**Multi-Method Approaches to Understanding Bidirectional Links
Between Sexuality and Testosterone in Women**

by

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DEDICATION

For my grandmother, Luciana Loposzko, who inspired me by earning her Ph.D. in Pharmacy at the University of Bologna over 60 years ago.

And in loving memory of my grandfather, Joseph Loposzko, who encouraged me to pursue a Ph.D., and my grandmother (-in-law) Hazel Blaine, whose support and sense of humor helped encourage me through it.

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ABSTRACT

Testosterone (T) is often studied for its role in causally influencing (male) sexual behavior. However, research in females and males from a variety of species also demonstrates evidence for the 'reverse relationship', i.e., effects of sexual stimuli and behaviors on T. Although sexuality clearly modulates T, T does not respond the same way in every individual or in every sexual situation. What accounts for this variability in sexually-modulated T is not well-characterized. However, the social context surrounding a sexual interaction, over and above specific sensory modalities or behaviors, seems important in shaping sexual modulation of T. Additionally, in humans, sexual thoughts in the absence of external stimuli or the mere anticipation of sexual activity can increase T. These findings suggest that one source of variability in sexually-modulated T may be how an event is experienced internally (i.e., cognitively, perceptually, and affectively).

In this dissertation, I examined how internal experiences shaped sexual modulation of T and bidirectional sexuality-T associations in women. To address my research questions, I employed longitudinal, qualitative, and experimental methods. First, I demonstrated that women's T was positively associated with solitary sexual behavior (i.e., being sexual alone) but negatively associated with dyadic sexual behavior (i.e., being sexual with a partner). Second, mirroring their differential associations with T, solitary and dyadic sexuality were described as qualitatively different experiences by women themselves. In focus group discussions, women defined solitary sexual pleasure as oriented around autonomy and orgasm, and dyadic sexual pleasure as oriented around nurturant intimacy (among other components). These findings

supported theoretical predictions that sexual contexts oriented around genital/erotic pleasure would be linked with higher T, and those oriented around nurturance would be linked with lower T. Finally, I showed that cognitive/emotional experiences predicted women's acute T responses to visual sexual stimuli. Specifically, identification with stimuli (i.e., taking the perspective of film characters) moderated T responses to self-chosen versus researcher-chosen erotic films. Taken together, my findings highlight (a) the bidirectional and dynamic nature of T-sexuality associations and (b) the power of even subtle internal cues to shape physiology.

CHAPTER 1

GENERAL INTRODUCTION: SEXUAL MODULATION OF TESTOSTERONE[*]

   Sexual behavior is a primary focus of study among researchers interested in evolution for obvious reasons – in almost all vertebrates, sex is essential for reproduction. Yet, sexual behavior can serve many adaptive functions besides fertilization, including pair bond maintenance, conflict management, alliance formation, expression of dominance or power dynamics, experiencing pleasure, and resource acquisition (Abramson & Pinkerton, 2002; Pfaus et al., 2012; Snowdon, Ziegler, Schultz-Darken, & Ferris, 2006; Vasey & Sommer, 2006; Wallen & Zehr, 2004). Moreover, some sexual behaviors like solitary sexuality or masturbation may not have an adaptive function, but are still evolutionarily relevant; i.e., they may be by-products of adaptive sexual behaviors (Vasey & Sommer, 2006).

   Just as ultimate functions of sexual behavior are more diverse than they might seem at first glance, the expression of sexual behavior itself is highly varied. Obviously, the contexts in which sexual behavior occurs and the corresponding behavioral patterns differ among species. However, they also vary among individuals within a species, as in Japanese macaques (*Macaca fuscata*), where the frequency of female-female consortships varies between populations and also between individual females within the same population (Vasey, 2006). Within individuals, the expression of sexual behavior further changes across development and life-history stage. As an

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[*] This chapter (including Figure 1.1) is based on material previously published in: Goldey, K.L., & van Anders, S.M. (2015). Sexual modulation of testosterone: Insights for humans from across species. *Adaptive Human Behavior and Physiology, Special Issue: Social Neuroendocrinology, 1*(2), 93-123, with permission of Springer Science+Business Media.

example, female downy woodpeckers' (*Picoides pubescens*) sexual solicitations lead to copulation in the spring, but not in the winter (when they may function in pair bond maintenance) (Kellam, Wingfield, & Lucas, 2004). Finally, the immediate social context can have profound effects on sexual behavior, even within the same individual during the same life-history stage (Oliveira, 2009; Wallen, 2001). For example, social housing conditions have strong effects on copulation frequency in rhesus macaques (*Macaca mulatta*), such that females limit sexual behavior to the fertile period of their cycle when in one male-multiple female groups, but copulate throughout the cycle when housed in female-male dyads (which involve no sexual competition *and* fewer social behavioral alternatives to copulation) (Wallen, 2001). Far from just a stereotyped set of motor patterns, sexual behavior varies across species, individuals, life-history stages, and contexts. How do individuals regulate their behavior in response to the challenges posed by any given sexual context?

Hormones are key physiological mediators of behavioral flexibility in response to changing social environments (Oliveira, 2009). In particular, testosterone (T) is implicated in tradeoffs relevant to life-history strategies, such that high T is linked with competition (i.e., acquisition or defense of resources, including sexual partners or opportunities) and low T is linked with nurturance (i.e., warm, loving contact between partners, parents and offspring, or others) (van Anders, Goldey, & Kuo, 2011). T and other androgens respond dynamically to social stimuli, such that T-behavior associations are often bidirectional or iterative (van Anders & Watson, 2006). A critical role for T in the organization, activation, and maintenance of (male) sexual behavior has been clearly established via hormone administration and ablation studies (Adkins-Regan, 2012; Munakata & Kobayashi, 2010), but how T *responds* to sexual contexts across species is less well-characterized, particularly compared to modulation of T by other

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social behaviors such as aggression, competition, and parenting. Filling this gap in knowledge is important, as the assumption of a reciprocal relationship between T and social behavior is critical to assertions that T adaptively fine-tunes behavior in response to context (Oliveira, 2009; van Anders & Watson, 2006). That is, for T to adjust sexual behavior in response to context, its expression must be sensitive to context. Therefore, characterizing how sexuality modulates T is key to a complete understanding of hormone-sexuality relationships.

In this chapter, I first briefly outline a rationale for a comparative approach to sexual modulation of T, and then I introduce T in terms of its costs and benefits for physiology and social behavior. Next, I review and synthesize findings on sexual modulation of T in fish, birds, rodents, and primates (including humans), with attention to the specific elements of sexual situations that drive T responses. After reviewing findings on sexual modulation of T across species, I synthesize these findings to ask what drives sexual modulation of T: What is the evidence that sexual modulation of T is driven by sexual behavior itself? By specific sensory cues? By social context? Finally, I conclude by discussing gaps in current knowledge that set the stage for my dissertation research on sexual modulation of T in women. Throughout, I use the abbreviation ΔT for T responses to sexual stimuli or behaviors (i.e., sexually-modulated T), and I use *sexuality* to refer to sexual contexts broadly, encompassing sexual behavior and exposure to sexual cues.

A Comparative Approach

Why address research on fish or birds to draw conclusions about sexual modulation of T in humans? In Sexual Configurations Theory, van Anders (2015) illustrates that comparative frameworks are useful for studying humans (and in general) because they simultaneously attend to species-specific particularities *and* cross-species generalities. That is, a comparative

framework uses both a "micro lens" to study species-specific social and ecological contexts and a "macro lens" to draw conclusions about shared patterns across species, without privileging one lens over the other (van Anders, 2015). Of course, humans are no exception in possessing both shared patterns and species-specificities, and an especially important human-specific particularity is the presence of social constructs, i.e., phenomena created and developed through cultures and societies (van Anders, 2013). For example, Wallen (2001) showed how human-specific particularities, such as actively preventing pregnancy or increasing sexual frequency on weekends, can obscure or overwhelm measurable associations between hormones and sexual behavior that are present in other primates. Thus, studying humans in relation to other species *and* as unique is informative for research on T and other phenomena (van Anders, 2013).

A comparative perspective can provide valuable and sometimes unexpected insights for theorizing about sexuality in humans. For example, Sexual Configurations Theory (van Anders, 2015) applies the comparative concepts of generalities and particularities to understanding how multiple minority and majority sexualities exist in relation to one another. Via a sexual diversity lens, Sexual Configurations Theory addresses the unique particularities of specific sexualities alongside generalities across sexualities (van Anders, 2015). Like comparative frameworks, a sexual diversity lens moves beyond group differences to focus on within-group heterogeneity and between-group commonalities (van Anders, 2015). In this way, comparative frameworks can provide insights even for human-specific phenomena (e.g., sexual identities).

Attending to shared principles and diversity across species is similarly useful for understanding sexual modulation of T. Using interchanging micro and macro lenses, researchers can ask species-specific questions (e.g., how does housing with a pair bonded mate affect ΔT to ovulatory odors from novel females in male common marmosets (*Callithrix jacchus*)? (Ziegler,

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Schultz-Darken, Scott, Snowdon, & Ferris, 2005)) alongside questions about broader principles (e.g., how does pair bond status modulate potential costs and benefits of ΔT?) (van Anders, 2013, 2015). Synthesizing research from a broad array of species helps clarify when the dynamics of sexually modulated T in humans reflect conserved roles for T across vertebrates versus human-specific patterns (Goodson, 2013; van Anders, 2013). Similarly, comparative approaches are useful in making predictions about how broader patterns might play out in humans given human-specific particularities (van Anders, 2013). In sum, comparative research has been highly valuable to the fields of behavioral and social neuroendocrinology (Adkins-Regan, 1990, 2009, 2012; Oliveira, 2009; van Anders, 2013, 2015) and is likely to provide important insights about sexual modulation of T in humans.

Testosterone: Costs and Benefits

In many species, modulating T expression is one means by which individuals regulate their behavior and physiology in response to competing life-history challenges (e.g., survival vs. reproduction) (Bribiescas, 2001; Ketterson & Nolan, 1992; Muehlenbein, 2006; Oliveira, 2009). T carries behavioral and physiological benefits and costs. Behaviorally, T promotes competition for resources, including sexual partners, territories, and status, but inhibits nurturant contact with offspring or partners (e.g., feeding, grooming) (van Anders et al., 2011). As an example of this tradeoff, male dark-eyed juncos (*Junco hyemalis*) treated with T have higher extra-pair fertilization rates but smaller nestlings relative to controls (Reed et al., 2006). Females of this species also show evidence of T-mediated behavioral tradeoffs between competition and nurturance, but the form of the tradeoff may differ: measures of T production positively predicted female-female aggression *and* nestling provisioning, but negatively predicted time spent brooding (Cain & Ketterson 2012, 2013). Additional behavioral tradeoffs indicate potential

costs of T in terms of survival: in some species, T increases locomotor activity and risk-taking behavior, which can facilitate sexual and territorial competition but increase the risk of injury (Ketterson & Nolan, 1992; Wingfield, Lynn, & Soma, 2001). Physiologically, T allocates energy toward skeletal muscle anabolism and away from fat storage and immune functions (Bribiescas, 2001; Muehlenbein & Bribiescas, 2005; Muehlenbein, 2006; Wingfield et al., 2001). Although findings are complex, overall, androgens appear to have immunosuppressive effects in mammals and birds (Muehlenbein & Bribiescas, 2005) and perhaps in fish (Yamaguchi, Watanuki, & Sakai, 2001), and humans down-regulate T in response to even mild immune challenges (Simmons & Roney, 2009). Most research on physiological costs of T focuses on males, but research with birds suggests some physiological costs are similar in females and males (e.g., delayed molt, immunosuppression) (Ketterson, Nolan, & Sandell, 2005). Given the costs of T, researchers have hypothesized that individuals should limit T expression to the times it is most advantageous, such as when potential sexual partners are present (Muehlenbein, 2006; Wingfield et al., 2001).

Several functions of T may be especially useful in sexual contexts, though there is debate about whether ΔT is adaptive and if so, what its specific functions are. In addition to promoting intrasexual competition for partners, hypothesized functions for ΔT include supporting physiological responses involved in sexual behavior, reducing anxiety and encouraging exploration, signaling quality to potential partners, and reinforcing associations between sexual activity and relevant contextual cues (Gleason, Fuxjager, Oyegbile, & Marler, 2009; Nyby, 2008; van Anders & Watson, 2006). However, these potential benefits must be balanced with costs of elevated T, so it follows that ΔT should not occur with equal magnitude to every sexual event and instead should be sensitive to specific parameters of the encounter. For example, ΔT should

be responsive to cues that indicate the likelihood of a successful sexual encounter, such as the behavior and characteristics of a partner, the types of sensory stimuli present, or the presence of potential competitors. If partner compatibility is low or several higher-ranking competitors are present, mounting a T response could sacrifice energetic resources with little chance of benefit. Secondly, ΔT should not occur (or at least should be less pronounced) when individuals are less equipped to handle the costs of elevated T, e.g., when energetic or immune resources are already depleted, or when an individual is currently pair bonded or parenting and inhibitory effects of T on nurturance could be costly. However, this prediction is complicated by the fact that maintaining lower baseline T and transiently elevating T in response to sexual or other social stimuli could be one successful strategy for offsetting T's energetic or behavioral costs (Wingfield et al., 2001). Thus, effects are likely nuanced such that the severity of an energy deficit or the stage of parenting could influence the extent to which even a short-term T response is costly.

Finally, given that sexual encounters can serve many functions (e.g., expression of dominance vs. pair bond maintenance), ΔT should be most pronounced when its downstream effects would be most advantageous. Some potential effects of ΔT, like decreased anxiety, might be especially beneficial in novel sexual situations or with new partners but unnecessary when sexuality occurs within an established pair bond (Gleason et al., 2009). Other effects, like T's rewarding properties, might be beneficial in a variety of sexual contexts; T could enhance the reward value of a particular location or a particular partner (Gleason et al., 2009). An important first step to elucidating the potentially context-dependent functions of ΔT is to characterize the types of sexual experiences that elicit this response.

Comparative Perspectives on Sexual Modulation of T: Insights for Humans

Sexual Modulation of T Is Highly Sensitive to Social Context in Primates

Anthropoid primates, including humans, are unique in that females' physical capacity to mate is decoupled from periods of fertility (Wallen & Zehr, 2004). Because of this, sexual behavior is especially sensitive to social context and likely to serve functions besides reproduction, such as alliance formation or affiliation (Wallen & Zehr, 2004). Diverse social roles for sexuality in female and male primates suggest that social context may regulate how sexual behavior affects T, so I focus particularly on how factors such as aggression, competition, pair bonding, and parenting affect sexual modulation of T in both longer-term contexts (e.g., links between T and sexual behavior patterns across seasons) and acute contexts (i.e., T responses to discrete sexual events).

Sexual stimuli and behavior acutely affect T in nuanced ways in humans. Acute T responses to different modalities of sexual stimuli have been examined more extensively in humans than in other primates; as a whole, this research indicates that while humans' T can respond to very subtle sexual cues, T does not respond to sexual stimuli or behavior in every context (for the physiological cascade of events leading to ΔT in humans, see Figure 1.1).
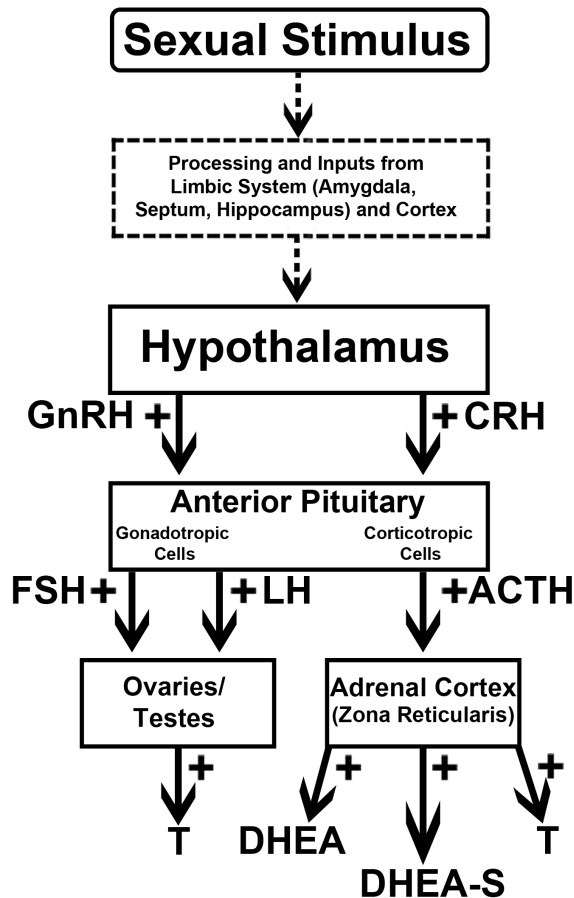
Figure 1.1. *Sexuality-to-Testosterone Cascade: The Neural Processing of Sexual Stimuli That Leads to Androgen Release in Humans.* The adrenal cortex is likely to be a larger contributor to sexually-modulated testosterone (ΔT) in women, whereas the gonads are likely larger contributors to ΔT in men. An important role for upstream releasers like kisspeptin and neurokinin B in stimulating GnRH release has been established in non-human animals (Navarro, 2012), but these releasers are less well understood in humans (Chan, 2013). Given the rapidity of ΔT in some contexts, mechanisms besides the hypothalamic-pituitary-gonadal or hypothalamic-pituitary-adrenal axes (e.g., changes in concentrations of binding proteins) may also contribute to ΔT (Flinn, Ponzi, & Muehlenbein, 2012). Abbreviations: GnRH = Gonadotropin-releasing hormone; FSH = Follicle-stimulating hormone; LH = Luteinizing hormone; CRH = Corticotropin-releasing hormone; ACTH = Adrenocorticotropic hormone; DHEA = Dehydroepiandrosterone; DHEA-S = Dehydroepiandrosterone sulfate.

