Distance* were compared against a test value of zero. Unimodal baseline is defined as being equal to zero for baseline-corrected scores (Noel et al., 2015a), with negative values indicating an RT facilitation—a proxy for the PPS boundary. Scores significantly smaller than zero indicate the advantage of visuotactile over tactile-only processing.

Determining the effect of testosterone on the size of PPS.

Analysis 1: Testing for an overall facilitation effect. RT scores were subjected to a two-factor repeated measures ANOVA to test for a significant interaction between the two within-subjects factors *Testosterone* (placebo, testosterone) and *Distance* (D1–D5) on the

dependent variable, *RT*. This analysis shows whether testosterone had an effect on PPS mapping.

Assumptions. The dependant variable is continuous and both within-subjects factors consist of matched pairs. The distribution of the dependent variable in each combination of the related groups was established as being normally distributed. Significant outliers in all combinations of the related groups (defined as having studentised residuals with an absolute value greater than three) were corrected for. Mauchly's test indicated that the assumption of sphericity was violated for *Distance*, $\chi_2(9) = 35.06$, $p < .001$, as well as for the interaction between factors, $\chi_2(9) = 31.80$, $p < .001$. Because epsilon in both cases was greater than .75 ($\varepsilon = .97$), the Huynh-Feldt correction was used.

Analysis 2: Testing for a facilitation effect in each condition. To determine whether there were any simple main effects in the factor *Distance*, we conducted repeated measures ANOVAs on each *Testosterone* condition separately.

Assumptions. Mauchly's test showed that the assumption of sphericity was violated for *Distance*, $\chi_2(9) = 26.71$, $p = .002$. Epsilon was greater than .75 ($\varepsilon = .98$), so we applied the Huynh-Feldt correction. As already discussed, this data met all other assumptions for this analysis.

Analysis 3: Establishing the location of the facilitation effect. Bonferroni-corrected post-hoc pairwise comparisons from the two groups' ANOVA analyses showed where RTs significantly speeded up between sequential distance points. We also ran one-sample t-tests comparing RTs at each level of *Distance* in the two groups against unimodal baseline.

Both analyses are widely-used in practice to establish the critical distances at which PPS is located (Iachini et al., 2014; Noel et al., 2015a; Serino et al., 2015b; Teneggi et al., 2013). The first sequential approach compares distances against one another (Pellencin et al., 2017; Teneggi et al., 2013), while the second sets a static baseline of zero (no speed), allowing for net difference comparisons across distance points (Noel et al., 2015a; Serino et al., 2015b).

Assumptions. All assumptions were met for these analyses.

Determining the effect of testosterone on the PPS gradient. PPS gradients were determined through a calculation of their slope values. The slope parameter is extracted by fitting the data onto a sigmoid function. Only data that fitted well to the sigmoid curve was used for this analysis (as indicated by an R^2 value > 0.2), as ill-fitting data produces erroneous results.

These analyses were conducted for each individual participant's data under both conditions in collaboration with specialist Andrea Serino's laboratory, the EPFL (Ecole Polytechnique Fédérale de Lausanne).

The slope values were compared across testosterone and placebo conditions using a paired samples *t*-test to establish whether the gradient was indeed sharper (as indicated by a smaller slope value) under the testosterone condition, as predicted.

Additional analyses

The sigmoidal fitting also yields a central point parameter, an alternative indicator of the PPS boundary—and one of the most widely used in the PPS literature (Canzoneri, Magosso, & Serino, 2012; Ferri, Tajadura-Jiménez, Väljamäe, Vastano, & Costantini, 2015; Pellencin et al., 2017; Serino et al., 2015a; Serino et al., 2015b). We compared these more precise single central point values (PPS boundary proxies) to each other using a paired samples *t*-test.

Lastly, all RT data was compared across the two groups with a paired-samples *t*-test, contributing another point of interest to the discussion.

Results

Individual one-sample *t*-tests showed the distances at which PPS was located for each person across conditions, by comparing scores at each distance level to the unimodal baseline of zero. RT data is known to be 'noisy' and other studies have found that not all participants show a discernible PPS (Teneggi et al., 2013). Of the 18 participants in the sample, 13 participants showed RTs significantly faster than the unimodal baseline at one or more distance points under placebo, while under testosterone, 14 participants showed this effect. 9 participants showed PPS across both conditions (see Figure 1).