Sexual thoughts in the absence of sensory stimuli are sufficient to increase T in women (Goldey & van Anders, 2011). In men, sexual thoughts do not increase T overall (Goldey & van Anders, 2012b), but the content of thoughts is linked with T responses, such that lower inclusion of nurturant content (i.e., related to warm, loving aspects of sexuality) predicts higher ΔT

(Goldey et al., 2014). Consistent with effects of sexual thoughts on T, women's T increases in anticipation of sex (Hamilton & Meston, 2010; van Anders, Brotto, Farrell, & Yule, 2009), and a classic study involving a single male subject suggests men's T may do so as well (Anonymous, 1970). Multiple studies have shown that viewing erotic films increases T in men (Hellhammer, Hubert, & Schurmeyer, 1985; Pirke, Kockott, & Dittmar, 1974; Redoute et al., 2000; Stoleru, Ennaji, Cournot, & Spira, 1993; Stoleru et al., 1999) (cf. Carani et al., 1990; Rowland et al., 1987), but three studies have found that erotic films do not significantly change T in women (Hamilton, Fogle, & Meston, 2008; Heiman, Rowland, Hatch, & Gladue, 1991; van Anders et al., 2009), though means are in the expected directions with large between-subjects variability (Hamilton et al., 2008; van Anders et al., 2009). Overall, sexual cues in the absence of behavior can affect T in women and men, though effects of thoughts on T are stronger for women and effects of visual stimuli stronger for men.

What about ΔT in response to sexual *behavior* in humans? Partnered (i.e., dyadic) sexual activity (defined as intercourse in most studies) increases T in women, with mixed results in men (Dabbs & Mohammed, 1992; Escasa, Casey, & Gray, 2011; Fox, Ismail, Love, Kirkham, & Loraine, 1972; Hirschenhauser, Frigerio, Grammer, & Magnusson, 2002; Kraemer et al., 1976; Lee, Jaffe, & Midgley, 1974; Sagarin, Cutler, Cutler, Lawler-Sagarin, & Matuszewich, 2009; Stearns, Winter, & Faiman, 1973; Strom, Ingberg, Druvefors, Theodorsson, & Theodorsson, 2012; van Anders, Hamilton, Schmidt, & Watson, 2007). Whereas women's T increases rapidly (within 15 minutes) after sexual activity (van Anders, Hamilton, Schmidt et al., 2007) and returns to baseline levels by the following morning (Prasad et al., 2014; van Anders, Hamilton, Schmidt et al., 2007), two studies suggest that men's T may respond to sexual activity at a delay (e.g., the morning after the activity) (Hirschenhauser et al., 2002; Kraemer et al., 1976). A

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delayed response in men is consistent with findings in captive male rhesus monkeys, where T responses to sexual activity are most evident after at least 24 hours (Bernstein, Rose, & Gordon, 1977; Phoenix, Dixson, & Resko, 1977). In men, ΔT also seems more likely to occur following sexual interactions that could be perceived as especially salient or competitive, such as interactions with unfamiliar or multiple partners or at a sex club (Escasa et al., 2011; Hirschenhauser et al., 2002). In these interactions, ΔT could function to alleviate anxiety that might occur with an unfamiliar partner or location. Taken together, findings suggest rapid T responses to partnered sexual behavior in women, but context-dependent, delayed, or no T responses in men.

Addressing the question of whether partner presence is necessary for T responses to sexual behavior, solitary masturbation produces a marginally significant increase in T in women (i.e., at $p = 0.05$) (Exton et al., 1999), whereas most studies find that masturbation does not significantly change men's T (Exton et al., 2001; Fox et al., 1972; Kruger et al., 1998, 2003; Strom et al., 2012; Stárka, Hill, Havlíková, Kancheva, & Sobotka, 2006) (cf. Purvis, Landgren, Cekan, & Diczfalusy, 1976). Masturbation may also be linked with 'trait' or baseline T in women, such that women with higher T report more frequent solitary orgasms (van Anders, Hamilton, Schmidt et al., 2007). However, directionality of this association (whether masturbation leads to higher T or vice versa) is unclear. Additionally, research to date has neglected whether T responses to solitary masturbation, like those to partnered sexual behavior, are at all context-dependent (cf. van Anders & Dunn, 2009). For example, is ΔT to solitary masturbation linked with fantasy content, experiences of pleasure during masturbation, or motivations for masturbation?

How might we make sense of the overall pattern of findings on acute T responses to sexual stimuli and behavior in humans? Why would sexual thoughts increase women's T when visual stimuli do not, and why would sexual behavior have inconsistent effects on men's T if visual stimuli are sufficient for ΔT? It may be that the same stimulus modality can have different effects on T depending on context. van Anders (2013) predicted that sexual contexts oriented around genital/erotic pleasure, power, or jealousy will increase T, whereas sexual contexts oriented around nurturance (e.g., closeness, pair bonding) will decrease T. For example, perhaps viewing erotic films typically involves more erotic pleasure and positive affect for men than women, given different past histories and socialization experiences around pornography (van Anders, 2013). Would women's (and men's) affective responses to visual sexual stimuli predict their T responses? Addressing this question would help dissociate the roles of stimulus modality and affect in eliciting ΔT.

An additional factor relevant to gender/sex differences in ΔT by stimulus modality is differences in basal T levels between women and men. Average baseline T levels for men are about three times the average for women (e.g., van Anders, Hampson, & Watson, 2006), and men's baseline T values also show larger between-person differences, with a range nearly four times that of women's (Schudson & van Anders, unpublished data). In women, T shows moderate variation across the ovarian cycle, with a gradual increase during the follicular phase, a peak around ovulation, and a gradual decrease during the luteal phase (reviewed in van Anders, Goldey, & Bell, 2014), although this variation is relatively small compared with individual differences (Dabbs & de La Rue, 1991). Given men's higher baseline levels of T relative to women's, it may be that social stimuli can more easily increase women's T (because there is more 'room' for T to increase) and more easily decrease men's T (van Anders, 2013; Goldey,

Avery, & van Anders, 2014). This physiological ceiling effect is an additional potential explanation for why some subtle sexual stimuli (e.g., sexual thoughts) have been shown to acutely increase T in women but not men. Additionally, because of women's lower baseline T levels, smaller absolute changes in T may be more meaningful for women in terms of downstream behavioral effects (Bancroft, 2002). Open questions remain about how acute T responses to sexual stimuli relate to baseline T levels: Do individuals with lower baseline T tend to show larger increases in response to social stimuli (see also Wingfield, Hegner, Dufty, & Ball, 1990 for similar predictions across species)? Or, can short-term increases in T accumulate over time and translate to *higher* baseline T, such that individuals who encounter erotic stimuli more frequently might have elevated baseline T relative to others? Overall, these findings and questions complicate distinctions between short-term changes in T and baseline T, and they suggest that baseline T is an important factor to consider when studying sexual modulation of T.

'Courtship' interactions modulate T in humans. A complementary literature addresses humans' T responses to stimuli from potential partners, rather than to explicitly sexual stimuli. Heterosexual men show rapid T responses to brief (5-15 minute) social interactions with unfamiliar women (Roney, Mahler, & Maestripieri, 2003; Roney, Lukaszewski, & Simmons, 2007; van der Meij, Buunk, van de Sande, & Salvador, 2008), and close physical contact (dancing) increases T in women and men (Murcia, Bongard, & Kreutz, 2009). Physical presence of potential mates does not seem necessary for this response, as exposure to pictures of other-sex faces increases T in heterosexual women and men (Zilioli, Caldbick, & Watson, 2014), and a simulated (videotaped) courtship interaction is sufficient to increase women's T (Lopez, Hay, & Conklin, 2009). Like ΔT to sexual stimuli and behaviors, these responses are not all-or-nothing and are sensitive to context. For example, men in a rural Dominican community had lower T

when interacting with a close friend's female partner than when interacting with an unpartnered woman or a woman in a relationship with someone who was not a close friend (Flinn et al., 2012). Given the importance of social alliances in humans, inhibition of neuroendocrine responses to close friends' mates could facilitate cooperation and limit competition between in-group members (Flinn et al., 2012).

Individual factors, including androgen receptor gene polymorphisms, baseline hormone concentrations, personality, and (inconsistently) sexual experience, also explain variation in men's ΔT to potential mates. Men with the greatest number of CAG repeats in the androgen receptor gene, indicative of the lowest androgen receptor activity, showed the smallest ΔT in response to a social interaction with a woman (Roney, Simmons, & Lukaszewski, 2010). Thus, androgen receptor activity may increase the sensitivity of neural circuits responsible for T release (Roney et al., 2010). Furthermore, men with higher baseline cortisol had lower ΔT (Roney et al., 2010), perhaps because higher baseline cortisol reflected an energy deficit (Peters et al., 2004) or chronic stress and thus lack of energetic resources to expend on pursuit of sexual activity. Finally, a more aggressive, dominant personality predicted higher ΔT (van der Meij et al., 2008), and one study found that ΔT only occurred in men with recent sexual experience (Roney et al., 2003), though three others did not replicate this finding (Roney et al., 2007, 2010; van der Meij et al., 2008). Together, these results suggest that ΔT to potential mates occurs most strongly in individuals for whom ΔT is more likely to translate into a behavioral response given personality and genetic factors, and/or those who are best prepared for costs of ΔT or sexual activity.

T responses to interactions with potential mates have been linked with behaviors relevant to courtship or sexual competition. For example, women's ΔT to simulated courtship interactions predicted higher sexual and romantic interest (Lopez et al., 2009). In men, higher ΔT predicted

more "show-off" or display behaviors (e.g., talking about oneself) in conversations with women in the laboratory (Roney et al., 2003, 2007) and increased risk-taking behavior in a naturalistic study (Ronay & von Hippel, 2010). It is unclear whether ΔT increases courtship behaviors or whether displaying more of these behaviors leads to higher ΔT. However, one recent study found that heterosexual men's T responses to competition predicted affiliative and display behaviors in a subsequent interaction with a woman, suggesting that changes in T can facilitate courtship behaviors (van der Meij, Almela, Buunk, Fawcett, & Salvador, 2012). Overall, these findings, together with those on ΔT to partnered sexual activity, reinforce the pattern that interactions perceived or experienced as competitive (as may occur when meeting a potential partner for the first time) lead to higher ΔT.

Aggression underlies some longer-term associations between sexuality and T in non-human primates. Paralleling findings that especially salient or competitive sexual interactions lead to the strongest short-term increases in men's T, research on male non-human primates suggests that intrasexual competition may underlie apparent links between T and sexuality in longer-term contexts. For example, male chacma baboons (*Papio hamadryas ursinus*) in consortships with females had higher T than non-consorting males, but this link was secondary to associations between T and dominance rank, which controls access to mates in this species (Beehner, Bergman, Cheney, Seyfarth, & Whitten, 2006). Sexual behavior did not predict T when controlling for aggression in male ring-tailed lemurs (*Lemur catta*) (Cavigelli & Pereira, 2000) and, in male black howlers (*Alouatta pigra*), T was linked with the potential for competition from extragroup males rather than with sexual behavior (Rangel-Negrin, Dias, Chavira, & Canales-Espinosa, 2011). In chimpanzees (*Pan troglodytes*), males' T increased in the presence of parous but not nulliparous receptive females; male chimpanzees copulate with

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both parous and nulliparous females but only parous females elicit male-male competition, suggesting that the rise in T is more closely coupled with sexual competition than sexual behavior itself (Muller & Wrangham, 2004). Finally, male muriquis (*Brachyteles arachnoides*), who show very low levels of aggression, did not show consistent parallels between T profiles and copulatory periods (Strier, Ziegler, & Wittwer, 1999; Strier, Lynch, & Ziegler, 2003). Together, these findings suggest links between males' T and sexual behavior, when they occur, may result from heightened intermale aggression during periods of female receptivity.

An interesting exception to the above pattern is the tufted capuchin monkey (*Cebus apella nigritus*). In capuchins, sexuality-related measures (consortships, copulation frequency, females in behavioral estrus, and days of sexual activity) positively predicted T in males, but rank and aggression-related measures did not (Lynch, Ziegler, & Strier, 2002). In this species, consortships are maintained by females, who actively solicit males with frequent approaches and withdrawals accompanied by vocalizations; males typically do not reciprocate with sexual behaviors until after some delay (Alfaro, 2005; Carosi & Visalberghi, 2002). Perhaps sexual stimuli are especially important for T in species where female proceptivity and mate choice, more so than male-male aggression, contribute to males' reproductive success (Lynch et al., 2002). Thus, in male primates, associations between sexuality and T may often be secondary to associations between aggression and T, but there are also some exceptions to this pattern.

In one of the few studies examining how fluctuations in T were linked with sexual behaviors in female non-human primates, Sannen and colleagues (2005) found nuanced associations between urinary T metabolites and specific sexual behaviors in female bonobos (*Pan paniscus*). In the long-term (i.e., across months), T was positively correlated with the frequency of female-female genitogenital rubbing, negatively correlated with the frequency of

sexual inspections, and uncorrelated with other sexual behaviors (e.g., copulation, masturbation). Unlike in the longer-term, T and sexual behaviors were not linked on a day-to-day basis. Although the factors underlying this specific pattern of associations are unclear, this study suggests that (a) some non-reproductive female sexual behaviors are associated with T, (b) sexual behavior is not always linked with higher T (and sometimes is linked with lower T), and (c) the pattern of T-sexuality associations may differ based on time course (e.g., days versus months). On the whole, research on longer-term links between sexuality and T in non-human primates points to an important role for aggression in males and nuanced results (including links with non-reproductive sexual behaviors) in females.

T responses to olfactory cues are contextually-situated in humans and non-human primates. Whereas the above studies examined sexual modulation of T over longer time-scales (e.g., seasons), a few have examined how more discrete sexual events affect T in non-human primates. Short-term (30 minutes to 2 hour) exposure to olfactory cues from ovulatory or pre-ovulatory females increased T in male common marmosets (Ziegler et al., 2005) and stumptailed macaques (*Macaca arctoides*) (Cerda-Molina et al., 2006). Some research suggests that olfactory cues may also affect androgens in humans. In one study, exposure to male axillary extract shortened the interval between luteinizing hormone (LH) pulses in heterosexual women (Preti, Wysocki, Barnhart, Sondheimer, & Leyden, 2003), but studies on the effects of women's ovulatory scents on men's T have yielded conflicting results (Cerda-Molina, Hernandez-Lopez, de la O, Chavira-Ramirez, & Mondragon-Ceballos, 2013; Miller & Maner, 2010; Roney & Simmons, 2012).

Responses to ovulatory cues are contextually situated in humans and non-human primates: in men, knowledge that the odors are from women seems to be important for ΔT

(Roney & Simmons, 2012), as does the specific source of the odors, with vulvar odors eliciting a longer-lasting effect on T than axillary odors (Cerda-Molina et al., 2013). Based on these results, Cerda-Molina and colleagues (2013) hypothesized that T responses to vulvar odors could mediate increased sexual interest in the partner performing cunnilingus in addition to the partner receiving it; this hypothesis underscores the importance of studying ΔT to sexual activities besides penis-vagina intercourse. For common marmosets, who are socially monogamous, ΔT to novel female odors depends on a male's pair bonding and parenting status, such that T increases in single males but not those currently parenting; pair bonded males not currently parenting show an intermediate T response (Ziegler et al., 2005). Thus, pair bonded males, especially father males, may inhibit their neuroendocrine arousal responses to sexual stimuli provided by any individuals except their own mate (Snowdon et al., 2006). Determining whether father males would respond to their *own* mates' cues with T increases would clarify whether pair bonding and parenting inhibit ΔT in general (perhaps to avoid any suppressive effects of T on nurturance), or simply make ΔT more selective, responding only to the mate's cues. All in all, findings on ΔT to olfactory cues highlight the importance of social context (e.g., pair bond or parenting status) in shaping ΔT.

Sexuality, pair bonding, and parenting may have interactive effects on T in humans. Pair bonding and parenting contexts may modulate how T is coupled with sexuality in humans as well. Hirschenhauser and colleagues (2002) found that bidirectional links between men's daily T levels and sexual activity were most pronounced in men who wanted children with their current female partner. Furthermore, these T-sexual activity patterns followed a monthly trajectory, suggesting that pair bonded men who desire children can respond hormonally and behaviorally to their partner's fertility status (Hirschenhauser et al., 2002). In a longitudinal study, Gettler et

al. (2013) found that men who reported more frequent sexual intercourse with their partners experienced less of a decline in T during the transition to pair bonding and parenthood. Men who did not form long-term pair bonds did not show similar T-sexual frequency links (Gettler et al., 2013). Accordingly, declines in men's sexual intercourse frequency may correspond to declines in T, but specifically for pair bonded and parenting men.

Sexual activity may underlie T-pair bonding links in women as well, but in a different manner: in one study, partnered women's more frequent dyadic sexual activity accounted for their lower T relative to single women (van Anders & Goldey, 2010). This finding suggests that dyadic sexual activity may predict *lower* baseline T in women, even as it acutely increases T. Some findings also suggest a potential role for masturbation in explaining single women's higher T, but effects are less clear than for dyadic sexual activity (van Anders & Watson, 2007; van Anders, Hamilton, Schmidt et al., 2007; van Anders & Goldey, 2010). Together, studies suggest a role for both solitary and dyadic sexual activity in regulating T-pair bonding links, though these findings need clarification in women. And, it is unclear how pair bonding status might moderate T-sexuality links in women (i.e., would solitary and dyadic sexuality be linked with T in the same ways in single and pair bonded women?). Finally, directionality of links between baseline T and solitary and dyadic sexual activity is an open question, given that T can promote sexual behavior *and* sexual behavior can change T.

Conclusion: Sexual modulation of T is highly sensitive to social context in primates. In humans and other primates, *what* the sexual stimulus is may be less important for T than the context in which it occurs. The extent to which sexual interactions are characterized by competition or are likely to elicit aggression or harassment affects links between sexuality and T, as does pair bonding or parenting status of the individuals involved. Dissociating the potential

additive and interactive contributions of solitary sexual behavior, dyadic sexual behavior, and pair bonding status to women's T profiles remains an important direction for research. Finally, internal sexual stimuli like thoughts or anticipation are sufficient to increase women's T, raising the question of how cognitive appraisals might modulate ΔT to external stimuli like visual sexual stimuli or dyadic sexual activity.

Cues From Sexual Partners Modulate T in Male and Female Birds

Hormone-behavior relationships are extensively studied in birds partly due to the diversity of their mating and social systems. Although 90% of bird species are socially monogamous, sexual monogamy is much rarer (Griffith, Owens, & Thuman, 2002), and polyandry, polygyny, polygynandry, and cooperative breeding are also present among birds. Research with birds in both captive and field environments is common, often within the same species, such that naturalistic observations of sexual behavior can be combined with more controlled laboratory investigations. Thus, definitions of 'sexual interactions' range from the relatively broad (e.g., presence and proximity of potential sexual partners; performance of courtship displays) to the very specific (e.g., cloacal contact and muscle activity; see Adkins-Regan & Leung, 2006) depending on study methods. An especially important consideration in birds is seasonality, such that sexual behavior – and T-behavior associations – are highly dependent on photoperiod (Wingfield et al.,1990).

Cues from females modulate T in males of some – but not all – bird species. In many species of birds, especially those living in temperate zones, males' T is higher during the breeding season than at other times of the year (Wingfield et al., 1990). The Challenge Hypothesis (Wingfield et al., 1990), which has guided much research on T and social behavior in birds and other vertebrates (Hirschenhauser & Oliveira, 2006), proposes that T levels above a

breeding season baseline are a function of male-male competition for territories or mates. However, because sexual interactions have received relatively less attention than male-male competition, it is less clear to what extent sexual cues and behavior contribute to elevated T. Males' T is generally elevated when their mates or other females in the population are fertile (Peters, Astheimer, & Cockburn, 2001; Wingfield et al., 1990); is the higher T in response to heightened mate guarding and aggressive interactions with other males, as seems to be the case in some primates, or to the sexual stimuli provided by females (Goymann, Landys, & Wingfield, 2007; Pinxten, de Ridder, & Eens, 2003)?

Several pieces of evidence suggest that female cues and behavior can shape males' T profiles. Females' solicitation behaviors regulated the transition from the higher-T courtship phase to the lower-T incubation phase in male white-crowned sparrows (*Zonotrichia leucophrys*) (Moore, 1982) and male ring doves (*Streptopelia risoria*) (O'Connell, Silver, Feder, & Reboulleau, 1981). Furthermore, male ring doves' T increased in response to pairing with a gonadally intact female but not an ovariectomized female (O'Connell, Reboulleau, Feder, & Silver, 1981). Although males' ΔT was not significantly correlated with either their own or their mates' courtship behaviors, only female behavior differed between the gonadally intact and ovariectomized conditions, suggesting female sexual behavior may contribute to ΔT more so than males' own behavior (O'Connell et al., 1981). In a more recent and parallel finding, male European starlings' (*Sturnus vulgaris*) T increased after brief exposure to a female compared to a control condition, even in a subset of males who showed no behavioral response to the female (Pinxten et al., 2003).

Several aspects of these findings in birds are analogous to those in humans and other primates. First, T changes and behavioral changes may not occur in concert, as evidenced by

findings in European starlings and capuchin monkeys that cues from a partner can elicit ΔT even in the absence of one's own behavioral responses (Lynch et al., 2002; Pinxten et al., 2003). In addition to the dissociation of ΔT and behavioral changes, evidence for whether ΔT is linked with changes in genital or psychological sexual arousal in humans is highly mixed; ΔT is not clearly correlated with changes in arousal (Carani et al., 1990; Goldey & van Anders, 2011, 2012b; Heiman et al., 1991; Pirke et al., 1974; Rowland et al., 1987; Stoleru et al., 1993; van Anders et al., 2009). Finally, in both biparental birds and humans, sexual behavior offsets a decline in males' T when parenting (Gettler et al., 2013; Moore, 1982; O'Connell et al., 1981), implying a role for T-sexuality links in coordinating the transition from earlier stages of a pair bond to parenting.

In birds, the importance of female behavior in eliciting males' ΔT suggests hormone responses could function to coordinate the timing of reproduction within pairs (Moore, 1983; O'Connell, Silver et al., 1981; Pinxten et al., 2003). This coordination could be especially crucial for biparental species that tend toward social monogamy, like white-crowned sparrows, ring doves, and European starlings (though male European starlings are facultatively polygynous (Sandell, Smith, & Bruun, 1996)). Importantly, not all male birds show ΔT. Sexual interactions with females did not increase T in male Japanese quail (*Coturnix japonica*) (Delville, Sulon, Hendrick, & Balthazart, 1984; Meddle et al., 1997), and housing with females had little to no effect on T in male brown-headed cowbirds (*Molothrus ater*) (Dufty & Wingfield, 1986) or Willow ptarmigan (*Lagopus lagopus lagopus*) (Stokkan & Sharp, 1980). That males of these species, which are non-paternal, highly aggressive, and/or tend toward polygyny, failed to show ΔT is consistent with predictions of the Challenge Hypothesis, such that T may be already maximally elevated in these species and thus less malleable in response to social challenges

(Wingfield et al., 1990). On the whole, research with male birds thus far suggests an important role for species' life-history factors (mating, social, and parenting systems) and a partner's behavior in determining ΔT.

ΔT is sensitive to partner quality in female birds. Though studies on ΔT in male birds certainly outnumber those in females, research with birds has been key to elucidating the evolved role of T in females (Ketterson et al., 2005). As in males, cues from a partner are important for ΔT in females. Female canaries (*Serinus canaria*) show higher androgen responses to male song experimentally manipulated to be "attractive" compared to less attractive song (Marshall, Leisler, Catchpole, & Schwabl, 2005). Notably, auditory cues are important for males' T responses as well, such that deafening male ring doves blocks their T response to females (O'Connell et al., 1981). Although female European starlings do not show T responses to interactions with males, they do show LH responses, especially when paired with a male who has previously won a territorial contest (Gwinner, Van't Hof, & Zeman, 2002). Interestingly, for males in this study, the strongest predictor of T responses was the presence of nest boxes, which may elicit T release because of their association with sexual or agonistic encounters (Gwinner et al., 2002).

In female Japanese quail, characteristics of a partner and the sexual interaction itself drive T responses. Overall, female quails' T did not differ significantly from baseline to five minutes post-mating, although the means were in the expected direction, with higher T post-mating (Correa, Horan, Johnson, & Adkins-Regan, 2011). However, females who experienced more mounts or were mated to males in better body condition had higher ΔT, and in turn, post-mating T predicted parameters relevant to maternal investment, specifically offspring sex ratio and the proportion of fertilized eggs (Correa et al., 2011). Especially in a species like Japanese quail,

where males can force copulation, sensitivity of hormone responses to parameters of the sexual interaction would allow females to adjust their parental investment post-copulation and minimize costs of mating with unattractive males (Correa et al., 2011).

Overall, there is clear evidence that androgens respond to traits that signal partner quality or attractiveness in female birds (e.g., 'sexy' song, dominance, body condition), raising questions of whether this might reflect a broader pattern across taxa. If partner quality is important for ΔT, could this be why women show T responses to sexual thoughts and partnered sexual activity, but not visual sexual stimuli? Studies of women's T responses to visual sexual stimuli have used pornographic films chosen by researchers, so the actors in the films may rarely match participants' individual preferences for attractiveness. Testing whether women would show ΔT to erotic films they chose *themselves* would address the role of individual preferences in ΔT. Alternatively, pornography may not contain any true cues to partner quality *at all*, given that the stereotyped and scripted nature of the interactions prohibits any evaluation of an individual's behavior. Perhaps even *imagining* a self-defined attractive partner, as in the sexual thoughts study (Goldey & van Anders, 2011), is a stronger stimulus for women's T than *watching* sexual interactions between unknown actors who are highly unlikely to ever be potential partners. In support of the hypothesis that cues to partner quality predict ΔT, heterosexual women's T responses to films of 'courtship' interactions were positively correlated with their ratings of the physical and behavioral attractiveness of the man in the film (Lopez et al., 2009). Thus, findings from research with birds suggest novel insights about the potential role of cues to partner quality in women's T responses.

Sexual Interactions Modulate T and Other Androgens in Fish

Like birds, teleost fish, and especially cichlid fish, are model organisms for studying hormone-behavior relationships due to the diversity of mating and parenting systems across species (Oliveira, 2009). Furthermore, many species of fish show extreme plasticity of behavior (e.g., sex-changing) in response to environmental cues (Oliveira, 2009). Most teleost species fertilize externally, and teleosts display distinct patterns of courtship behavior that vary across species but often include color changes, pheromone release, vocalizations, or motor patterns (Gonçalves & Oliveira, 2010). Although courtship displays are more commonly performed by males, in some species, particularly those with high paternal investment, females display to compete for males (reviewed in Gonçalves & Oliveira, 2010). Courtship displays typically culminate in the release of eggs and sperm, or spawning. Like displays, methods of spawning vary between species but may involve behaviors such as body quivering or tail flipping (to mix eggs and sperm) (reviewed in Gonçalves & Oliveira, 2010; Munakata & Kobayashi, 2010).

Research with teleost fish has been essential in demonstrating that androgens are responsive to sexual behavior. This work has focused on both T and 11-ketotestosterone (11-KT), which is considered the most active androgen in male teleosts (Borg, 1994). Whereas T levels are generally similar between females and males, 11-KT is typically higher in males (Borg, 1994). 11-KT increases in response to female cues, courtship interactions, or spawning in males of some cichlids, but T responds less consistently (Hirschenhauser, Taborsky, Oliveira, Canàrio, & Oliveira, 2004; Kidd et al., 2013; O'Connell, Rigney, Dykstra, & Hofmann, 2013; Sessa, Harris, & Hofmann, 2013). Some of the few studies with females have shown elevated T prior to and during spawning in gilthead seabream (*Sparus aurata*) (Jerez, Rodriguez, Cejas, Bolanos, & Lorenzo, 2006) and a peak in T four days prior to spawning in African cichlids

(*Astatotilapia burtoni*) (Kidd et al., 2013). In female rainbow trout (*Salmo gairdneri*), an increase in T clearly precedes ovulation and spawning, but whether a male is present seems to have little effect on T in ovulating females (Liley, Fostier, Breton, & Tan, 1986). Although T shows fluctuations linked with reproductive cycles in female fish, the extent to which females' T is responsive to sexual cues remains open, but important; this research could highlight whether females' T might respond to cues indicative of partner quality in taxa besides birds, or if other factors are more essential for ΔT in female fish.

Beyond providing evidence that sexual modulation of androgens occurs, work with teleosts demonstrates nuances in androgen responses to sexual stimuli. Specifically, androgen responses vary based on the social context immediately prior to the sexual encounter and the types of sensory stimuli present during the encounter. After a period of social isolation, exposure to a female increased 11-KT in male *Oreochromis mossambicus* (Hirschenhauser et al., 2004). In contrast, exposure to females *decreased* T and 11-KT after males of the same species spent several days in all-male groups (Oliveira, Almada, & Canario, 1996). These findings raise the question of what represents a meaningful 'baseline' to compare with responses to sexual stimuli. In a non-laboratory environment, sexual interactions are likely preceded by a number of other affiliative or agonistic interactions, and it follows that if androgens are already elevated (e.g., because of territorial conflicts), sexual encounters may not increase them further, or could actually elicit an apparent decrease in androgens. Stimuli during the sexual interaction are also important: in male African cichlids, visual sexual cues alone increased T whereas chemical cues alone did not (O'Connell et al., 2013). This may be a function of species-specific breeding systems, such that visual cues are a stronger stimulus for androgens because chemical cues from receptive females are always present in natural environments for this continuously breeding

species (O'Connell et al., 2013). Therefore, the social and environmental context both prior to and during the sexual encounter is important for how sexuality modulates androgens in teleost fish.

In sum, research with teleost fish echoes findings from other taxa that while androgens are highly responsive to sexual stimuli, the species-specific environmental context of the sexual interaction modulates androgen responses. Future research is needed to characterize androgen responses to sexual interactions in female fish, and the diversity of sexual behaviors and social systems among teleosts (e.g., female vs. male-initiated courtship; maternal vs. paternal vs. biparental care) provides an ample base to explore predictors of androgen responses in females. Although few studies have examined androgen responses to sexual stimuli in females, research in fish and birds is suggestive that ΔT may be conserved across species in females as well as males.

Sexual Modulation of T in Rodents Highlights the Importance of Learning and Experience

Sexually-stimulated T responses have been extensively investigated in laboratory paradigms with rodents (see Gleason et al., 2009 and Nyby, 2008 for reviews), though research on ΔT in rodents has exclusively focused on males. Male house mice (*Mus musculus*) and rats (*Rattus norvegicus*) show a spike in LH followed by a rise in T shortly after encountering a novel female and again following ejaculation (Gleason et al., 2009; Nyby, 2008). Tactile contact is not required for ΔT, as males show LH and/or T responses when separated from a receptive female by a partition (Amstislavskaya & Khrapova, 2002; Amstislavskaya & Popova, 2004; Amstislavskaya, Bulygina, Tikhonova, & Maslova, 2013; Bonilla-Jaime, Vazquez-Palacios, Arteaga-Silva, & Retana-Marquez, 2006) and even to female urine alone (Clancy, Singer, Macrides, Bronson, & Agosta, 1988; Coquelin & Bronson, 1980; James, Nyby, & Saviolakis,

2006). These findings raise the question of whether pheromones – which are present in all of these situations – are the primary stimulus driving ΔT in male mice and rats. However, while removal of the vomeronasal organ in male mice blocked LH responses to female *urine*, LH still responded to an interaction with a female, suggesting that visual and/or auditory components of female behavior can compensate for the lack of pheromonal stimuli (Coquelin, Clancy, Macrides, Noble, & Gorski, 1984). Thus, pheromonal stimuli may be sufficient but not necessary for ΔT in male rodents (see also Nyby, 2008).

Social cues and prior experiences modulate ΔT in male rats and house mice. Previous sexual experience potentiates ΔT in male rats (Bonilla-Jaime et al., 2006; Kamel, Mock, Wright, & Frankel, 1975; Kamel, Wright, Mock, & Frankel, 1977), and – consistent with findings that *anticipating* sexual activity increases T in humans (Anonymous, 1970; Hamilton & Meston, 2010; van Anders et al., 2009) – male rats' T also responds to initially neutral stimuli associated with sexual encounters (e.g., a testing arena, a neutral odor) (Graham & Desjardins, 1980; Kamel et al., 1975). A novel female is a stronger stimulus for androgens than a female the male has interacted with previously (Coquelin & Bronson, 1979), but the importance of the female's sexual receptivity is less clear (Amstislavskaya & Popova, 2004; Bonilla-Jaime et al., 2006; Coquelin & Bronson, 1979, 1980). Finally, cues from conspecific males can also modulate ΔT. The presence of other males' urine completely suppresses LH responses to female urine in male mice (Clancy et al., 1988), suggesting that competitors may be able to block each others' hormonal responses. Missing from the current picture is whether this effect is moderated by rank or social status; for example, might an individual still mount a T response in the presence of a competitor of a lower rank, but not when an individual of higher rank is present?

Studies with rodent species other than house mice and rats, while less numerous, have provided insights about the role of ΔT in species with varied mating systems. In the monogamous, biparental California mouse (*Peromyscus californicus*), males' T following a one-hour courtship interaction (which included behaviors like following, sniffing, wrestling, and chasing, but not copulation) was higher on average than T while parenting, but not significantly different from a baseline (pre-courtship) T measure (Gleason & Marler, 2010). However, males' T responses to courtship were highly variable -- 53% of males showed a *decrease* in T in response to courtship, while the remaining 47% showed an increase – and this variation predicted paternal quality, such that males with a higher ΔT later displayed reduced latency to approach pups and increased huddling (Gleason & Marler, 2010). In a follow-up study, the authors investigated whether female California mice might use males' ΔT as a signal to choose mates who provide better quality paternal care. Unexpectedly, males' ΔT did not predict either female preference or reproductive success; instead, results suggested that biological or behavioral compatibility of the pair might be a better predictor of reproductive success in this biparental species (Gleason, Holschbach, & Marler, 2012). However, like findings in birds and primates, these results point to a role for T in both sexual/courtship and parental interactions.

As a whole, research with rodent models has greatly contributed to knowledge of the specific sensory cues required for ΔT and how previous experience modulates ΔT. In particular, this research demonstrates the sensitivity of ΔT to subtle cues (e.g., initially neutral stimuli associated with sexual encounters) and points to some parallels between rodents and humans (e.g., stronger ΔT to novel partners; substantial variability in ΔT).

What Drives Sexual Modulation of T?

The studies reviewed demonstrate broad evidence for sexual modulation of androgens across fish, birds, rodents, and primates, despite the diversity of sexual behaviors between and within these taxa. Clearly, T does not just affect sexual behavior, but responds dynamically to sexual contexts, and this response appears to be conserved across at least some vertebrate taxa. However, in addition to the pervasiveness of sexual modulation of T, my review also highlights its variability. ΔT does not occur to the same degree in every species, individual, or sexual situation. And, some sexual situations can *decrease* T in some individuals, counter to common assumptions about associations between sexuality and T. What factors account for this variability? That is, what factors predict whether and to what magnitude ΔT will occur?

The Case for Sexual or Courtship Behavior

Although sexual and courtship behaviors increase T across many of the species reviewed, evidence that overt behavior is required for ΔT is relatively limited. In primates, birds, fish, and rodents, T responds to sexual cues in the absence of sexual behavior, including (depending on the species) visual cues, olfactory cues, auditory cues, and cognitions. Initially neutral cues previously paired with sexual activity can increase androgens (Graham & Desjardins, 1980; Gwinner et al., 2002; Kamel et al., 1975), and ΔT can occur in response to a partner's solicitations in the absence of any behavioral response (Lynch et al., 2002; Pinxten et al., 2003). In one of the few findings linking ΔT to overt courtship behavior, men's ΔT was positively correlated with their display behaviors to potential mates, but it is unclear whether display behaviors elicited higher ΔT or vice versa (Roney et al., 2003, 2007). And, ΔT can also occur to cues from potential mates in the absence of an opportunity for behavioral response (Lopez et al., 2009; Zilioli et al., 2014). Importantly, some research does suggest that ΔT is stronger when

participating in than when viewing sexual activity (Escasa et al., 2011), such that there may be additive effects of sexual behavior and cues on T. As a whole, however, research indicates that sexual cues in the absence of behavioral responses are often sufficient to elicit ΔT, and this is consistent with research showing that viewing a competitive interaction without participating is sufficient to increase androgens (reviewed in Oliveira, 2009).

The Case for Specific Sensory Modalities

If overt behavior is not required for ΔT, do specific sensory cues drive this response? On one hand, some findings suggest that particular sensory modalities may be required for ΔT (or have stronger effects on T than other sensory modalities) in species-specific ways. For example, deafening male ring doves blocks ΔT (O'Connell et al., 1981), and visual cues, but not chemical cues, elicit ΔT in male African cichlids (O'Connell et al., 2013). There may also be nuances by gender/sex in the effects of different sensory modalities on ΔT, as visual sexual stimuli seem to elicit ΔT more strongly in men than in women (Hamilton et al., 2008; Heiman et al., 1991; Hellhammer et al., 1985; Pirke et al., 1974; Redoute et al., 2000; Stoleru et al., 1993, 1999; van Anders et al., 2009).