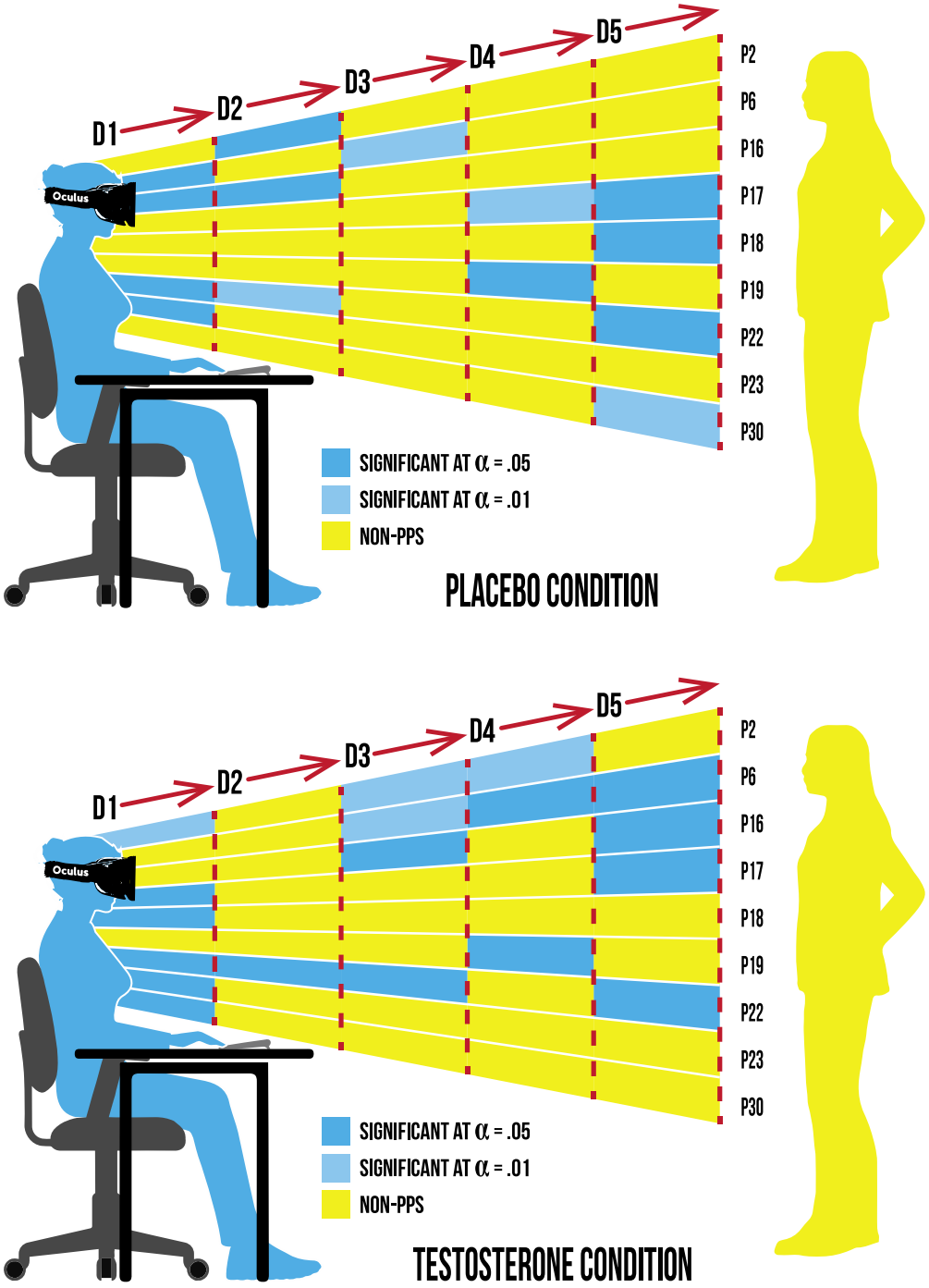

Figure 1. Summary Diagram of Individual PPS Boundaries under Both Conditions

Even though the individual PPS results are mixed, all participants were included in the group analyses in line with protocols followed by most PPS studies, as the heterogeneity of the data was not considered to not compromise the overall result. Each of the distance categories under both conditions show similar standard distributions of the dependant variable and there is no missing data (see Table 1).

Table 1.
Descriptive Statistics for RT at each Level of Distance

		M	*SD*	*N*
Placebo	D1	-.03	.06	360
	D2	.01	.07	360
	D3	.02	.05	360
	D4	.01	.05	360
	D5	-.01	.05	360
Testosterone	D1	-.02	.06	360
	D2	-.001	.05	360
	D3	.01	.05	360
	D4	.01	.06	360
	D5	-.01	.04	360

Using the Huynh-Feldt correction, the two-factor repeated measures ANOVA yielded a significant main effect of *Distance*, $F(3.86, 1386.09) = 69.87$, $p < .001$, with a large effect size ($\eta^2_p = .16$), but no significant main effect of *Testosterone*, $F(1, 359) = 3.25$, $p = .072$. This shows that *RT* was not uniformly modulated by testosterone. Critically, a significant interaction was found between *Distance* and *Testosterone*, $F(3.88, 1391.83) = 3.98$, $p = .004$, $\eta^2_p = .01$, indicating a testosterone PPS facilitation effect at certain distance points.