On the other hand, findings across taxa indicate that ΔT is not exclusively a function of the modalities of sensory stimuli present. The *same* stimulus modality can elicit different androgen responses based on factors such as stimulus attractiveness (for female birds: Marshall et al., 2005) and social housing conditions (for male marmosets and cichlid fish: Hirschenhauser et al., 2004; Oliveira et al., 1996; Ziegler et al., 2005). In men, olfactory cues only increase T when coupled with the knowledge that the stimuli come from women, suggesting a role for cognitions in this response (Roney & Simmons, 2012). In a similar vein, it is unknown whether women's and men's different patterns of T response to visual sexual stimuli are truly a

consequence of stimulus modality or of gender-specific socialization experiences with

pornography (van Anders, 2013). Finally, it seems that ΔT can compensate for the absence of

some sensory cues when others are present. For example, although pheromones are a reliable

stimulus for ΔT in rodents, other cues can still elicit ΔT if the ability to detect pheromones is

blocked (Coquelin et al., 1984). Thus, although some sensory modalities may have stronger

effects on ΔT than others in species- and gender/sex-specific ways, the effects of sensory

modalities on ΔT are clearly context-dependent.

The Case for Social Context

The above synthesis suggests that ΔT is not simply a function of either overt behavior or

specific sensory modalities, but rather of the broader social context surrounding a sexual

interaction. Findings across species suggest several overarching patterns in the ways social

context modulates ΔT. First, sexual contexts are most likely to increase T when they signal that

competition for sexual partners is likely to occur. For example, only the presence of parous

females, who elicit male-male competition, increases T in male chimpanzees (Muller &

Wrangham, 2004). Similarly, dyadic sexual behavior is especially likely to increase T in men in

situations that could be perceived or experienced as competitive (e.g., with unfamiliar or multiple

partners, at a sex club: Escasa et al., 2011; Hirschenhauser et al., 2002). Competition can also

modulate ΔT in more nuanced ways: sexual interactions preceded by competition may decrease

T in fish, potentially due to ceiling effects on T (Hirschenhauser et al., 2004; Oliveira et al.,

1996). Finally, ΔT may be suppressed at times when competition would be costly, as shown in

men when in the presence of close friends' mates (Flinn et al., 2012).

In species that form pair bonds, a second important factor that predicts ΔT is an

individual's current pair bond or parenting status. Although partner novelty generally increases

ΔT, ΔT to novel partner cues is inhibited in pair bonded and parenting male marmosets (Ziegler et al., 2005). More generally, findings suggest a role for ΔT in coordinating transitions from earlier stages of a pair bond to parenting and in underlying pair bonding-T links (Gettler et al., 2013; Moore, 1982; O'Connell et al., 1981; van Anders & Goldey, 2010). Additionally, cues that predict partner quality appear important for ΔT in females specifically, and in female birds, ΔT may modulate parental investment (Correa et al., 2011; Gwinner et al., 2002; Lopez et al., 2009; Marshall et al., 2005).

In humans especially, 'social context' may be expanded to include internal processes like cognitions and perceptions in addition to external elements of the social environment. Sexual cognitions are sufficient to increase T in women, as is sexual anticipation in women and perhaps in men (Anonymous, 1970; Goldey & van Anders, 2011; Hamilton & Meston, 2010; van Anders et al., 2009). More ambiguous is how cognitions and perceptions modulate ΔT to external stimuli, though some findings are suggestive – conscious desire for children has been shown to increase the strength of T-sexual behavior links in pair bonded men (Hirschenhauser et al., 2002), and knowledge that the stimuli are from women seems necessary for men's ΔT to olfactory cues (Roney & Simmons, 2012). There is some evidence that 'perceptions' can influence social modulation of androgens in non-human species as well – male cichlid fish do not show an androgen response to competition when they have no information on their chance of winning, despite engaging in fighting behaviors (Oliveira, Carneiro, & Canario, 2005). Although cognitions and perceptions are likely important for ΔT across species, an advantage of studying humans is the ability to *ask* participants about their thoughts and feelings directly. In sum, considering not only the external social context but also the 'internal context', encompassing how an event is experienced cognitively, perceptually, and affectively, could yield a more

complete understanding of when and why sexual stimuli affect T, and this approach may be especially fruitful in humans.

The ability to adjust ΔT based on internal and external context, rather than mounting ΔT automatically in response to particular sensory modalities or behaviors, may help individuals adaptively fine-tune their T expression and behavior in accordance with the costs and benefits of T and of a given sexual situation. For example, sensitivity of ΔT to partner quality in females could modulate the reward value of specific partners and the likelihood of engaging in (or repeating) sexual activity with that partner. Inhibiting ΔT to novel sexual cues could be adaptive for pair bonded individuals in species where extra-pair mating decreases fitness. In general, factors such as prior experiences with a specific partner, presence of competitors, location, or cognitive appraisals of a situation may be more accurate predictors than sensory stimulus modalities of whether pursuing a sexual encounter will be costly or beneficial, and thus whether a T response is worthwhile.

Gaps in Research on Sexual Modulation of T (and Bidirectional Sexuality-T Links)

Research on sexual modulation of T to date demonstrates the malleability of androgens in response to the social environment. Not only does sexuality modulate T, but social context in turn modulates the extent of sexuality's effect on T, over and above effects of specific sensory modalities or behaviors. Although the importance of social context in sexual modulation of T is clear, open questions remain about how the *internal* context shapes T responses, and women and non-human females are especially understudied in research on ΔT. Below, I outline four major gaps in research on sexual modulation of T that I address in my dissertation research.

How Does Sexuality Modulate T in Women?

As evidenced by the above review, sexual modulation of T is understudied in women, and data are even more severely lacking in non-human females. This gap is especially surprising given findings from our lab showing that experimental manipulations inducing sexual arousal or competitive feelings increase T *more* strongly in women than in men, perhaps because women's lower baseline T has more room to respond to social stimuli (Goldey & van Anders, 2011, 2012b; Ritchie & van Anders, 2015; van Anders, 2013). Research suggests that the overarching social role of T is similar in women and men, with some nuances by gender/sex in how T responds to social context (van Anders et al., 2011; van Anders, 2013). Therefore, including women in research on sexual modulation of T can address questions about the social role of T across genders/sexes as well as gender/sex-specificities (e.g., how might gender-specific socialization experiences constrain women's T responses to erotic films?).

How Do Pair Bonding and Sexuality Interact to Shape T Profiles?

Findings across species indicate that sexuality does not exist in isolation in terms of its effects on T, but interacts with other social contexts like competition, aggression, pair bonding, and parenting. Interactive effects of sexuality and pair bonding on T are especially interesting in light of the 'intimacy paradox': sexual activity facilitates pair bond formation and maintenance, yet sexual activity acutely increases T, which inhibits nurturance (van Anders et al., 2011). How can sexual activity increase T but also facilitate nurturance within pair bonds?

One resolution to the intimacy paradox involves differential effects of sexual activity on T and peptides: sexual activity increases oxytocin in addition to T, and the faciliatory effects of oxytocin on nurturance could offset inhibitory effects of T (van Anders et al., 2011). However, a complementary resolution to the intimacy paradox lies in the potential for differential effects of

dyadic sexual activity on T in the short-term and long-term. In women, even as dyadic sexual activity acutely increases T, research links more frequent dyadic sexual activity to lower baseline T. In fact, one study showed that pair bonded women's lower baseline T relative to single women was mediated by pair bonded women's more frequent dyadic sexual activity (van Anders & Goldey, 2010).

Although these findings are suggestive, past research on dyadic sexual activity and T has been cross-sectional, so it is unknown whether within-person fluctuations in dyadic sexual activity actually correspond to within-person fluctuations in T (i.e., does an individual woman have lower T during periods of dyadic activity than during periods of abstinence?). Addressing this question is crucial to understanding how dyadic sexual activity may contribute to lower baseline T among women even as it acutely increases T, and thus to understanding the role of sexual intimacy in facilitating pair bonds.

How Is Solitary Sexuality Linked With T?

Solitary sexual behaviors, or those that occur in the absence of a partner (e.g., solo masturbation or fantasy), have received relatively limited attention in research on sexual modulation of T and in sexuality research in general (Tiefer, 1998; van Anders, 2013). An exception is solitary viewing of visual sexual stimuli, which is commonly used as a paradigm for studying ΔT in humans – though viewing erotic films is often implicitly treated as a proxy for dyadic sexual activity (e.g., to isolate the role of visual cues in ΔT to dyadic activity). The idea that erotic films are a valid proxy for dyadic sexual activity persists even though pornography is unlikely to contain realistic depictions of sexual partners or situations (such that participants may not be able to imagine the actors as potential partners) and despite research showing that the mere presence of a partner changes women's genital and self-reported arousal to erotic films

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(van Anders, 2013; van Lankveld et al., 2014). Solitary contexts besides viewing erotica, like masturbation and fantasy, are less frequently studied in terms of their links with T, especially in women.

Because masturbation is non-reproductive, it may thus be deemed irrelevant for research conducted from an evolutionary or comparative perspective (van Anders, 2013). Yet, all behaviors, even those that are functionless by-products of adaptations, can be considered in terms of their evolutionary history (Vasey & Sommer, 2006). Masturbation is not a human-specific phenomenon; it has been observed in a number of non-human primate species and among both captive and wild populations (Dixson, 2012). Although masturbation has been observed in males of a wider variety of species, its occurrence has been reported in females of several primate species (e.g., Japanese macaques, *Macaca fuscata*; stumptail macaques, *Macaca arctiodes*; olive baboons, *Papio anubis*; chimpanzees, *Pan troglodytes*; orangutans, *Pongo* spp.; see Dixson, 2012).

Popular conceptions depict solitary and dyadic sexuality as different manifestations of the same underlying phenomenon, such that an individual has a characteristic level of sex drive that can be expressed with a partner or, in the absence of a partner, via masturbation (Laumann, Gagnon, Michael, & Michaels, 1994; van Anders, 2015). In this way, solitary sexuality is positioned as a 'lesser substitute' for dyadic sexuality: both fulfill the same underlying need – sexual gratification – though solitary sexuality reflects the *lack* of a dyadic alternative (Laumann et al., 1994; van Anders, 2015). Data from humans and non-human primates suggest this is an oversimplification. In humans, masturbation frequency aligns less clearly with the availability of a steady partner than with age and with social factors like education (Laumann et al., 1994). In other primates, masturbation seems unrelated to copulation frequency or the availability of

potential mates, suggesting that the lack of a dyadic alternative cannot completely account for the occurrence of masturbation (Dixson, 2012). Rather, solitary sexuality may best be understood as "complementary, supplementary, or independent" of dyadic sexuality (Laumann et al., 1994) and, like dyadic sexuality, as complex and context-dependent (Fahs & Frank, 2014; Laumann et al., 1994; van Anders, 2015) – though research on *how* solitary sexuality is socially situated is limited.

Studying how solitary sexuality and T are linked can yield important insights about which elements of sexuality T responds to, as well as about sexuality more generally. In one of the few studies exploring links between masturbation and T in non-human primates, T was not significantly associated with masturbation frequency in female bonobos, though T was positively correlated with another non-reproductive sexual behavior (genitogenital rubbing) (Sannen et al., 2005). In women, the few studies conducted to date have linked solitary sexuality with higher T via more frequent solitary orgasms (van Anders, Hamilton, Schmidt et al., 2007), more relaxing solitary orgasm experiences (van Anders & Dunn, 2009), and higher solitary sexual desire (van Anders, 2012b), though directionality of these links is an open question. Additionally, dyadic sexuality may not be the only variable underlying the T-pair bonding link in women: some research suggests a role for masturbation in mediating this association, albeit more weakly than dyadic sexuality (van Anders & Watson, 2007; van Anders, Hamilton, Schmidt et al., 2007; van Anders & Goldey, 2010). Studying how solitary *and* dyadic sexuality are linked with T could help answer questions like: Are solitary and dyadic sexuality truly the same phenomenon, or are they distinct (in terms of individuals' experiences and in terms of links with T)? If masturbation and solitary orgasms are linked with increases in T, is genital/erotic *pleasure* an important cue

for T release (van Anders, 2013)? And, is masturbation implicated as a mechanism for adjusting T in response to partnering status?

How Does the Internal Context Shape ΔT to External Stimuli?

As discussed above, sexual thoughts in the absence of external stimuli are sufficient to increase T in women (Goldey & van Anders, 2011), suggesting that cognitions could also play a role in shaping T responses to external sexual stimuli. However, the question of how internal context modulates ΔT to external sexual stimuli in women is unaddressed, despite research showing that cognitive appraisals are important predictors of hormone responses in other social contexts (e.g., competition, stress) (Dickerson, Gruenewald, & Kemeny, 2004; Oliveira et al., 2013; Salvador, 2005; Salvador & Costa, 2009). There is reason to believe that internal context is important for how T responds to intimacy as well. In women, cuddling with a relationship partner increased T (van Anders, Hamilton, Schmidt et al., 2007), which was surprising given that cuddling is typically assumed to be nurturant (and thus should decrease T) (van Anders et al., 2011). Follow-up research confirmed that although cuddling is perceived as a nurturant, non-sexual behavior, it is *experienced* as erotic (e.g., it often precedes or follows sexual activity, and is somewhat sexually arousing) (van Anders et al., 2011; van Anders, 2013; van Anders, Edelstein, Wade, & Samples-Steele, 2013). Thus, attention to how intimate contexts are experienced is crucial for explaining unexpected associations with T. This finding also highlights nuances such that different elements of the internal context (perceptions vs. experiences) can contribute to T responses in distinct ways (van Anders, 2013).

A further element missing from the current framework is an understanding of what factors influence the internal context in the first place. How sexuality is perceived and experienced is likely shaped by individual characteristics as well as by the external social

context, such that external and internal context feed back on one another. In my dissertation, I address several specific factors that could influence how sexuality is experienced, including relationship context (Study 1), social location, specifically sexual identity and age (Study 2), and autonomy over erotic stimulus selection (Study 3).

Research Questions

The broad, overarching goal of my dissertation is to examine how the ways in which sexuality is experienced shape sexual modulation of T and bidirectional T-sexuality links among women. I address three research questions relevant to this larger goal, and each research question is outlined below.

Q1: How Do Solitary Sexual Activity, Dyadic Sexual Activity, and Pair Bonding Additively and Interactively Contribute to Women's T Profiles?

Some evidence suggests that pair bonded women have lower T than singles (Barrett et al., 2013; van Anders & Watson, 2006, 2007; van Anders & Goldey, 2010), but directionality of this effect – whether lower T predicts pair bonding or whether pair bonding changes T – is unclear. And, research indicates that dyadic sexual activity and/or masturbation may underlie T-pair bonding links in women (van Anders & Watson, 2007; van Anders, Hamilton, Schmidt et al., 2007; van Anders & Goldey, 2010), though exactly how sexuality and pair bonding interact to predict T on a within-person level needs clarification. In Chapter 2, I present results from a longitudinal investigation of partnering, sexuality, and T among women transitioning to college. My goals were to: (a) Clarify that pair bonded women have lower T than singles; (b) Elucidate the directionality of the T-pair bonding link (i.e., test whether T predicts future pair bonding or vice versa); (c) Determine how solitary and dyadic sexual activity are linked with within-person

fluctuations in T; and (d) Test whether pair bond status and sexual activity interact to shape T profiles.

My results showed that women had lower T when pair bonded than when single, and T and pair bonding were bidirectionally linked. T was associated with both solitary and dyadic sexual activity, but in different ways. Specifically, engaging in masturbation was associated with higher T across pair bond statuses. By contrast, engaging in dyadic sexual activity was associated with lower T when women were pair bonded, but not when single or casually partnered. These findings highlight the dynamic, reciprocal interplay between T and social behavior. They also point to the value of examining pair bonding and sexuality together, and of distinguishing between solitary and dyadic sexuality, to understand within-person fluctuations in T in women.

Q2: How Do Women Define Pleasure During Solitary and Dyadic Sexuality?

Solitary and dyadic sexuality are often assumed to represent the 'same' phenomenon, with solitary sexuality depicted as a 'lesser substitute' for dyadic sexuality when partners are unavailable (Laumann et al., 1994; van Anders, 2015). If this is true, why does empirical evidence point to distinct associations with T (e.g., in Chapter 2) and separation in other domains (e.g., solitary desire is distinguishable from dyadic desire: Spector et al., 1996)? I hypothesize that solitary and dyadic sexuality are linked with T in different ways because they represent distinct experiences for women. Specifically, solitary sexuality may be linked with higher T because it is oriented around genital/erotic pleasure, whereas dyadic sexuality may be linked with lower T because it is oriented around nurturance (van Anders, 2013). In Chapter 3, I present the results of a qualitative study on women's definitions of solitary and dyadic sexual pleasure. The goals of this study were to: (a) Describe how women's definitions of sexual pleasure overlap and diverge in solitary and dyadic contexts; and (b) Discuss how experiences of pleasure are

similar or different across age ranges and sexual identities. I discuss the implications of these results for understanding sexuality-T associations.

Results showed that women defined solitary and dyadic pleasure in overlapping but far from identical ways. Autonomy, or total control over the experience, was central to definitions of solitary pleasure, whereas trusting a partner enough to give up control, giving a partner pleasure, and closeness were important elements of dyadic pleasure. Definitions of pleasure were largely similar across age and sexual identity groups, but social location also shaped experiences of pleasure. Queer women, as well as heterosexual women over 40, were relatively more likely than younger heterosexual women to prioritize orgasm in their definitions of dyadic pleasure and to feel comfortable engaging in solitary masturbation when in a romantic relationship. Overall, findings support understandings of solitary and dyadic pleasure as qualitatively different experiences for women in ways that have implications for their associations with T. Specifically, solitary pleasure maps more closely onto genital/erotic pleasure and dyadic pleasure more closely onto nurturance, supporting theoretical predictions (van Anders, 2013).

Q3: How Does Autonomy in Selection of Visual Sexual Stimuli Affect Women's T Responses?

Solitary sexual activity was associated with higher T in my longitudinal study (Chapter 2), and participants in my qualitative study identified autonomy as a key element of solitary sexual pleasure (Chapter 3). Is autonomy relevant to sexual modulation of T?