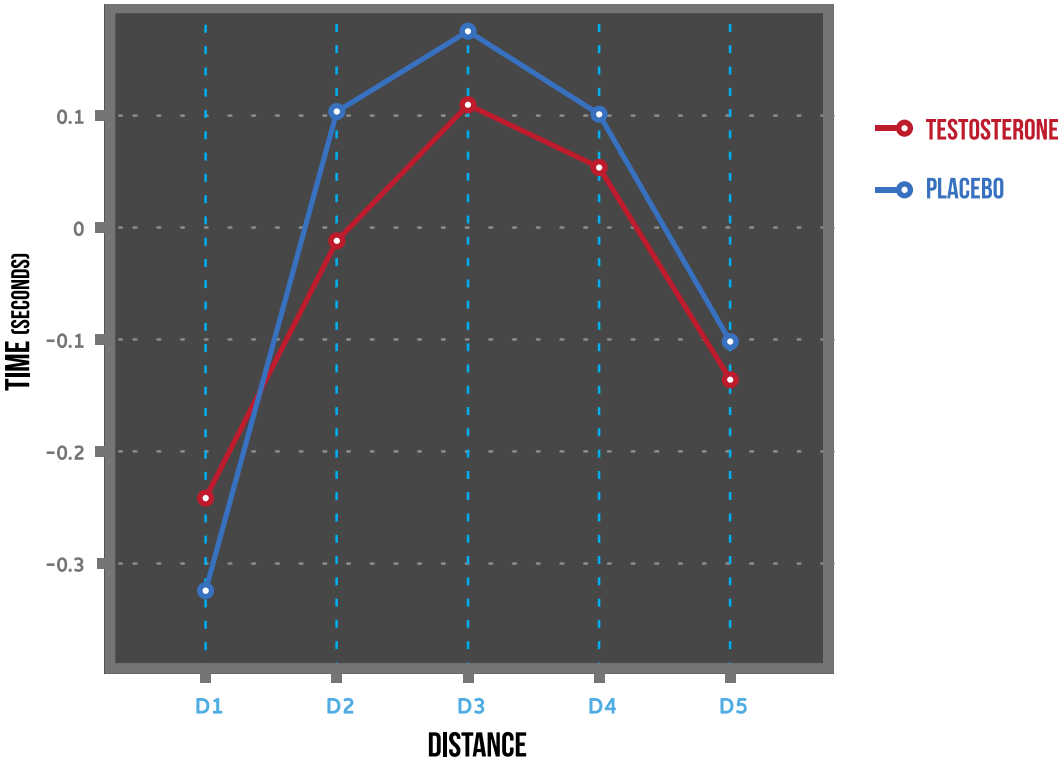

Figure 2. RT Means under Testosterone and Placebo Condition

As graphically represented by the means plot (Figure 2), the RTs at D1 and D5 are much faster than at the other distance points, with testosterone showing faster RTs to placebo at each level of *Distance* with the exception of D1. This visual impression appears to offer support for the hypothesis that testosterone acts to boost response times.

The source of the significant two-way interaction was explored with two repeated measures ANOVAs (using the Huynh-Feldt correction) on the placebo and testosterone data separately. Both ANOVAs showed a significant simple main effect of *Distance.* Analysis of the placebo group showed a large effect size (η^2_p = .13), $F(3.90, 1400.68) = 51.51$, $p < .001$, while the testosterone analysis showed a medium one (η^2_p = .07), $F(3.89, 1396.88) = 28.32$, $p < .001$. These results indicate the presence of a PPS facilitation effect in both conditions.

Bonferroni-corrected pairwise comparison tests of sequential distance levels in each condition (see Table 2) show significant differences under placebo between D1 (*M* = -.03, *SD* = .06) and D2 (*M* = .01, *SD* = .07), *p* <.001, and between D4 (*M* = .01, *SD* = .05) and D5 (*M* = -.01, *SD* = .05), *p* <.001. Under testosterone, a significant difference was found between D1 (*M* = -.02, *SD* = .06) and D2 (*M* = -.001, *SD* = .05), *p* <.001 as well as between D2 and D3 (*M* = .01, *SD* = .05), *p* =.007. *Distance* levels D4 (*M* = .01, *SD* = .06) and D5 (*M* = -.01, *SD* = .04) were also significantly different, *p* <.001.

Table 2.
Pairwise Comparisons in the Distance Factor for Testosterone and Placebo Conditions

		Placebo		Testosterone	
Distance 1	Distance 2	Distance 1-2	*p*	Distance 1-2	*p*
D1	D2	-.04	<.001*	-.02	<.001*
D2	D3	-.01	1.00	-.01	.007*
D3	D4	.01	.493	.01	1.00
D4	D5	.02	<.001*	.02	<.001*

* Significant at α = .05

These results show a facilitation effect from the body space up to D2 under placebo, while this is seen to continue to D3 under testosterone—indicating a larger PPS boundary (see Figure 3). In both conditions, this effect is seen again at D5.

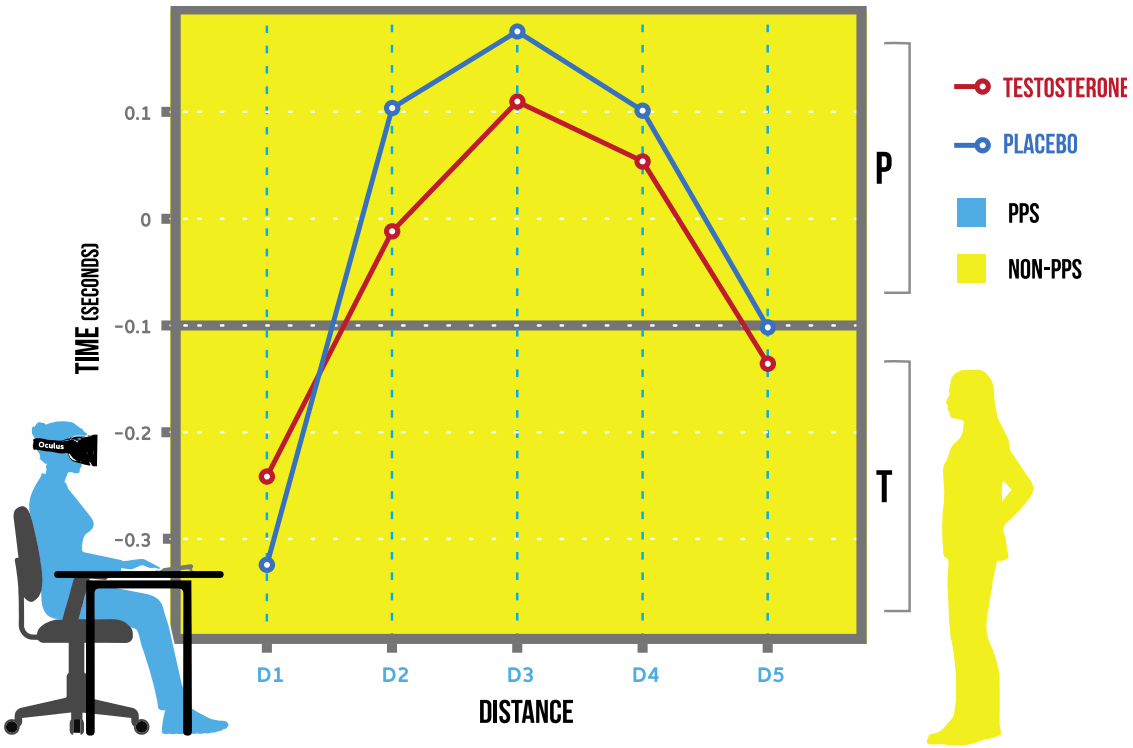

Figure 3. RT Facilitation Across Conditions According to Pairwise Comparisons

Following Noel and colleagues (2015a), we ran one-sample *t*-tests at each distance point against a unimodal baseline of zero (see Table 3). On placebo, RTs were significantly boosted at D1, $t(359) = -10.51$, $p < .001$, and at D5, $t(359) = -3.64$, $p < .001$. Distances D3 and D4 showed significant differences to the unimodal baseline, but in the opposite direction, i.e., a slowing. In the testosterone condition, scores also showed a significant speeding at D1, $t(359) = -7.34$, $p < .001$, and D5, $t(359) = -5.77$, $p < .001$. D3 showed significantly slower RTs to baseline, while D2 showed a speeding up, without reaching significance ($p = .609$).

Table 3
One-Sample T-Tests at each Level of Distance against the Unimodal Baseline of Zero

		t	*df*	*p*	Mean Difference
Placebo	D1	-10.51	359	<.001*	-.03
	D2	2.97	359	.003	.01
	D3	6.37	359	<.001*	.02
	D4	3.72	359	<.001*	.01
	D5	-3.64	359	<.001*	-.01
Testosterone	D1	-7.34	359	<.001*	-.02
	D2	-.51	359	.609	-.001
	D3	3.76	359	<.001*	.01
	D4	1.82	359	.070	.01
	D5	-5.77	359	<.001*	-.01

* Significant at $\alpha = .05$

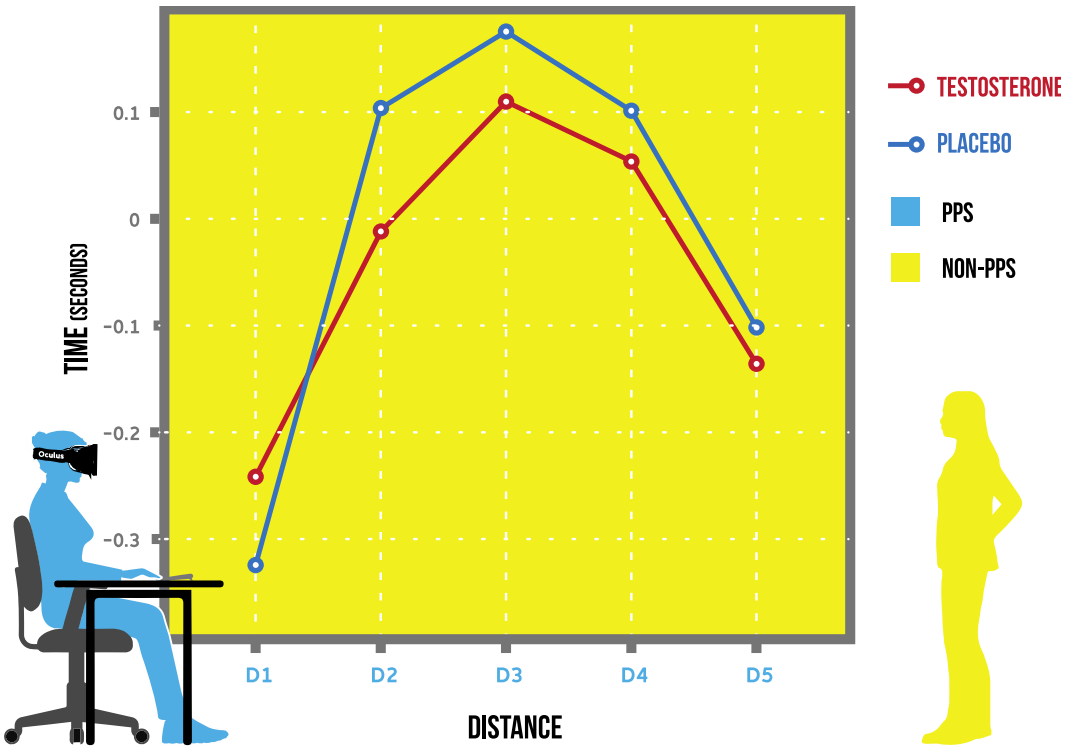

Figure 4. RT Facilitation Across Conditions According to One Sample T-Tests

This approach plots the PPS boundary between D1 and D2 for both conditions (see Figure 4). We further found a second space of facilitation under both conditions in the near-space of the confederate (D5), suggesting the presence of a shared action space. These results align with those of the pairwise comparisons, except that D2 was not found to be significantly boosted in the testosterone condition when compared against a baseline of zero. These findings show similar PPS boundaries across conditions, but differ in the size of the significant slowing down region (D3 and D4 in placebo, versus D3 only under testosterone).

Table 4.
Slope Values under Placebo and Testosterone

Participant	Placebo	Testosterone
2	0.18	12.71
8	0.16	2.10
11	0.10	1.17
12	0.12	2.76
15	6.95	1.30
22	0.14	0.98
27	0.41	5.79

To determine the sharpness of PPS gradients, slope value parameters were calculated for each participant's *Testosterone* conditions (see Table 4). Of the total sample, 7 participants' data fitted onto a sigmoidal curve successfully ($R^2 > 0.2$) with placebo showing a steeper gradient (M = 1.15, SD = 2.56) to testosterone (M = 3.83, SD = 4.25). However, this difference was not statistically different, $t(6) = -1.30$, $p = .243$.

Table 5.
Central Point Values under Placebo and Testosterone

Participant	Placebo	Testosterone
2	3.10	4.85
8	1.88	3.43
11	1.91	2.32
12	1.80	4.17
15	0.65	2.12
22	1.93	2.50
27	1.88	5.13

The central point parameters extracted from the sigmoidal curve (see Table 5) offer alternative proxies for participants' PPS boundaries, plotting these at a single, more spatially precise point within the broader distance areas. The testosterone group (M = 3.50, SD = 1.24) returned a significantly larger PPS to placebo (M = 1.88, SD = .71), $t(6) = -4.37$, $p = .005$. This finding is consistent with the results of the pairwise comparisons, that also indicated a significantly larger PPS on testosterone.