Sexual thoughts are sufficient to increase T in women, yet erotic films are not (Goldey & van Anders, 2011; Hamilton et al., 2008; Heiman et al., 1991; van Anders et al., 2009). A key confound in past studies is autonomy in stimulus selection: women chose the content of their sexual thoughts but films have been selected by researchers. This may be especially important

given evidence from non-human species that partner quality modulates ΔT in females (Correa et al., 2011; Gwinner et al., 2002; Marshall et al., 2005); films chosen by others may not match women's individual preferences for partners or sexual situations. In Chapter 4, I present the results of an experimental study comparing women's cognitive/affective and T responses to a neutral documentary control condition and three erotic film conditions varying in autonomy: high choice (self-chosen erotica from participants' own sources), moderate choice (self-chosen erotica from films preselected by sexuality researchers), or no choice (researcher-chosen erotica). I hypothesized that compared to researcher-chosen erotic films, self-chosen erotic films would: (a) increase women's self-reported sexual arousal; (b) increase enjoyment; (c) decrease negative affect; (d) increase identification with film stimuli (i.e., taking the perspective of film characters); and (e) increase T.

As expected, compared to researcher-chosen erotica, self-chosen erotica increased self-reported arousal and enjoyment, but also unexpectedly increased negative affect (disgust, guilt, and embarrassment). Self-chosen erotica only marginally increased identification with stimuli compared to researcher-chosen erotica. Overall, film condition did not affect T, but individual differences in identification moderated T responses: among women reporting lower levels of identification with stimuli, the moderate choice condition decreased T compared to the no choice condition, but this difference was not observed among women with higher identification. My findings highlight the importance of internal cognitive and emotional experiences, specifically identification with stimuli, in shaping T responses to external sexual stimuli. However, choosing erotica resulted in ambivalent rather than unequivocally positive cognitive/emotional responses. Taken together, these results suggest that autonomy may be a 'double-edged sword' (Bay-Cheng,

2015), such that high autonomy increases arousal but also increases participants' feelings of responsibility for engaging in an already stigmatized behavior.

Synthesis

In Chapter 5, I synthesize findings from the above three studies with attention to three overarching themes: (a) the distinctness of solitary and dyadic sexuality, experientially and hormonally; (b) the bidirectional, dynamic nature of T-sexuality links; and (c) the malleability of biology, such that T responds not only to the external social environment, but also to internal context. I also discuss future directions for research on sexual modulation of T in humans.

CHAPTER 2

DYNAMIC ASSOCIATIONS BETWEEN TESTOSTERONE, PARTNERING, AND SEXUALITY DURING THE COLLEGE TRANSITION IN WOMEN

Introduction

Pair bonds exist among only about 5% of mammalian species (Kleiman, 1977) yet are a hallmark of human cultures (Hawkes, 2004; Quinlan & Quinlan, 2007). Pair bonds present an interesting evolutionary puzzle because they limit opportunities for new or more sexual partners, even despite the extra-pair sexual contacts that occur in the majority of pair bonding species (Hawkes, 2004; van Anders et al., 2011). In addition to the evolved functions of pair bonding (Gavrilets, 2012; Hawkes, 2004; Quinlan & Quinlan, 2007), research has focused on the proximate mechanisms that mediate tradeoffs between pair bonding and seeking new or more partners; one candidate for mediating these tradeoffs is the hormone testosterone (T) (van Anders & Gray, 2007; van Anders et al., 2011).

The vast majority of research on T and pair bonding has focused on men, perhaps reflecting cultural assumptions that tie T to maleness and masculinity (van Anders, 2013). This research consistently shows that partnered heterosexual men have lower T than their single counterparts (e.g., Gray, Kahlenberg, Barrett, Lipson, & Ellison, 2002; Gray, Ellison, & Campbell, 2007; van Anders & Goldey, 2010), which is typically interpreted as evidence of a tradeoff between higher T and mating effort versus lower T and parenting effort. But pair bonds can involve both, which makes predictions for T messy. In the Steroid/Peptide Theory of Social Bonds (S/P Theory), van Anders et al. (2011) provide a set of behavioral contrasts that maps

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more closely onto T contrasts and is useful for theorizing about pair bonds and partnering. In the S/P Theory, there is a tradeoff between higher T and competition (resource acquisition or defense, broadly defined to include partners and sexual opportunities) and lower T and nurturance (warm, loving, affiliative contact with partners, offspring, or others). In terms of partnering, the S/P Theory predicts that higher T is linked with seeking, having, or openness to new or more partners (which falls into competition), and lower T with focusing on warm, loving aspects of pair bonded relationships (which falls into nurturance) (van Anders et al., 2011; van Anders, 2013). In support, desire for new or more dating partners mediates partnering-T links in men (van Anders & Goldey, 2010), and partnered men interested in noncommitted sexual activity show similar T to single men (Edelstein, Chopik, & Kean, 2011). Therefore, an approach to relationships (i.e., relationship orientation) characterized by interest in new or more partners, rather than single status per se, is linked with higher T in men (McIntyre et al., 2006).

Importantly, the S/P Theory explicitly makes similar overarching predictions about partnering and T for women *and* men, with room for gender/sex specificities in mechanisms and directionality (van Anders, 2013). In support of overarching similarities by gender/sex, research suggests partnered women have lower T than singles (Barrett et al., 2013; van Anders & Watson, 2006, 2007; van Anders & Goldey, 2010). However, there are some mixed findings (Edelstein et al., 2011; Hooper, Gangestad, Thompson, & Bryan, 2011; van Anders, Hamilton, & Watson, 2007), such that conclusions are more tentative in women than in men. In terms of gender/sex specificities, one previous study found that casually partnered men had similar T to single men, whereas casually partnered women had similar T to women in committed relationships (van Anders & Goldey, 2010). Furthermore, research suggests that state cues or behavioral variables (e.g., frequency of dyadic sexual activity) may explain partnering-T links in women (van Anders

& Watson, 2007; van Anders & Goldey, 2010). Thus, T may be linked with relationship *status* in women, but with relationship orientation in men (van Anders & Goldey, 2010).

Directionality of Partnering-T Links in Women Is Unclear

Directionality of T-partnering links – whether lower T predicts pair bonding or pair bonding decreases T – is still controversial in men (Gettler, McDade, Feranil, & Kuzawa, 2011; Mazur & Michalek, 1998; van Anders & Watson, 2006) but almost entirely untested in women. Only two previous studies have examined longitudinal associations between T and partnering in samples including women (Marazziti & Canale, 2004; van Anders & Watson, 2006). Among single or casually partnered women (and men), lower T predicted being pair bonded approximately six months later, and there was no evidence that becoming pair bonded changed T (van Anders & Watson, 2006). Whether T predicted the transition from pair bonded to single or casually partnered (or whether this transition changed T) could not be tested due to the very small number of observations in this group (van Anders & Watson, 2006). These results – which point to a 'trait' association, such that lower T predicts pair bonding but pair bonding does not change T – are somewhat surprising given cross-sectional evidence that state variables contribute to partnered women's lower T. The gap in longitudinal research makes it difficult to reconcile the (limited) evidence that T predicts future partnering rather than the reverse in women, even while state cues are important in mediating T-partnering links.

Adding further nuance, some research suggests that relationship transitions may themselves be unique contexts for T, such that new and established committed relationships are linked with T in different ways. Marazziti and Canale (2004) found that women in early stages (i.e., the first six months) of loving relationships had higher T than a group of control participants, who were either single or in longer-term relationships. T levels of the participants

who had fallen in love but maintained the same relationship were similar to controls 12-28 months later, suggesting that the higher T reflected a transient increase specific to relationship formation (Marazziti & Canale, 2004). Within the S/P Theory, *changes* in T levels, or T responses, are particularly useful for classifying 'tricky' behavioral contexts (i.e., those that are difficult to classify because they may involve competition, nurturance, or both) in terms of their evolved function (van Anders et al., 2011). Therefore, if new committed relationships increase T, relationship formation may be best characterized as a competitive context and not only a nurturant context as might be presumed. Newer committed relationships do differ from more established committed relationships on several key parameters, including frequency of dyadic sexual activity, sexual desire, desire for nurturance, and sexual and emotional satisfaction (Badcock et al., 2014; Klusmann, 2002). Thus, attention to how relationship transitions are linked with changes in T is especially informative for understanding the evolutionary significance of specific stages of partnering.

Sexuality Underlies Partnering-T Links in Women

Sexual activity promotes pair bond formation and maintenance in humans and other species, but can occur within or outside of pair bonds (Insel, Winslow, Wang, & Young, 1998; Snowdon et al., 2006; Sprecher, 2002; van Anders, Hamilton, Schmidt et al., 2007; van Anders et al., 2011). State cues relevant to sexuality – specifically, frequency of masturbation and of dyadic sexual activity – have been shown to underlie partnering-T links in women, such that links between T and partnering may actually be secondary to links between T and sexuality (van Anders & Goldey, 2010). T is associated with sexuality (including sexual activity and sexual desire) in women, though sometimes in ways that run counter to common expectations. Sexuality is commonly conceptualized as uniformly linked to high T, but, like partnering, sexuality is

actually a 'tricky' context with multiple elements that may be differentially associated with T (van Anders, 2013).

Perhaps counterintuitively, more frequent dyadic sexual activity has been linked with *lower* T in women (van Anders & Goldey, 2010). This finding aligns with research showing that women with higher *desire* for dyadic sexual activity have lower T (van Anders, 2012b). Dyadic sexual desire and activity may be linked with lower T because they could reflect nurturant motivations and experiences (e.g., emotional intimacy, relationship maintenance) in addition to or more so than erotic ones (e.g., orgasm, genital pleasure, power) (Burke, Goldey, & van Anders, under review; van Anders, 2013). Importantly, dyadic sexual activity is implicated as a mechanism for T-pair bonding links in women. In a previous study, the key variable explaining casually partnered and committed women's lower T relative to singles was partnered women's more frequent dyadic sexual activity (van Anders & Goldey, 2010). This finding suggests that partnered women may have lower T than singles because they engage in dyadic sexual activity more frequently, and dyadic sexual activity predicts lower T.

An important caveat is that dyadic sexuality may only be linked with lower T to the extent that it maps onto nurturant motivations and experiences. For example, among partnered women, more experience with *noncommitted* sexual activity was linked with higher T, such that only partnered women who reported low levels of noncommitted sexual experience had lower T than single women (Edelstein et al., 2011). Therefore, dyadic sexuality may be linked with lower T in some but not all contexts, and the pair bond context may moderate how T and dyadic sexual behavior are linked.

In contrast to findings with dyadic sexual activity (and more in line with common expectations linking sexuality to high T), solitary masturbation has consistently been linked with

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higher T in women. Specifically, women with higher T report more frequent solitary orgasms and higher solitary sexual desire (van Anders, Hamilton, Schmidt et al., 2007; van Anders, 2012b). These findings generated predictions that masturbation frequency would underlie T-partnering links in women; that is, single women might engage in masturbation more frequently, accounting for their higher T. In support, single women did masturbate marginally more frequently than casually partnered or committed women, and masturbation frequency accounted for a significant portion of variance between partnering and T (van Anders & Goldey, 2010). However, dyadic sexual activity emerged as the stronger mediator of T-partnering links over masturbation when both were included in regression models (van Anders & Goldey, 2010). Thus, masturbation might be *part* of the explanation for differences in women's T by partnering status, but perhaps less so than dyadic sexual activity.

Taken together, past findings from women indicate that masturbation is linked with higher T and dyadic sexual activity is usually linked with lower T, and that both these variables – but dyadic sexual activity more so – account for T-partnering links. However, because previous studies of mediators have been cross-sectional, it is unknown whether T-sexuality links extend to a within-person context. That is, women with higher T report more frequent masturbation, but does an individual woman have higher T at times when she engages in masturbation than at times when she does not? And, although some findings are suggestive (Edelstein et al., 2011), the extent to which partnering status and sexual activity interact to influence T profiles is unclear, highlighting the importance of examining partnering and sexuality together.

The Current Study

In the current study, I sought to clarify within-person links between T, partnering, and sexuality in women by exploring month-to-month changes in T and relationship status among

women transitioning to college. I explored whether T predicted changes in relationship status or vice versa in the short-term (i.e., the following month), as well as how T was linked with specific types of relationship transitions (becoming committed versus becoming single or casually partnered). Finally, I investigated how T was linked with masturbation and dyadic sexual activity, and whether these sexuality variables accounted for T-relationship status links. I expected that the college transition would be a dynamic period for romantic and sexual relationships (Bogle, 2008), making this an ideal population for addressing my research questions. My hypotheses were as follows:

1. Status as single will be linked with higher current T than status as in a committed relationship.

2. Casual relationships will be similar to commitment in terms of T (van Anders & Goldey, 2010).

3. Although evidence regarding directionality is mixed, I expect that changes in partnering status will predict changes in T. Alternatively, it may be that there are bidirectional associations between T and partnering status (van Anders & Watson, 2006).

4. Masturbation will be linked with higher T (van Anders, Hamilton, Schmidt et al., 2007).

5. Dyadic sexual activity will be linked with lower T, and will mediate (or moderate) relationship status-T links (van Anders & Goldey, 2010).

Method

Participants

Participants were first-year college students recruited for the Implications of Partnerships Around the College Transition (ImPACT) Study (van Anders, Goldey, Conley, Snipes, & Patel, 2012). The larger project included women and men, and I focused on the 78 women who

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participated. At baseline, all participants were between 18-20 years old (with three non-responders). Participants self-identified their race/ethnicity by choosing from a preset list of options (including an "Other" option with an open-ended textbox); 2 identified as African American/Black, 1 as Arab-American, 21 as Asian, 1 as Hispanic/Latina, 8 as Multiracial, and 44 as White, with 1 non-responder. Most participants ($n = 64$) had lived in the United States their entire lives. About 9% ($n = 7$) reported being the first in their family to attend college or university. No participants reported having children.

Design

Participants enrolled in the study between August and October of their first year of college, and they completed eight study sessions (one baseline session plus seven follow-ups) at approximately monthly intervals during their first academic year. Between August and October of their second year of college, participants completed one final study session. At each session, participants completed online questionnaires (with a larger set of questionnaires at the baseline and final sessions) and provided a saliva sample. 51% of participants completed questionnaires for at least seven of the nine sessions. Because of the longitudinal design of the study, the decision was made to stop data collection when 400 total participants (women and men) had been recruited, or at the end of October, whichever came first.

Measures

Health and demographics questionnaire. The full version of this questionnaire, completed at the baseline and final sessions, included demographic items to describe the sample and items targeting potential hormone confounds, such as medication use (including hormonal contraceptive [HC] use), medical conditions, and height and weight to calculate body mass index

[BMI]. A shortened version of this questionnaire, completed at follow-up sessions, included items about HC and other medication use.

Relationships questionnaire. Participants indicated their relationship status from a list of options accompanied by definitions and examples (van Anders & Goldey, 2010), including single, sexual encounters (defined as sexual interactions with another person that do not include a longer-term connection; e.g., 'one-night stands' or 'friends with benefits'), dating (defined as a casual relationship that is 'romantic' and may be sexual; e.g., going out to the movies or dinner), and committed relationship (defined as involving a commitment on the part of the participant and the person to be together as relationship partners for some time). Participants could select more than one option and could indicate "Other" and describe their relationship status in more detail. Participants also reported their number of sexual/relationship partners, and those who selected sexual encounters, dating, and/or committed relationship reported their number of partners for each relationship status. Based on these responses, participants were coded as *single* if they indicated a single relationship status and no relationship or sexual partners; as *casually partnered* if they indicated any combination of relationship statuses involving sexual encounters or dating (e.g., "sexual encounters and committed relationship", "single and dating"); or as *committed* if they indicated being in committed relationship(s) without any dating or sexual encounter relationships. Participants who indicated having one or more current relationship partners were asked additional questions (e.g., genders/sexes of partners).

Sexuality questionnaire. Among other sexuality variables, participants reported on their self-identified sexual orientation and dyadic and solitary sexual behaviors. In my analyses, *dyadic sexual activity* refers to whether participants had at least one sexual partner in the past month (yes/no). This was coded from an item in which participants indicated the number of

different individuals they had consensual physical sexual contact (including passionate kissing or touching, oral sex, vaginal sex, anal sex, etc.) with in the past month on a scale from 0 to 21+. Participants reported their frequency of masturbation in the past week and their average weekly masturbation frequency in the past month; these two measures were highly correlated ($\beta = 0.55$, $p < 0.001$), so I used past week's masturbation frequency. The distribution of past week's masturbation frequency was highly skewed, with less than a quarter of observations reporting *any* masturbation in the past week. Therefore, I dichotomized this variable into "no" or "some" masturbation in the past week.

Saliva samples. Saliva samples provide a minimally invasive, widely used, and well-validated method for measuring T (for review, see van Anders et al., 2014). Participants provided saliva samples via passive drool into 17mL polystyrene tubes. To ensure the quality of saliva samples, participants were instructed to avoid eating, drinking beverages other than water, smoking, chewing gum, or brushing their teeth for an hour prior to saliva collection. Samples were immediately frozen at -20 °C if provided in the lab (at the baseline session). If samples were provided at home (as was the case for most follow-up and final sessions), participants were instructed to freeze the sample as soon as possible after providing it; once samples were picked up from participants or dropped off at the laboratory, they were frozen at -20 °C until assay. Samples were radioimmunoassayed in duplicate for T at the Core Assay Facility at the University of Michigan following a validated protocol (Campbell, Schultheiss, & McClelland, 1999) and using commercially available kits from Siemens (Washington, DC, USA). Intra-assay CVs were 3.16% at high T and 12.83% at low T, and inter-assay CVs were 8.60%, 8.20%, and 25.90% at high, medium, and low T, respectively.

Procedure

All procedures were approved by the University of Michigan Institutional Review Board and carried out in accordance with the World Medical Association Declaration of Helsinki. Participants' baseline sessions occurred in the laboratory between 12pm and 7pm to avoid the high and fluctuating T levels that occur during the morning (van Anders et al., 2014). At baseline, participants completed an informed consent form, a saliva sample, the full health and demographics questionnaire, relationships questionnaire, sexuality questionnaire, and a number of measures related to the team project but not the current analyses: the Investment Model Scale, Quality Marriage Index, UCLA Multidimensional Condom Attitudes Scale, Index of Sexual Satisfaction, Experiences in Close Relationships Scale, General Well-Being Schedule, Klein Sexuality Grid, Multidimensional Scale of Perceived Social Support, Perceived Stress Scale, Positive and Negative Affect Schedule, Rosenberg Self-Esteem Scale, Sex-Role Traditionalism Scale, Sexual Desire Inventory, and UCLA Loneliness Scale.