The group comparison of all data showed faster RTs under testosterone (M = -.005, SD = .06) to placebo (M = -.001, SD = .06). This finding was statistically significant, $t(1799) = -2.07$, $p = .039$, suggesting an overall testosterone facilitation.

Discussion

We hypothesised that raising testosterone levels would translate into a larger PPS boundary in the presence of an unknown person, compared to placebo. This would establish a larger defensive space in the face of the uncertain motivational valence posed by the other party. Statistical and mathematical analyses indeed pointed to a larger PPS boundary under testosterone, with two of the three analyses achieving statistical significance. Additionally, a second area of multisensory processing facilitation was found under both conditions at the farthest distance measured (80–100cm+) at the region of space closest to a confederate. This will be addressed on its own terms later on in the discussion, as this finding is seen to hold a further level of meaning.

There are a range of statistical approaches to calculating PPS via bimodal RTs from sensory integration tasks (Iachini et al., 2014; Noel et al., 2015a; Pellencin et al., 2017; Serino et al., 2015b; Teneggi et al., 2013). The three PPS boundary calculations used here are the ones most commonly drawn on in PPS studies and, as such, they can be seen to offer salient responses to the question posed. In addition, they provide a means of triangulating the results—although, owing to the fact that the central points analysis omits eleven participants' data, it can be seen to contribute towards rather than constitute the main findings.

Sequential pairwise distance comparisons indicated an approximately 20cm larger PPS boundary on testosterone, extending 40cm–60cm from the body periphery, compared to 20cm–40cm on placebo. This approach is useful in that it demonstrates the region where RT begins to be significantly enhanced as a function of near-space. However, an alternative approach to calculating the PPS boundary endorsed by Noel and colleagues (2015a) that compares scores at each distance point to a static baseline (zero), showed no widening effect of testosterone, locating the PPS boundary 20cm from the body in both groups. The area from 20–40cm continued to show boosted speeds (faster than baseline) in the testosterone group, but this facilitation fell short of reaching significance. This finding is nonetheless meaningful in that at the equivalent distance in the placebo condition, response times showed no facilitation, i.e. they were slower than baseline.

Although this method defines PPS in terms of whether or not a speeding effect is faster than a single baseline value, i.e. a facilitation effect, tracing the degree of change in reaction time from one distance point to the next—as modelled by the sequential analysis—can arguably be seen to provide a more true-to-life, ecological representation of PPS as it demarcates the region where processing speed accelerates significantly. This is more in line with a definition of the PPS boundary as the region of space where processing begins to speed up significantly (de Vignemont & Iannetti, 2015; di Pellegrino & Làdavas, 2015; Gallese, 2000; Rizzolatti et al., 1981; Teneggi et al., 2013).

Echoing the findings of the sequential approach, the central points analysis confirmed a larger PPS boundary in the testosterone group, describing a PPS boundary one and two thirds—or 33.33cm—larger under testosterone than placebo for the seven participants analysed. Together, these findings seem to provide support for a moderately, but significantly larger PPS boundary in the testosterone condition. Given the established link between testosterone and 'territorial-type' behaviour, it seems apposite that an extended PPS boundary would be found on elevated testosterone. What this means, in terms of dominance motivation,

is the conference of a clear social advantage via a larger defensive space for threat monitoring and action readiness.

In line with this, response speeds under testosterone were found to be consistently faster to those in the placebo condition for each distance with the exception of D1 (where the placebo mean is 10 milliseconds quicker), with overall response speeds boosted by 4 milliseconds. The general boost in processing speed across distances moving away from the body affords a performance edge with distinct benefits for competitive contexts.

In keeping with the literature on PPS as a defensive space (de Vignemont & Iannetti, 2015; Iachini et al., 2014; Valdés-Conroy et al., 2012), elevated testosterone was predicted to sharpen the gradient of PPS, reflecting more vigilant monitoring of PPS in the face of an unfamiliar 'other' and a more abrupt PPS transition between self and other. However, this hypothesis was nullified by the analysis. Instead, placebo slope values described a steeper curve, by a difference of 2.69 points. This difference was not found to be statistically significant.

This finding needs to be interpreted in the context of the facilitation effect found 80–100cm from the participant (and possibly beyond), corresponding to the near space of the confederate, who was positioned approximately 1.25m ahead of the participant. It is possible that this second, discrete PPS explains the extended (i.e. more gradual) transition, where the shallow boundary slope does not indicate a relatedness or a blurring of the self-other boundary as described in the literature (Noel et al., 2017), but rather the extension of a monitoring function through the activation of a satellite-self, a space of an amplified alertness in the face of the unknown other.

Prior research supports the claim that individuals in a social context have been found to form shared action spaces, where another's action plan is incorporated into one's own (de Bruijn et al., 2008; Làdavas & Serino, 2008; Pezzulo et al., 2013; Ruys & Aarts, 2010). This is a space of heightened sensitivity to the other, thought to be one in which actions can be anticipated and intentions perceived (Ruys & Aarts, 2010). The finding of another space of boosted multisensory processing, consistent with the principles of shared action space, emerged similarly across conditions. In fact, response speeds at this distance were more alike than at any other distance, suggesting that this effect served to iron out some of the testosterone advantage seen elsewhere. In keeping with the motivations underlying shared representations of space, it is plausible that the appearance of an unknown and unexplained person could elicit the activation of a hyper-attuned defensive space in the other's near-space, facilitating the subject's readiness for any eventuality.

On a case by case basis, PPS responses appear strikingly individual and mixed. While testosterone exerted an observable effect on these varied PPS representations, it did not cancel out the differences. The 'noise' or heterogeneity seen across individual PPS boundary findings is in line with the rationale behind PPS construction as critically determined by intra-individual traits and social motivations (Noel et al., 2015b; Ruys & Aarts, 2010). However, when viewed globally, the two groups showed a similar pattern of performance, suggesting that the construction of space was appreciably influenced by factors other than testosterone, such as, most notably, the social element.

Findings suggest that the presence of a stranger is associated with a strong PPS response, irrespective of physiological testosterone levels. Considering this retrospectively, it is possible that the presence of the confederate had a larger effect than anticipated in that it may have presented a competing factor to the testosterone condition. As this was not an independent variable, we cannot compare the PPS result to a non-confederate condition. This is a possible limitation of this study.

The decision to maintain the presence of the confederate across conditions was made on the basis that it established a social factor, which is a central, defining feature of this study. In order to investigate participants' PPS boundaries without the other's presence, we would have needed to have set up a third predictor variable, resulting in four conditions. This was beyond the scope of this study, on a practical basis. The small sample size can be said to be another limitation, in that it increases the possibility that some of the effect seen was due to chance. However, this study, although self-contained, also constituted the first stage of a larger study. Part of its utility was in aiming to scope out this new territory to inform future directions, which it can be said to have achieved.

Much of the true value of the findings of the current study will be in laying a good foundation for the investigations that follow. As well as drawing attention to an ostensibly fertile area for future study, these findings also offer a small contribution to existing knowledge on the social modulation of PPS boundaries. These can be said to be preliminary observations, prospecting how the subjective representation of personal space, as seen through the properties of PPS boundaries, bring to light hidden social dynamics.

Conclusion

Positioned at the intersection of two well established areas of research in the neuroscientific community, this study brought PPS and testosterone into the laboratory together for the first time. Drawing from their respective knowledge bases, we postulated some possible effects of testosterone versus placebo on PPS representation. Findings in

favour of our hypotheses were mixed, but consistent with PPS as well as testosterone theory, providing valuable insights as a first foray into a new area.

Testosterone was indeed found to have an effect on PPS representation, although modest—as evidenced by the interaction's small effect size and the absence of a significant main effect in the *Testosterone* variable. Nevertheless, there is a clear trend across the various results in support of the hypothesis that testosterone, known to underlie social dominance motivations, is positively related to a larger PPS boundary and boosted RTs, as compared to placebo. It was not found to sharpen the gradient of the PPS boundary; however, a likely explanation for this is the finding of a shared action space in the near-space of the confederate which may have acted to extend the gradient slope.

It can be said from this evidence that physiological testosterone levels indeed play a determining role in PPS representation, with higher levels associated with accelerated multisensory processing. Raised testosterone also has the important implication of enhancing attentional abilities in the near environment. It is premature to speculate on whether the measurement of PPS reliably serves as a neural marker of unseen social attitudes and dynamics. More evidence is needed of trends of interpersonal response across settings. What can be surmised though, is that PPS representations appear to reveal areas of heightened attention, opening up a potentially fruitful avenue for exploration of subject matter hitherto only examinable phenomenologically in the social sciences.

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Appendix A

	RESEARCH ACCESS TO STUDENTS	DSA 100

NOTES

1. This form must be **FULLY** completed by all applicants that want to access UCT students for the purpose of research.
2. Return the fully completed **(a) DSA 100** application form **by email**, in **the same word format**, together with **your: (b) research proposal inclusive of your survey, (c) copy of your ethics approval letter / proof (d) informed consent letter** to: Moonira.Khan@uct.ac.za. You application will be attended to by the Executive Director, Department of Student Affairs (DSA), UCT.
3. The turnaround time for a reply is **approximately 10 working days.**
4. NB: It is the responsibility of the researcher/s to apply for and to obtain **ethics approval and to comply with amendments that may be requested;** as well as **to obtain** approval to access UCT staff and/or UCT students, from the following, at UCT, respectively: (a) **Ethics:** Chairperson, Faculty Research Ethics Committee' (FREC) for ethics approval, (b) **Staff access:** Executive Director: HR for approval to access UCT staff, and (c) Student **access:** Executive Director: Student Affairs for approval to access UCT students.
5. **Note:** UCT Senate Research Protocols requires compliance to the above, **even if prior approval has been obtained from any other institution/agency. UCT's research protocol requirements applies to *all* persons, institutions and agencies from UCT and external to UCT who want to conduct research on human subjects for academic, marketing or service related reasons at UCT.**
6. **Should approval be granted to access UCT students for this research study, such approval is effective for a period of one year from the date of approval (as stated in Section D of this form), and the approval expires automatically on the last day.**
7. **The approving authority reserves the right to revoke an approval based on reasonable grounds and/or new information.**

SECTION A: RESEARCH APPLICANT/S DETAILS

Position	Staff / Student No	Title and Name	Contact Details (Email / Cell / land line)
A.1 Student Number	PRVADA001	Ms Adala Michelle Prévost	adalamichelle@gmail.com / 074 1440033 / 021 7889291
A.2 Academic / PASS Staff No.			
A.3 Visitor/ Researcher ID No.			
A.4 University at which a student or employee	UCT	**Address if *not* UCT:**	
A.5 Faculty/ Department/School	Psychology		
A.6 APPLICANTS DETAILS If different from above	**Title and Name**	**Tel.**	**Email**

SECTION B: RESEARCHER/S SUPERVISOR/S DETAILS

Position	Title and Name	Tel.	Email
B.1 Supervisor	Prof. Mark Solms	021 650 3437	mark.solms@uct.ac.za
B.2 Co-Supervisor/s	Donné van der Westhuizen Jane Masson	n/a	donvanwest@gmail.com massoncjane@gmail.com