Following the baseline session, participants were contacted at monthly intervals to complete follow-up sessions. Researchers sent reminder emails to participants if they had not yet completed a follow-up questionnaire 1-2 weeks after the initial notification. Participants were given the option to complete follow-up sessions at home or in the laboratory; most participants elected to complete them at home. Participants were instructed to collect a saliva sample between 2pm and 6pm on the same day they completed the online questionnaire if possible. Of 325 observations with recorded dates for both saliva and survey data collection, 78% ($n = 252$) of saliva collections were completed on the same date as the survey, and 96% ($n = 311$) were completed within a window of 5 days prior to and 5 days after the survey. Of 327 saliva samples with recorded times of collection, 73% ($n = 240$) were completed between the afternoon hours of

12pm and 7pm. At each follow-up, participants completed the shortened health and demographics questionnaire and the relationships and sexuality questionnaires, in addition to a subset of the additional measures completed at baseline. Participants' final study session involved a longer questionnaire identical to the baseline session. Participants received $15 for the baseline session, $10 for each subsequent session, and an additional $25 for completing at least eight sessions. Participants who completed at least eight sessions were also eligible to win one of two $100 prizes.

Analyses

Participants were excluded from analyses at sessions when they reported using medications affecting T (other than HCs) or had medical conditions affecting T ($n = 48$ observations across 15 participants). T outliers (over 3 SD from the mean and/or visual outliers) were excluded ($n = 15$ observations across 8 participants). Finally, sexual orientation/identity has been an inconsistent moderator of T-relationship status links in women in the past (van Anders & Watson, 2006; van Anders, Hamilton, & Watson, 2007; van Anders & Goldey, 2010); excluding participants with sexual minority identities or same-sex partners ($n = 41$ observations across 9 participants) did change the pattern of results, so I limited my analyses to heterosexual women given that the sample of sexual minority women was too small to conduct comparisons by sexual identity. This resulted in a total of 104 observations across 30 participants excluded.

I conducted analyses using SPSS 18.0 and STATA 13. To test for associations between relationship status and T, I used linear mixed models (LMMs) with a random subject intercept, which account for the interdependence of repeated measurements from the same individual (Garson, 2013; West, 2009). My initial model predicted T from relationship status (single, casual, or committed), session (i.e., baseline, follow-up 1, etc.), and control variables. Session

was coded with baseline as 0, follow-up 1 as 1, etc., with the final session coded as Session 11 rather than Session 8 to account for the approximately 4-month lag between follow-up 7 and the final session. I checked whether BMI, time of day of saliva sample (sampling time), nicotine use (yes/no), and HC use (yes/no) were associated with T, and retained covariates that showed a significant or trend-level association with T (van Anders et al., 2014). All predictors except BMI (which was only measured at baseline) were time variant in the models. T was not significantly linked with BMI ($\beta = 0.07$, $p > 0.250$) or nicotine use ($\beta = 0.03$, $p > 0.250$), but T was significantly associated with sampling time ($\beta < -0.01$, $p = 0.048$), and participants had significantly lower T when using HCs than when naturally cycling ($\beta = -5.20$, $p < 0.001$). Therefore, I included sampling time and HC use as covariates.

I tested whether relationship status predicted T or vice versa in two ways. First, I tested whether current T was linked with relationship status at the following session, and/or whether relationship status at the previous session predicted current T (e.g., Hewitt, Turrell, & Giskes, 2012). In these models, current T was always the dependent variable, either the next session's relationship status (lead variable) or previous session's relationship status (lag variable) was the predictor of interest, and sampling time and HC use were included at the current session rather than as lead or lag variables (so control variables and T were matched in time).

Second, to more specifically examine how different types of relationship transitions (e.g., becoming committed vs. becoming noncommitted) were linked with T, I categorized observations as stably committed (committed at the current and following sessions), committed → noncommitted (committed at the current session but single or casually partnered the following session), stably noncommitted (single or casually partnered at the current and following sessions), or noncommitted → committed (single or casually partnered the current session but

committed the following session)[1]. I then tested whether a) current T was associated with

relationship transitions at the following session and b) whether relationship transitions predicted

the *change* in T (next session's T – current session's T) from the current to following session

(e.g., Gettler et al., 2011). Unlike absolute levels of T, session-to-session changes in T were not

intercorrelated within a participant, so LMM was not appropriate for this analysis. Instead, I used

a linear regression with clustered standard errors based on participant, with change in T as the

dependent variable and relationship transition category, session, HC use (current and next

session), and sampling time (current and next session) as predictors. Participants were excluded

from this regression analysis if they reported medications/conditions affecting T at the current or

next session ($n = 6$ additional excluded observations) or if they identified as a sexual minority at

the current or next session ($n = 2$ additional observations).

Finally, I included dyadic sexual activity and masturbation as predictors in the initial

models to see how these factors were associated with T and whether they accounted for

relationship status-T links.

Results

T and Relationship Status Were Bidirectionally Linked

Overall, there was relative stability in relationship status from session to session (see

Table 2.1).

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[1] For ease of interpretation and given the small number of session-to-session changes in relationship status (see Table 2.1), I collapsed single and casually partnered into "noncommitted" for these analyses.

Table 2.1

Session-to-Session Changes in Relationship Status

Current Relationship Status	Previous Session's Relationship Status			Next Session's Relationship Status		
	Single	Casual	Committed	Single	Casual	Committed
Single *n* = 128 (10)	76 (3)	9 (0)	3 (1)	83 (4)	12 (1)	4 (1)
Casual *n* = 38 (7)	11 (0)	13 (4)	0 (0)	10 (0)	16 (4)	1 (0)
Committed *n* = 117 (63)	3 (0)	1 (0)	83 (48)	3 (1)	2 (1)	87 (49)

Note. Numbers represent number of observations (not number of participants). The table includes only observations used in analyses (i.e., not excluded for medication use or having missing data for testosterone or control variables). Numbers in parentheses indicate number of observations using hormonal contraceptives at the current session.

Women had marginally higher T when single than when committed, $\beta = 1.66$, 95% CI = [-0.05, 3.37], $z = 1.90$, $p = 0.057$, with no other significant or trend-level differences based on relationship status (see Figure 2.1; Table 2.2).

There was evidence for bidirectional associations between T and relationship status, such that current T was marginally linked with both prior and future relationship status (see Figure 2.1; Table 2.2). T predicted future relationship status: status as casually partnered at the following session was linked with marginally higher current T than status as committed at the following session, $\beta = 2.26$, 95% CI = [-0.12, 4.64], $z = 1.86$, $p = 0.063$. And, relationship status predicted future T: status as single at the previous session predicted marginally higher current T than status as committed at the previous session, $\beta = 1.99$, 95% CI = [-0.16, 4.15], $z = 1.81$, $p = 0.070$.

Table 2.2

Results of Linear Mixed Models Predicting Current Testosterone (T) From Current, Next Session's, or Previous Session's Relationship Status and Control Variables

	β [CI]	*z* value	*p* value
Model 1: Current Relationship Status[a]			
Session	0.21 [0.04, 0.38]	2.48	0.013
HC	-4.80 [-6.66, -2.94]	-5.07	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-2.33	0.020
Single relationship status	1.66 [-0.05, 3.37]	1.90	0.057
Casual relationship status	1.52 [-0.56, 3.60]	1.43	0.152
Model 2: Next Session's Relationship Status			
Session	0.20 [-0.07, 0.48]	1.45	0.146
HC	-5.02 [-7.18, -2.86]	-4.55	<0.001
Sampling time	>-0.01 [>-0.01, <0.01]	-1.67	0.096
Single relationship status	1.17 [-0.90, 3.23]	1.11	0.268
Casual relationship status	2.26 [-0.12, 4.64]	1.86	0.063
Model 3: Previous Session's Relationship Status			
Session	0.20 [-0.05, 0.45]	1.58	0.114
HC	-5.20 [-7.57, -2.83]	-4.31	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-2.23	0.026
Single relationship status	1.99 [-0.16, 4.15]	1.81	0.070
Casual relationship status	0.75 [-1.95, 3.46]	0.55	0.585

Note. Committed relationship was the reference category.

[a]A significant proportion of variance in the model could be attributed to between-subject variance, β = 9.00, 95% CI = [5.10, 15.87], *z* = 3.46, *p* = 0.001 (ICC from null model = 0.43), indicating that LMM was appropriate to account for the nesting of sessions within individuals.
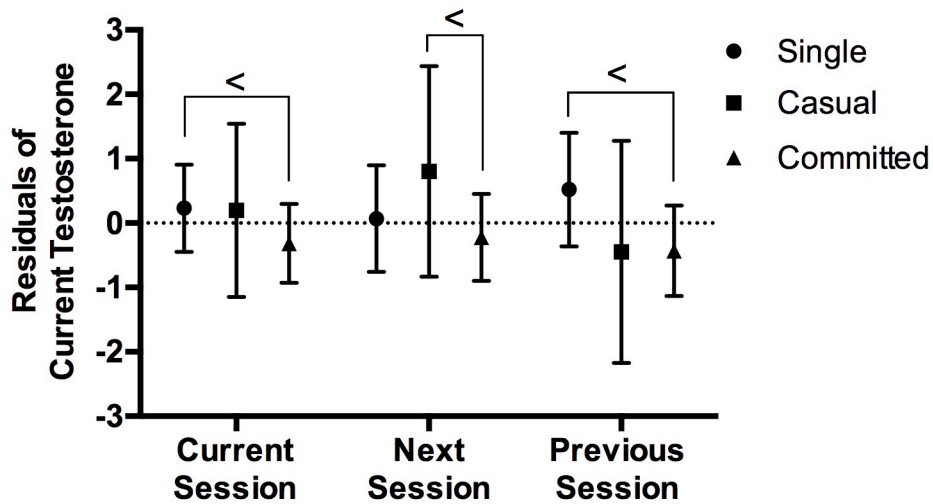
Figure 2.1. *Testosterone and Relationship Status Were Bidirectionally Linked.* The figure shows associations between current testosterone and relationship status at the current, next, and previous session in women. The *y* axis shows residuals of current testosterone obtained from linear mixed models predicting current testosterone from potential confounds (session, HC use, and sampling time) with a random subject intercept. Bars show 95% confidence intervals. '<' indicates a trend in the linear mixed model (Table 2.2) at *p* < 0.10.

Lower T Predicted Commitment, but Commitment Increased T

Next, I examined how specific types of relationship transitions were linked with T. T predicted future relationship transitions, such that, among noncommitted women, lower T predicted the transition into a committed relationship at a trend level, $\beta = -3.74$, 95% CI = [-7.91, 0.44], $z = -1.75$, $p = 0.080$. However, T did not predict transitioning *out* of committed relationships (see Table 2.3; Figure 2.2a).

Relationship transitions were also linked with changes in T. Specifically, transitioning into a committed relationship was linked with an increase in T ($\beta = 6.41$, 95% CI = [2.31, 10.51], $t = 3.16$, $p = 0.003$, compared with stably committed; $\beta = 5.26$, 95% CI = [2.02, 8.50], $t = 3.28$, $p = 0.002$, compared with stably noncommitted), with no other significant differences based on relationship transition category (see Table 2.3; Figures 2.2b and 2.2c). While these findings should be interpreted with some caution given the small number of observations that changed

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relationship status, these results suggest that lower T may predict the transition from

noncommitted to committed relationships in women, but women may actually experience an

increase in T shortly after becoming committed.

Table 2.3
Results of Models Predicting Current Testosterone (T) and Change in T From Relationship Transition Category (Current → Next Session) and Control Variables

	β [CI]	z or t value	p value
Model 1: Current T (Linear Mixed Model)			
Session	0.19 [-0.08, 0.47]	1.39	0.166
HC	-4.94 [-7.11, -2.77]	-4.46	<0.001
Sampling time	>-0.01 [>-0.01, <0.01]	-1.83	0.067
Stably committed	-1.37 [-3.48, 0.73]	-1.28	0.201
Committed → noncommitted	-1.43 [-5.59, 2.72]	-0.68	0.499
Noncommitted → committed	-3.74 [-7.91, 0.44]	-1.75	0.080
Model 2: Change in T (Regression)			
Session	-0.07 [-0.35, 0.21]	-0.50	0.623
HC (current)	5.76 [-1.04, 12.56]	1.71	0.095
HC (next)	-4.66 [-11.79, 2.47]	-1.32	0.194
Sampling time (current)	<0.01 [<0.01, <0.01]	2.96	0.005
Sampling time (next)	>-0.01 [>-0.01, <0.01]	-1.54	0.131
Stably committed	-1.16 [-2.98, 0.67]	-1.28	0.208
Committed → noncommitted	3.39 [-5.49, 12.28]	0.77	0.445
Noncommitted → committed	5.26 [2.02, 8.50]	3.28	0.002

Note. Stably noncommitted was the reference category.
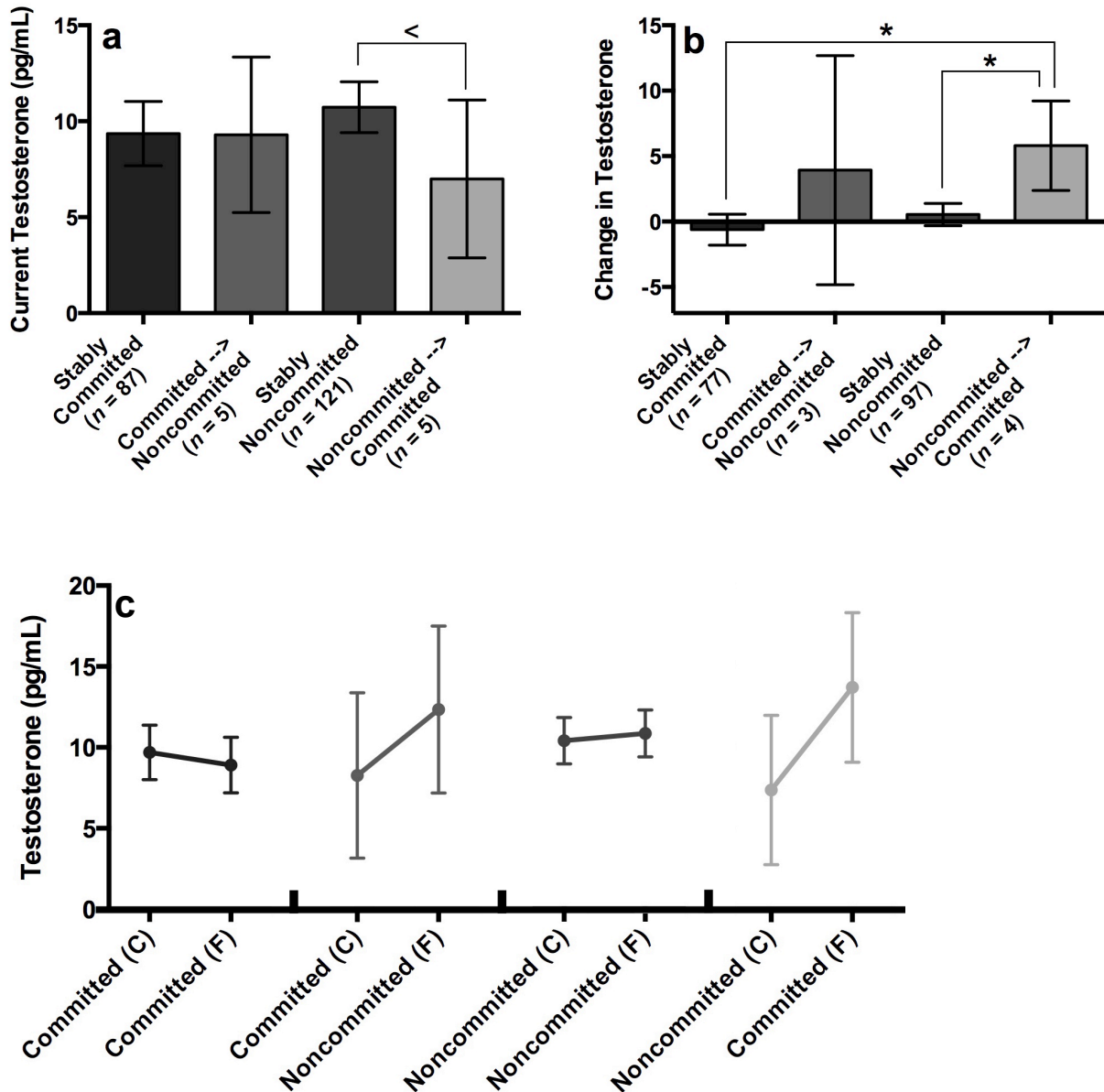
Figure 2.2. *Lower Testosterone Predicted Commitment, but Commitment Increased Testosterone.* Figures show *a)* Current testosterone and *b & c)* change in testosterone from the current to following session for women in the stably committed, committed → noncommitted, stably noncommitted, and noncommitted → committed groups, controlling for potential confounds. '*' indicates a significant difference at $p < 0.05$, and '<' indicates a trend at $p < 0.10$. Bars show 95% confidence intervals. *n*'s represent number of observations. In Figure 2.2c, C = current session and F = following session. *n*'s in 2.2c are identical to *n*'s in 2.2b.

Partner Number Was Not Linked With T

I checked whether number of partners was linked with T when women were casually partnered, given that this category could represent a casual relationship with one person ($n = 21$ observations) or more than one person ($n = 14$ observations). There was no significant difference in T based on being casually partnered with one partner ($M = 11.53$, $SE = 1.22$) versus multiple partners ($M = 9.32$, $SE = 1.51$), $\beta = 2.21$, 95% CI = [-1.64, 6.07], $z = 1.13$, $p > 0.250$. (Only one committed observation reported multiple partners.)

Masturbation Was Linked With Higher T

Table 2.4 shows the distribution of masturbation and dyadic sexual activity by relationship status.

Table 2.4
Masturbation and Dyadic Sexual Activity by Relationship Status

Current Relationship Status	Masturbation		Dyadic Sexual Activity	
	No	Yes	No	Yes
Single	94	25	105	23
Casual	27	8	4	34
Committed	85	29	16	101

Note. Numbers represent observations (not number of participants). The table includes only observations used in analyses (i.e., not excluded for medication use or having missing data for testosterone or control variables).