SECTION C: APPLICANT'S RESEARCH STUDY FIELD AND APPROVAL STATUS

C.1 Degree – if applicable	Honours
C.2 Research Project Title	The Effects of Testosterone on Peripersonal Space
C.3 Research Proposal	**Attached:** **Yes** [x] **No** [ ]
C.4 Target population	Women between 18 and 35 years not taking contraceptive or hormonal medication or pregnant
C.5 Lead Researcher details	**If different from applicant:** Donné van der Westhuizen (donvanwest@gmail.com)
C6. Will use research assistant/s	**Yes** [ ] **No** [x] **If yes- provide a list of names, contact details and ID no.**
C.7 Research Methodology and Informed consent:	**Research methodology**: **Informed consent:** Yes, attached
C.8 Ethics clearance status from UCT's Faculty Ethics Research Committee (FREC)	**Approved by the FREC** **Yes** [x] **With amendments: Yes** [ ] **No** [ ] **(a) Attach copy of your ethics approval. Attached: Yes** **(b) State date and reference no. of ethics approval: Date: 02/05/2017** **Ref. No. :868/2014**

SECTION D: APPLICANT/S APPROVAL STATUS FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE

(To be completed by the ED, DSA or Nominee)

	Approved / With Terms / Not	* Conditional approval with terms	Applicant/s Ref. No.:
D.1 APPROVAL STATUS	**(i) Yes** **(ii) With terms** **(iii) No** [ ]	**(a)** Access to students for this research study must only be undertaken after written ethics approval has been obtained. **(b)** In event any ethics conditions are attached, these must be complied with before access to students.	

	Designation	Name	Signature	Date of Approval
D.2 APPROVED BY:	***Executive Director Department of Student Affairs***			

Appendix B

PARTICIPANT INFORMATION LEAFLET AND 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 have understood everything written in it, and sign where indicated.

If you have any further questions or concerns, please feel free to contact: **Michelle Prevost – 074 144 0033**

Principal Investigator: Mark Solms – 021 650-3417
Department of Psychology
University of Cape Town
Rondebosch

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 the 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?
We will ask you to come in to the lab on two days, for two sessions per day, which will be four hours apart. The first session will last a maximum of 30 minutes and the second, 45 minutes. Prior to signing up, you will be given the opportunity to make bookings that are most convenient for you.

What procedures, drugs or other treatments are involved in this research?
On both days, you will be asked to take *either* 0.5mg of a testosterone or a 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, that you will collect personally in a private bathroom cubicle. The saliva samples will be used to measure the natural level of testosterone in your body. We will NOT use the saliva samples to test for anything else and they will be stored in a security-controlled laboratory.

What are the risks and discomforts of taking part in this research?
The testosterone is in liquid form with hydroxypropyl-β-cyclodextrin as a carrier. Testosterone can lead to adverse drug reactions such as headaches and nausea, but these reactions are quite rare. There are no known long-term effects from this dosage of testosterone.

Are there any benefits to you if you take part in this research?
You will be compensated with R350 for taking part in this study. If you are a psychology student, you will be compensated with course credit (3.5 RPP points) 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.

Confidentiality and anonymity
All information you provide will be kept strictly confidential. Your identity will remain anonymous throughout the research.

Having read through this information, please comment on whether you have understood everything.
If not, please comment on what you did not understand, or any concerns that you might have:

_____

_____

_____

_____

_____

Full names and surname (please print): _____

Signature: _____ Date: _____

What if something goes wrong?

Professor Mark Solms is covered under the 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 Professor 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

If 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 X828, PRETORIA 0001.

Appendix C

PARTICIPANT DEBRIEFING INFORMATION SHEET

We thank you for your participation in our study!

Prevention of disclosure of study information

We would like to remind you that all information you provide will be kept strictly confidential and that your identity will remain anonymous throughout the research. The saliva samples will be used to check your baseline testosterone levels and nothing else. They will be stored in a security-controlled laboratory.

Safety reminder

All women have naturally circulating testosterone in their bodies and the dosage that you ingested is less than the total amount produced during one day. It will be out of your system within about six hours from the time of administration and you will not experience any harmful side-effects. No long term harmful effects have been reported with this dosage of testosterone. The placebo solution is a harmless fluid with no active ingredients, made to taste the same as the testosterone.

What if something goes wrong?

Professor Mark Solms is covered under the 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?

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Observatory 7925
Tel: (021) 406 6626
Fax: (021) 406 6411
Email: lamees.emjedi@uct.ac.za

If 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 X828, PRETORIA 0001.

Why is this research being done – what is it trying to find out?
This is an exploratory study. This research is being done to investigate how the brain interprets the space around the body. We have used testosterone experimentally to boost feelings of social confidence and explore whether this increases reaction times to sensory input in our immediate space.

If you would like to see the final results of this study, please send us an email. You are also invited to email us with any further questions that you may have.