Controlling for relationship status and other potential confounds, engaging in masturbation in the past week predicted significantly higher T, $\beta = 2.32$, 95% CI = [0.79, 3.86], $z = 2.96$, $p = 0.003$ (see Table 2.5). Women's T was 24% higher during weeks when masturbation occurred than when masturbation did not occur (see Figure 2.3). When accounting for masturbation, women still had marginally higher T when single than when committed, $\beta = 1.62$, 95% CI = [-0.05, 3.29], $z = 1.90$, $p = 0.057$. I tested whether masturbation and relationship status interacted to predict T, but the interaction terms were not significant (single: $\beta = 0.19$, $p > 0.250$;

casually partnered: $\beta = -1.81$, $p > 0.250$), indicating that the positive link between masturbation and T was consistent across relationship statuses.

Did T predict future masturbation, or did masturbation predict future T? T was not significantly associated with either the next month's or the previous month's masturbation (see Table 2.5), indicating that the association between masturbation and T was tightly linked in time to the current session.

Finally, I checked whether more frequent current masturbation predicted higher current T within the "some masturbation" group. Overall, more frequent masturbation did not predict higher T, $\beta = -0.05$, $p > 0.250$. However, the distribution of masturbation frequency was highly skewed, with 87% of the "some masturbation" observations reporting one, two, or three instances of masturbation in the past week, and 12% reporting between four and ten instances. When considering only observations who reported one, two, or three instances of masturbation, the association was indeed in the expected direction. Women had higher T when they reported two instances, $\beta = 3.34$, 95% CI $= [-0.05, 6.74]$, $z = 1.93$, $p = 0.054$, or three instances, $\beta = 4.92$, 95% CI $= [0.64, 9.19]$, $z = 2.25$, $p = 0.024$, of masturbation in the past week than when they reported one instance of masturbation.

Table 2.5

Results of Linear Mixed Models Predicting Current Testosterone (T) From Current, Next Session's, or Previous Session's Masturbation and Control Variables

	β [CI]	*z* value	*p* value
Model 1: Current Masturbation			
Session	0.27 [0.10, 0.45]	3.06	0.002
HC	-4.59 [-6.38, -2.80]	-5.02	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-1.99	0.047
Single relationship status	1.62 [-0.05, 3.29]	1.90	0.057
Casual relationship status	1.30 [-0.78, 3.38]	1.22	0.222
Masturbation	2.32 [0.79, 3.86]	2.96	0.003
Model 2: Next Session's Masturbation			
Session	0.22 [-0.06, 0.51]	1.55	0.121
HC	-4.87 [-7.03, -2.71]	-4.42	<0.001
Sampling time	>-0.01 [>-0.01, <0.01]	-1.22	0.223
Single relationship status	1.00 [-1.01, 3.02]	0.98	0.329
Casual relationship status	0.57 [-1.97, 3.11]	0.44	0.660
Masturbation	0.60 [-1.11, 2.30]	0.69	0.491
Model 3: Previous Session's Masturbation			
Session	0.17 [-0.08, 0.43]	1.33	0.185
HC	-5.41 [-7.70, -3.13]	-4.64	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-2.32	0.020
Single relationship status	1.12 [-0.96, 3.21]	1.06	0.290
Casual relationship status	0.57 [-2.03, 3.17]	0.43	0.668
Masturbation	-0.26 [-2.12, 1.59]	-0.28	0.782

Note. Committed relationship was the reference category.
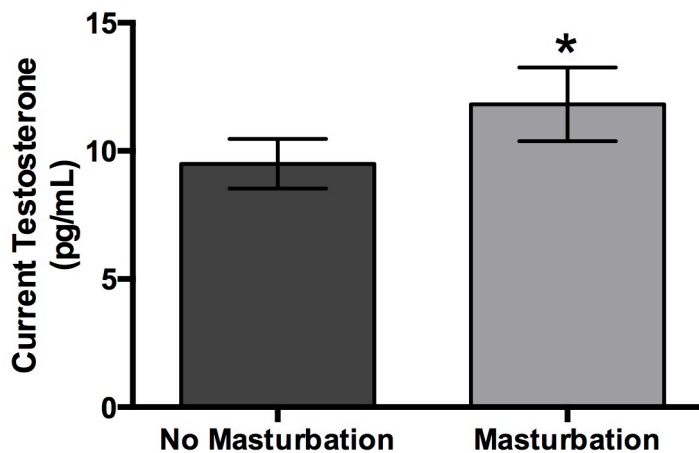
Figure 2.3. *Masturbation Was Linked With Higher Testosterone.* The figure shows current testosterone when women reported no masturbation versus some masturbation in the past week, controlling for potential confounds (session, HC use, sampling time, and relationship status). '*' indicates a significant difference at $p < 0.05$. Bars show 95% confidence intervals.

Dyadic Sexual Activity Predicted Lower T When Women Were Committed

Dyadic sexual activity significantly interacted with relationship status to predict T (see Table 2.6). Decomposing the interaction showed that being dyadically sexually active predicted significantly lower T, but only when women were in committed relationships ($p = 0.023$). Committed women's T was 26% lower when sexually active with a partner than when sexually inactive (see Figure 2.4). Furthermore, when considering only observations who were dyadically sexually active, women had significantly lower T when committed than when single ($p = 0.016$) or casually partnered ($p = 0.029$). But, when considering dyadically sexually inactive observations, women's T was marginally *higher* when committed than when casually partnered ($p = 0.083$) and commitment and singlehood did not significantly differ ($p = 0.364$). Thus, dyadic sexual activity predicted lower T for committed women specifically, and committed women had lower T than single or casually partnered women *only* when they were sexually active with a partner.

Among committed observations – for whom dyadic sexual activity was linked with lower T – I tested whether dyadic sexual activity predicted future T or vice versa. For women who were currently committed, being sexually active with a partner the previous month predicted significantly lower current T. However, current T was not significantly linked with future dyadic sexual activity (see Table 2.6). Thus, there was evidence that dyadic sexual activity predicted lower future T, but not vice versa.

Table 2.6

Results of Linear Mixed Models Predicting Current Testosterone (T) From Current, Next Session's, or Previous Session's Dyadic Sexual Activity and Control Variables

	β [CI]	z value	p value
Model 1: Current Dyadic Sexual Activity			
Session	0.22 [0.06, 0.39]	2.62	0.009
HC	-5.08 [-6.97, -3.20]	-5.29	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-2.40	0.016
Single relationship status	-1.36 [-4.28, 1.57]	-0.91	0.364
Casual relationship status	-4.60 [-9.79, 0.60]	-1.73	0.083
Dyadic sexual activity	-3.06 [-5.69, -0.43]	-2.28	0.023
Interaction terms			
Single*Dyadic activity	4.24 [0.79, 7.70]	2.41	0.016
Casual*Dyadic activity	7.01 [1.65, 12.38]	2.56	0.010
Model 2: Next Session's Dyadic Sexual Activity[a]			
Session	0.08 [-0.27, 0.42]	0.43	0.665
HC	-5.92 [-8.20, -3.65]	-5.11	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-3.06	0.002
Dyadic sexual activity	-0.86 [-3.34, 1.62]	-0.68	0.494
Model 3: Previous Session's Dyadic Sexual Activity[a]			
Session	0.11 [-0.20, 0.41]	0.68	0.496
HC	-5.26 [-7.81, -2.71]	-4.04	<0.001
Sampling time	>-0.01 [>-0.01, >-0.01]	-3.48	<0.001
Dyadic sexual activity	-3.37 [-5.78, -0.97]	-2.75	0.006

Note. Committed relationship was the reference category.

[a]Includes currently committed observations only
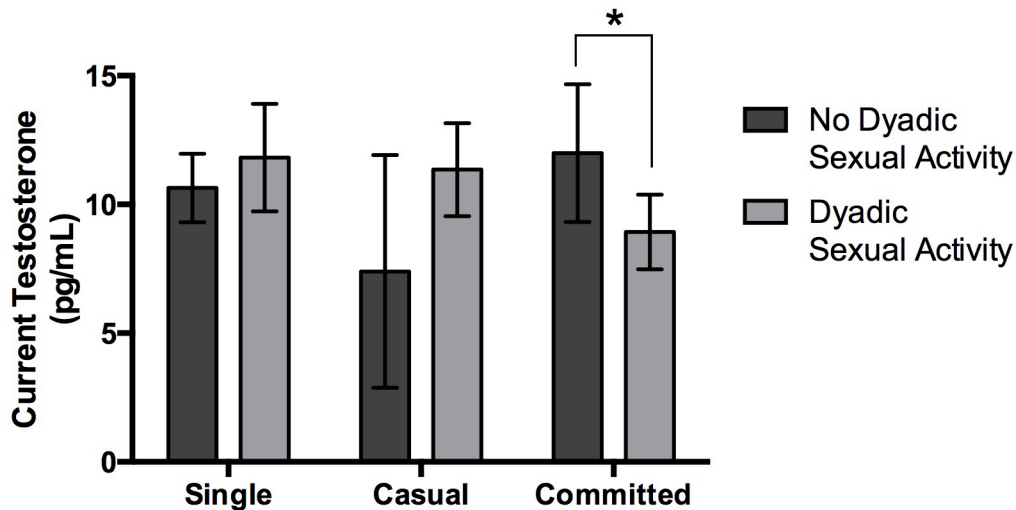
Figure 2.4. *Dyadic Sexual Activity Predicted Lower Testosterone When Women Were Committed.* The figure shows the interaction between relationship status and dyadic sexual activity to predict current testosterone, controlling for potential confounds (session, HC use, and sampling time). '*' indicates a significant difference at $p < 0.05$. Bars show 95% confidence intervals.

Discussion

Research on T and partnering primarily focuses on T as a mediator of tradeoffs between mating and parenting in men. By contrast, the S/P Theory predicts that higher T is linked with competitive aspects of partnering *and* lower T with nurturant aspects of partnering in women *and* men (van Anders et al., 2011; van Anders, 2013). Previous research had suggested that single women have higher T than women in committed relationships, but there were some mixed findings and directionality of the effect was unclear. Here, I used longitudinal data to show that women had marginally higher T when single than when in a committed relationship, and that relationship status and T were bidirectionally associated. Lower T predicted the transition into a committed relationship, and this transition was then followed by an increase in T. Dyadic sexual activity moderated T-partnering links, such that committed women only had lower T when they were sexually active with a partner. These results highlight the dynamic, reciprocal interplay between hormones and social relationships, specifically pair bonds.

Singlehood Is Linked With Marginally Higher T Than Commitment

This study is the first to demonstrate *within-person* evidence that singlehood is associated with marginally higher T than commitment in women. That is, my findings suggest that within an individual woman, periods of singlehood are associated with higher T than periods of commitment, supporting state interpretations of partnering-T links; however, this interpretation is qualified by the relatively small number of relationship transitions within my sample. Still, these findings support the S/P Theory by pointing to overarching similarities between women and men in the patterns of partnering-T links, with higher T among singles – who have a higher likelihood of seeking new partners – than among those in committed relationships.

Casual Relationships: A Heterogeneous Category?

In contrast to past findings (van Anders & Goldey, 2010), casual relationships did not significantly differ from commitment *or* singlehood in terms of T, and visually were more similar to singlehood. In the S/P Theory, relationship status labels are less meaningful for T than underlying competitive and nurturant emotions and behaviors (van Anders, 2013). Casual relationships could represent romantic dating relationships, friends-with-benefits relationships, one-night stands, or various combinations of all of these, such that any given casual relationship might fall within a wide range of the competition-nurturance continuum. Indeed, even casual sexual relationships (in the absence of dating) appear to be a more heterogeneous category than previously acknowledged in terms of the degree of nurturant intimacy (e.g., communication, self-disclosure, emotional connection, spending time together outside of sexual activity) and exclusivity (Mongeau, Knight, Williams, Eden, & Shaw, 2013; Wentland & Reissing, 2011). Thus, my findings raise questions about how different types of casual relationships might be linked with T in women.

Lower T Predicts Commitment, but Commitment Increases T

My main research question pertained to directionality of T-partnering links in women: does current T predict relationship status the following month, or vice versa? Past work was conflicting, such that lower T predicted future pair bonding, suggesting a 'trait' association (van Anders & Watson, 2006), yet state factors mediated partnering-T links (van Anders & Watson, 2007; van Anders & Goldey, 2010). My results resolve these controversies, as I found evidence for bidirectional links between T and relationship status. Thus, trait and state factors may additively contribute to lower T in pair bonded individuals and higher T in singles.

Although links between T and relationship status are bidirectional, the relative contribution of relationship orientation and status factors may depend on the specific relationship transition. My results confirm previous findings that lower T shortly precedes commitment (van Anders & Watson, 2006), while clarifying that higher T does not precede the transition from committed to single or casually partnered. Lower T predicting commitment could reflect a trait association, such that lower T individuals have characteristics that lead them to invest more in nurturant processes and less in competition for new partners. An alternative hypothesis, but one still consistent with trait explanations, is that individuals with lower T are more likely to be chosen as relationship partners. Women and men whose partners have lower T report higher relationship commitment and satisfaction (Edelstein, van Anders, Chopik, Goldey, & Wardecker, 2014), suggesting that choosing partners with lower T could be advantageous for maintaining long-term pair bonds in this cultural system. Finally, lower T predicting commitment the following month could reflect state processes that precede commitment, such as spending less effort seeking new partners or increasing desires for nurturant bonds. My results confirm that lower T predicts pair bonding in the short-term in women and suggest that both trait and state processes may be at play, given the bidirectional links between T and relationship status.

Although lower T predicted becoming committed, becoming committed *increased* T, in line with a past study showing higher T among women in the early stages of loving relationships (Marazziti & Canale, 2004). This previous study, together with my finding that commitment as a whole was linked with lower T, suggests that the T increase is transient and specific to relationship formation (Marazziti & Canale, 2004), such that new committed relationships may

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be distinct from established committed relationships in terms of T^2. If new relationships increase T, the S/P Theory yields the prediction that they involve some competitive aspects – and these might include eroticism and jealousy. In terms of eroticism, sexual thoughts increase T in women (Goldey & van Anders, 2011), and perhaps women in new relationships experience a higher frequency of sexual fantasies alongside more frequent dyadic sexual activity (Klusmann, 2002). An increase in fantasy may be especially likely to occur among women in new *committed* (as opposed to casual) relationships, given that women report higher sexual desire for relationship partners than strangers (Burke et al., under review) and that sexuality in general is more socially sanctioned for women within the context of committed romantic relationships than casual relationships (Levant, Rankin, Hall, Smalley, & Williams, 2012). Given negative links between dyadic sexual activity and T among committed women (see below), fantasy seems more likely than sexual activity itself to explain higher T among women in new committed relationships[3]. An additional possibility is that the increased T could be associated with jealousy or mate-guarding functions during the establishment of a new pair bond; imagining a jealousy-provoking situation increases T in partnered women (Ritchie & van Anders, 2015), supporting this interpretation. Of course, future research is needed to evaluate these hypotheses and clarify this result.

Masturbation Is Linked With Higher T, but Dyadic Sexual Activity With Lower T

Previous research has shown that women who engage in more frequent masturbation have higher T and those who engage in more frequent dyadic sexual activity have lower T (van

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[2] Additionally, T levels for newly committed observations ($M = 13.80$, 95% CI = [9.26, 18.33]) increased above absolute levels for the stably committed group ($M = 8.89$, 95% CI = [7.20, 10.59] ($p = 0.042$), suggesting that the increase was not simply an artifact of lower levels of T prior to commitment.

[3] Alternatively, links between dyadic sexual activity and T may differ for women in new versus established committed relationships, as they differ for women in casual versus committed relationships. In general, the ways in which new committed relationships might be distinct from casual relationships *and* established committed relationships remains an exciting question that could be further addressed by future studies with larger sample sizes for each relationship category.

Anders, Hamilton, Schmidt et al., 2007; van Anders & Goldey, 2010), and here I extend these findings by showing similar *within-person* associations between T and sexuality. Specifically, women's T was about 25% higher when they had engaged in masturbation in the past week than when they had not, but among committed women, T was about 25% *lower* when they had been dyadically sexually active in the past month than when they had not. These findings demonstrate the dynamic, responsive properties of T-sexuality associations, such that within-person fluctuations in masturbation and dyadic sexual activity are linked with fluctuations in T. My results also support understandings of solitary and dyadic sexuality as distinct constructs (van Anders, 2015); solitary masturbation may be linked with higher T because it is experienced as erotic (i.e., oriented around genital pleasure, orgasm, etc.), whereas dyadic sexual activity may be linked with lower T because it is experienced as nurturant (i.e., oriented around intimacy, closeness, etc.) (van Anders, 2013).

Although masturbation was linked with higher T across relationship statuses, masturbation did not account for T-partnering links, which makes sense given that engagement in masturbation was similarly likely (or unlikely) when women were single, casually partnered, or committed (see Table 2.4). However, dyadic sexual activity moderated partnering-T links, such that committed women had lower T than single or casually partnered women *only* when they were sexually active with a partner. And, dyadic sexual activity was linked with lower T *only* when women were committed, highlighting the importance of considering pair bonding and sexuality together when predicting T. Dyadic sexual activity may be linked with lower T specifically within pair bonds because dyadic sexuality may be more likely to serve nurturant functions in this context (though of course, sexuality may not always be experienced as nurturant

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within pair bonds, and could also be experienced as nurturant outside of pair bonds) (Goldey &

van Anders, 2015; van Anders, 2013).

Dyadic sexual activity predicted future T but T did not predict future dyadic sexual

activity, suggesting stronger downstream effects of sexual activity on T than vice versa.