Michelle Prevost: adalamichelle@gmail.com | Jane Masson: massoncjane@gmail.com

Appendix D

UNIVERSITY OF CAPE TOWN

HUMAN RESEARCH ETHICS COMMITTEE
- 2 MAY 2017
HEALTH SCIENCES FACULTY
UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA00001637; IRB00001938) This serves as notification of annual approval, including any documentation described below.			
☑ Approved	Annual progress report	Approved until/next renewal date	30.5.2018
☐ Not approved	See attached comments		
Signature Chairperson of the HREC		Date Signed	2/5/17

Comments to PI from the HREC

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	20 April 2017		
HREC REF Number	868/2014	Current Ethics Approval was granted until	28/02/17
Protocol title	Neuropsychological mechanisms of social power: the role of spatial representation and covert action simulation processes		
Protocol number (if applicable)			
Are there any sub-studies linked to this study?	☐ Yes x No		
If yes, could you please provide the HREC Ref's for all sub-studies? **Note:** A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Prof. Mark Solms		
Department / Office Internal Mail Address	Psychology / mark.solms@uct.ac.za		

1.1 Does this protocol receive US Federal funding?	☐ Yes	x No
1.2 If the study receives US Federal Funding, does the annual report require full committee approval?	☐ Yes	☐ No
1.3 Has sponsorship of this study changed? If yes, please attach a revised summary of the budget.	☐ Yes	☐ No

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)

UNIVERSITY OF CAPE TOWN

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

2. List of documentation for approval

NONE

3. Protocol status (tick ✓)

☑	Open to enrolment
☐	Closed to enrolment (tick ✓)
☑	Research-related activities are ongoing
☐	Research-related activities are complete, long-term follow-up only
☐	Research-related activities are complete, data analysis only
☐	Main study is complete but sub-study research-related activities are ongoing
☐	Study is closed → Please submit a Study Closure Form (FHS010)

4. Enrolment

Number of participants enrolled to date	83
Number of participants enrolled, since last HREC Progress report (continuing review)	11
Additional number of participants still required	40

5. Refusals

Total number of refusals (participants invited to join the study, but refused to take part)	0

6. Cumulative summary of participants

Total number of participants who provided consent	83
Number of participants determined to be ineligible (i.e. after screening)	30
Number of participants currently active on the study	0
Number of participants completed study (without events leading to withdrawal)	83
Number of participants withdrawn at participants' request (i.e. changed their mind)	0
Number of participants withdrawn by PI due to toxicity or adverse events	0
Number of participants withdrawn by PI for other reasons (e.g. pregnancy, poor compliance)	0
Number of participants lost to follow-up. Please comment below on reasons for loss of follow-up.	2
Failure to arrive or continue correspondance.	
Number of participants no longer taking part for reasons not listed above. Please provide reasons below:	0

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)

7. Progress of study

Please provide a brief summary of the research to date including the overall progress and the progress since the last annual report as well as any relevant comments/issues you would like to report to the HREC:
In 2015 we completed two studies, one that looked at the effects of testosterone on sensory-motor agency and another that looked at the effects of testosterone on the sense of body ownership – representations of the body in the brain are recruited for spatial processing. Last year we completed data collection for a third study on the effects of testosterone on interoceptive processing. We had some issues with our equipment but overall the study ran smoothly and we received a lot of interest from our participants. Our analyses revealed several significant findings. We are awaiting feedback from the journal, Psychoneuroendocrinology, for the manuscript on sense of agency and are in the processes are finalizing the other two papers for submission. We began piloting for the study on the effects of testosterone on peri-personal space (PPS) and hoped to begin data collection toward the end of the second semester. Due to the protest actions last year we were significantly delayed but pre-hormone testing is now in progress. We hope to begin hormone trials in April 2017.

8. Protocol violations and exceptions (tick ✓ all that apply)

☑	No prior violations or exceptions have occurred since the original approval
☐	Prior violations or exceptions have been reported since the last review and have already been acknowledged or approved
☐	Unreported minor violations that have occurred since the last review, as well as significant deviations not yet reported, are attached for review

9. Amendments (tick ✓ all that apply)

☐	No prior amendments have been made since the original approval
☐	Prior amendments have been reported since the last review and have already been approved
☑	New protocol changes/ amendments are requested as part of this continuing review (See note below)

(Additional researcher being added)
Note: If new protocol changes are being requested in this review, please complete an amendment form (FHS006).
Specific changes in the amended protocol and consent/assent forms must be **bolded**, *italicised* or tracked and all changes must include a rationale.

10. Adverse events

10.1 Please provide below or attach a narrative summary of serious adverse events and/ or unanticipated problems since the last progress report. Please indicate changes made to the protocol and informed consent document(s) as a result (if not already reported to the HREC). Please comment on whether causality to any study procedure or intervention could be established.
NO problems were reported.

10.2 Have participants received appropriate treatment/ follow-up/ referral when indicated (e.g. in the case of abnormal or incidental clinical findings, distress or anxiety)?		
☑ Yes	☐ No	☐ Not applicable
If yes, please describe:		
Debriefing e-mail.		

11. Summary of Monitoring and Audit Activities (tick ✓)

11.1 Was this study monitored or audited by an external agency (e.g. MCC, FDA)?		
☐ Yes	☑ No	☐ Not applicable

11.2 Did a Data and Safety Monitoring Board publish a report?		
☐ Yes	☑ No	☐ Not applicable

11.3 If yes, please identify the agency and attach a summary of the findings.					
Agency Name		Report attached	☐ Yes	☐ No	☐ Not applicable
		DSMB report attached	☐ Yes	☐ No	☐ Not applicable

11.4 Has there been any agency, institutional or other inquiry into non-compliance in this study, or any finding of non-compliance concerning a member of the research team?	
☐ Yes	☑ No
If yes, please explain:	

12. Level of risk (tick ✓)

12.1 In light of your experience of this research, please indicate whether the level of risk to participants has:	
☐	Increased
☐	Decreased
☑	Shown no change
If there has been a change, please explain:	

12.2 Please provide a narrative summary of recent relevant literature that may have a bearing on the level of risk.
N/A

13. Statement of conflict of interest

Has there been any change in the conflict of interest status of this protocol since the original approval? (tick ✓)	
☐ Yes	☑ No
If yes, please explain and if necessary attach a revised conflict of interest statement (Section #7 in the New Protocol Application Form FHS013):	

14. Signature

My signature certifies that the above is complete and correct.			
Signature of PI		Date	

(Note: Please complete the Closure form (FHS010) if the study is completed within the approval period)