Interestingly, dyadic sexual activity acutely increases T from pre-activity to 15-min post-activity

in partnered women (Dabbs & Mohammed, 1992; van Anders, Hamilton, Schmidt et al., 2007),

but in the longer-term translates to lower T. Differential effects of dyadic sexual activity on T in

the short-term versus longer-term may help explain why sexual activity facilitates pair bonding,

even as it acutely increases T, which inhibits nurturance (van Anders et al., 2011). My results

also suggest nuances by gender/sex in how pair bonding and sexuality interact to affect T – in

men, more frequent dyadic sexual activity *attenuates* declines in T during the transition to pair

bonding and parenthood (Gettler et al., 2013). Elucidating the specific mechanisms for

differential effects of dyadic sexual activity on T in the shorter- versus longer-term and by

gender/sex remains an exciting direction for future research. For example, my findings raise the

question of whether sexual desire might underlie links between sexual behavior and T or vice

versa, given that solitary desire is linked with higher T and dyadic desire with lower T in women

(van Anders, 2012b). Finally, I found that T was associated with the current session's

masturbation but not with masturbation at the previous or next session, such that directionality of

this association remains an open question. Future studies could measure T and masturbation over

shorter time scales (e.g., weeks or days rather than approximately monthly sessions) to clarify

whether T predicts future masturbation or vice versa.

Limitations, Future Directions, and Conclusions

An important caveat in interpreting my results concerns the small number of observations that transitioned relationship statuses on a session-to-session basis. Despite these small sample sizes, my findings align with those of several previous studies as described above (Marazziti & Canale, 2004; van Anders & Watson, 2006; van Anders & Goldey, 2010), and my study is unique in examining month-to-month associations between T and partnering in women. Interestingly, the relative infrequency of relationship status transitions in my sample points to the college transition as a period characterized by greater stability in relationships (or singlehood) than might be assumed (e.g., Bogle, 2008). Furthermore, because I collected data on relationship *statuses* rather than specific partnerships, it is unclear whether all participants classified as stably committed remained with the same relationship partner between sessions (and what the potential implications of a rapid transition from one committed relationship to another might be for T). In addition, because of the distribution of responses for masturbation and the nature of the survey items for dyadic sexual activity, I was only able to examine effects of some versus no sexual activity rather than nuances by sexual frequency. Finally, my findings raise questions about the extent to which the directionality of T-relationship status and T-sexuality links would be similar or different among sexual minority women (van Anders & Watson, 2006) or among a wider age range.

My results provide longitudinal evidence that associations between pair bonding and T in women are best understood as bidirectional, and specifically that lower T predicts pair bonding, while new committed relationships increase T. Findings support the existence of tradeoffs in women (and not just in men) between seeking new partners and maintaining nurturant pair bonds as per the S/P Theory. Sexuality and pair bonding interact to predict T, such that dyadic sexual

activity is linked with lower T only when women are pair bonded, though masturbation is linked with higher T across relationship statuses. Promising directions for future research include investigating how specific subtypes of casual relationships are linked with T, how eroticism and jealousy-related variables might explain increases in T among women in new committed relationships, and how differential experiences of solitary and dyadic sexuality (e.g., as erotic versus nurturant) underlie their associations with T.

CHAPTER 3

DEFINING PLEASURE: A FOCUS GROUP STUDY OF SOLITARY AND DYADIC SEXUAL PLEASURE IN QUEER AND HETEROSEXUAL WOMEN

Introduction

Solitary sexuality (i.e., being sexual alone, including solo masturbation, fantasy, erotica use, etc.) and dyadic sexuality (i.e., being sexual with a partner) are typically understood as different manifestations of the same underlying phenomenon. Both are commonly thought to reflect an individual's characteristic level of sex drive, which can be expressed with a partner, or, in the absence of a partner, via masturbation (Laumann et al., 1994; van Anders, 2015). Historically, both are assumed to be oriented around the same goal – experiencing orgasm (Kinsey, Pomeroy, Martin, & Gebhard, 1953; Masters & Johnson, 1966; Whalen, 1966) (reviewed in Spector et al., 1996; Tiefer, 2004). In these ways, solitary sexuality is conceptualized as "partnered sexuality minus the partner" (van Anders, 2015), or as a less complex and less context-dependent substitute for dyadic sexuality.

The idea that solitary and dyadic sexuality are fundamentally the same persists despite empirical evidence to the contrary. Solitary and dyadic sexuality have been shown to differ in several important ways. First, research suggests that sexual desire can be separated into solitary and dyadic components, which are only moderately intercorrelated (Spector et al., 1996; van Anders, 2012b). Solitary and dyadic desire differ on parameters such as gender-specificity (i.e., sensitivity to gender/sex of target) (Dawson & Chivers, 2014) and malleability in response to sexual cues (Goldey & van Anders, 2012a). Second, responses to sexual media differ when alone

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compared to when with a partner. Specifically, solitary and dyadic erotica use were differentially associated with relationship satisfaction in heterosexual couples (Bridges & Morokoff, 2011), and the mere presence of a partner affected women's and men's genital and self-reported arousal to visual erotica in a laboratory setting (van Lankveld et al., 2014). Third, although research suggests substantial overlap in sensory experiences of solitary and dyadic orgasms, cognitive-affective experiences of orgasm differ based on solitary versus dyadic context (Mah & Binik, 2002).

A further way that solitary and dyadic sexuality differ is in their associations with testosterone (T) in women. T is often assumed to be positively correlated with sexuality (including sexual desire, behavior, etc.) (reviewed in van Anders, 2013). In actuality, associations between T and sexuality differ based on the context as solitary or dyadic, at least in women. Whereas solitary sexuality has consistently been linked with higher T, dyadic sexuality has been linked with *lower* T – challenging assumptions that sexuality is always tied to higher T. Specifically, women with higher T report higher solitary sexual desire and more frequent solitary orgasms (van Anders, Hamilton, Schmidt et al., 2007; van Anders, 2012b). By contrast, women with *lower* T report higher dyadic sexual desire and more frequent dyadic sexual activity (van Anders & Goldey, 2010; van Anders, 2012b). These associations extend to a within-person context, such that young women have higher T at times when they have recently engaged in masturbation, but lower T when they have been sexually active with a partner in the past month (Goldey, Conley, & van Anders, in preparation; see Chapter 2). Together, these results suggest that solitary sexuality is linked with higher T and dyadic sexuality with lower T in two domains: desire and behavior.

Why would T be linked with solitary and dyadic sexuality in different ways? In the Steroid/Peptide Theory of Social Bonds (S/P Theory) (van Anders et al., 2011; van Anders, 2013), van Anders et al. propose that sexuality is a non-uniform context in terms of its link with T, because sexuality has multiple subcomponents that would be differentially linked with T. Sexuality oriented around eroticism – that is, genital/erotic pleasure, orgasm, power, or jealousy – is hypothesized to be linked with higher T, whereas sexuality oriented around nurturance – for example, pair bonding or closeness – is hypothesized to be linked with lower T. These predictions are supported within the domain of sexual desire: among women, higher desire to fantasize or to experience desire for its own sake (i.e., erotic desire) predicts higher T, whereas higher desire to make a partner feel emotionally closer (i.e., nurturant desire) predicts lower T (Burke et al., under review).

Differential associations with T are particularly useful for understanding how and why solitary and dyadic sexuality may represent distinct sets of experiences. The S/P Theory states that T responses (or associations with T) can be used to categorize difficult-to-classify behavioral contexts in terms of their ultimate (i.e., evolved) function (van Anders et al., 2011). That is, the S/P Theory predicts that sexual contexts that increase T (or are linked with higher T) can be classified as erotic, and those that decrease T (or are linked with lower T) can be classified as nurturant (van Anders, 2013). Therefore, based on links with T, solitary sexual desire and behavior would be classified as erotic, and dyadic sexual desire and behavior as nurturant. Some research supports these classifications: for women, masturbation is about 25% more likely to consistently result in orgasm than dyadic sexual activity (Laumann et al., 1994; Wade, Kremer, & Brown, 2005). The discrepancy may be especially large for heterosexual women, who have lower dyadic orgasm rates than lesbian women (Garcia, Lloyd, Wallen, & Fisher, 2014) and who

have comprised the majority of participants in studies of T and solitary and dyadic sexuality. Thus, at face value, dyadic sexuality may be less likely to map onto genital/erotic pleasure for (heterosexual) women than solitary sexuality (van Anders, 2013). A major gap remains, however, in our understanding of how solitary and dyadic sexual pleasure are experienced by women themselves. Though we know that orgasm rates for these two contexts differ, do women experience solitary and dyadic sexuality as involving different pleasures, or is solitary sexuality simply a substitute or stand-in for dyadic sexuality when a partner is unavailable? If women experience solitary pleasure as primarily erotic and dyadic pleasure as primarily nurturant, this could help explain why solitary and dyadic sexuality are associated with T in different ways.

Why focus on *pleasure*, when solitary versus dyadic sexual experiences could also be studied in a number of other domains? Previous research has addressed definitional complexity within sexual desire, arousal, and satisfaction (albeit mainly focusing on dyadic sexuality) (Burke et al., under review; Graham, Sanders, Milhausen, & McBride, 2004; Mark, Fortenberry, Herbenick, Sanders, & Reece, 2014; McClelland, 2011, 2013; Pascoal, Narciso, & Pereira, 2014). However, the meaning of sexual pleasure is often taken for granted as synonymous with orgasm – despite evidence that, although orgasm might be *one* element of pleasure, individuals do not consider pleasure and orgasm synonymous (Opperman, Braun, Clarke, & Rogers, 2014; Pascoal et al., 2014). Understanding complexity in meanings of pleasure has important applications for sexual health and well-being. Increasingly, the potential for pleasure, rather than simply the absence of sexual problems or dysfunction, has been acknowledged as key to sexual health (World Health Organization, 2006). Yet, a dearth of information on the meanings of sexual pleasure to individuals themselves makes it challenging to promote pleasure as an outcome (World Health Organization, 2010) (see also Pascoal et al., 2014). If pleasure is

experienced differently based on the context as solitary or dyadic, this suggests the need for multiple context-dependent definitions of pleasure as a sexual health outcome, rather than a simplistic understanding of pleasure as equivalent to orgasm.

Finally, pleasure may be an especially relevant construct for understanding sexuality-T links and the neurobiology of sexuality more broadly. Neural mechanisms responsible for sexual pleasure are highly conserved among humans and other animals (Berridge & Kringelbach, 2008; Georgiadis, Kringelbach, & Pfaus, 2012). These neural mechanisms are similar to those underlying other pleasures (e.g., eating), but distinct from those underlying desire or 'wanting' (Berridge & Kringelbach, 2008; Georgiadis et al., 2012). Some neural structures that appear to code for pleasure, like the orbitofrontal cortex, are androgen-sensitive (Berridge & Kringelbach, 2008; Finley & Kritzer, 1999), and T has also been shown to have reinforcing properties (Wood, 2004). In sexual contexts specifically, T has been linked with experiences that appear pleasurable at face value, such as relaxing orgasm experiences[1] (van Anders & Dunn, 2009). Based partly on these findings, some researchers have hypothesized that T is released in sexual and other social situations only (or especially) when individuals anticipate or experience pleasure (Chichinadze, Lazarashvili, Chichinadze, & Gachechiladze, 2012; van Anders, 2013). Therefore, differences in how *pleasure* is experienced might be especially relevant to understanding differential associations of solitary and dyadic sexuality with T.

Below, I review existing research on women's experiences of solitary and dyadic sexuality, and I then present the results of a qualitative study on how women define sexual pleasure in solitary and dyadic contexts. I discuss the implications of my findings for

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[1] Although, as discussed above, research is needed to clarify to what extent orgasms are as central to definitions of pleasure as commonly assumed.

understanding why solitary and dyadic sexuality are linked with T in different ways, as well as for sexual health and well-being more broadly.

Women's Experiences of Solitary Sexual Pleasure

Existing research has not specifically addressed how women define solitary sexual pleasure, but some studies have focused on describing one solitary sexual behavior, masturbation, in women. Much of this research has focused on masturbation prevalence or frequency, and researchers have argued for an increased focus on the diversity of experiences of masturbation, with attention to its historical context as a stigmatized behavior, especially for women (Coleman, 2003; Tiefer, 1998). Qualitative research on masturbation, which has focused primarily on young women, highlights tensions between masturbation as pleasurable and masturbation as taboo. For example, young women were more likely than young men to feel conflicted about masturbation and less likely to describe benefits of masturbation, such as self-discovery, improved communication with relationship partners, and an alternative to riskier sexual activities (Kaestle & Allen, 2011). Some young (16-18 year old) heterosexual women described sexual pleasure as something that should only occur with a male partner, rendering masturbation taboo or unnecessary (Hogarth & Ingham, 2009). In a sample of Chinese women aged 22-39, most described masturbation as healthy, but some women simultaneously felt the need to justify engaging in masturbation (e.g., as a way to enhance dyadic intimacy) or to assert that they did not need masturbation because they were in a sexual relationship (Yuxin & Ho Sik Ying, 2009). Taken together, this research reveals variation in (young) women's narratives of masturbation and highlights the extent to which the pleasure of masturbation is intertwined with cultural stigma surrounding this behavior. However, *what* exactly women identify as pleasurable

about masturbation is often taken for granted – is it just orgasm, or are other dimensions important to solitary sexual pleasure?

In contrast to the gap in knowledge about the ways solitary pleasure is experienced by women, we do know that women endorse a myriad of motivations for masturbation. These include experiencing orgasm but also experiencing physical pleasure, relief of sexual tension, feelings of self-affirmation and agency, stress relief or relaxation, and knowledge about one's body (Bowman, 2014; Carvalheira & Leal, 2013; Fahs & Frank, 2014; Laumann et al., 1994). To the extent that motivations for masturbation parallel its pleasures, these findings suggest that masturbation may involve both physical and emotional pleasures, but its pleasures may be largely *self*-oriented – perhaps in contrast to dyadic sexuality (see below). Although some women agree that masturbation serves as a substitute for when sexual partners are unavailable (Bowman, 2014; Laumann et al., 1994), masturbation likely also complements dyadic sexuality: women report more frequent masturbation when having *more* frequent and varied dyadic sexual activity (Carvalheira & Leal, 2013; Gerressu, Mercer, Graham, Wellings, & Johnson, 2008). In sum, research to date presents women's masturbation as a complex form of sexual expression rather than a simple substitute for dyadic sex. However, questions remain about the meanings of pleasure within solitary sexual contexts (and to what extent these overlap with definitions of dyadic pleasure), how masturbation might be intertwined with other potentially solitary sexual activities (e.g., erotica use, fantasy), and how solitary pleasure is experienced among sexual minority women and women beyond young adulthood (cf. Fahs & Frank, 2014).

Women's Experiences of Dyadic Sexual Pleasure

Research on dyadic sexual pleasure has largely focused on the meanings surrounding orgasm. On one hand, women and men describe orgasm as the pinnacle of pleasure, such that

dyadic activity is still pleasurable without orgasm, but less intensely so (Opperman et al., 2014). Yet, women (and men) typically prioritize their partner's orgasm above their own, and women view their own orgasm as important *for their partners* (i.e., to communicate their enjoyment of a sexual experience) more so than for their own pleasure (Fahs, 2011; Nicolson & Burr, 2003; Opperman et al., 2014). And, although women and men rate masturbation and dyadic intercourse as similarly fun and sexually satisfying, intercourse is rated as inducing more happiness and passion – despite masturbation being more likely to result in orgasm for women (Dekker & Schmidt, 2003). This suggests that there may be elements of pleasure beyond orgasm that are unique to dyadic sexuality, but what are these elements?

Although most research has not explicitly focused on defining pleasure but on related constructs (e.g., sexual satisfaction, arousal, or desire), this work has highlighted the importance of the partner's experience to individuals' own sexual experiences. When defining satisfaction, some women and queer men used their partner's satisfaction as a proxy for their own (McClelland, 2011). In a sample of heterosexual women and men in committed relationships, almost half referenced pleasure in their definitions of sexual satisfaction; importantly, pleasure was often intertwined with positive emotional feelings and mutuality (i.e., reciprocity) but clearly differentiated from orgasm (Pascoal et al., 2014). Similarly, emotional connectedness with a partner has been identified as a key component of women's sexual satisfaction (McClelland, 2013), dyadic sexual desire (Burke et al., under review), and peak sexual experiences (Fahs, 2011), and women state that feeling desired by a partner enhances their own arousal (Graham et al., 2004). Thus, there is reason to believe that dyadic pleasure, like dyadic satisfaction and desire, could involve nurturant elements – e.g., forming or maintaining a bond with a partner, and focusing on a partner's sexual needs.

Importantly, intimacy and physical pleasure are often intertwined in women's descriptions of their dyadic sexual experiences, such that eroticism and nurturance sometimes blur together. Allen (2002) found that young heterosexual women's descriptions of achieving intimacy and closeness via dyadic sexuality were often interconnected with descriptions of physical pleasure and touch. In Fahs' (2011) research, women identified their partner's attentiveness as important because it often led to their own intense physical pleasure. Relatedly, women described dyadic orgasms as involving intense bodily sensations but also intimacy and connection (Fahs, 2014) (see also Mah & Binik, 2005). These findings highlight the 'trickiness' of dyadic sexuality in terms of its classification as erotic or nurturant, such that both aspects may be present and difficult to separate. Overall, existing research on desire, arousal, and satisfaction suggests that emotional connection and a partner's pleasure are often central to women's dyadic sexual experiences, but the importance of orgasm and other physical pleasures should not be overlooked. And, as with sexual arousal, definitions of pleasure likely vary between individuals and based on context (e.g., casual vs. committed relationship) (Graham et al., 2004).

Social Location and Pleasure

Past research on pleasure and related constructs has generally focused on samples that were young on average and/or almost exclusively heterosexual (for important exceptions, see Fahs, 2011, 2014; Fahs & Frank, 2014; Graham et al., 2004; McClelland, 2011, 2013). However, there are reasons to think that sexual identity could be an important factor in experiences of pleasure: in quantitative research, sexual minority women scored higher than heterosexual women on measures of entitlement to pleasure from themselves and from a partner (Horne & Zimmer-Gembeck, 2006). This may be due to social scripts that prioritize men's sexual pleasure (Fahs, 2011), which could be especially salient for heterosexual women or women with male

partners. With regards to age, research demonstrates large individual differences in midlife and older lesbian, bisexual, and heterosexual women's experiences of sexuality (Garnets & Peplau, 2006; Hinchliff, Gott, & Ingleton, 2010; Montemurro & Gillen, 2013; Vares, Potts, Gavey, & Grace, 2007). Some women report a diminished importance or enjoyment of sexuality with age, often attributed to increased family responsibilities, menopause, or body image issues. By contrast, others report that greater self-acceptance, comfort with masturbation, self-knowledge, or openness contributed to positive shifts in their sexual enjoyment over time.

Importantly, differential links between solitary versus dyadic sexuality and T have been shown for specific demographic groups – e.g., young, heterosexual women (Goldey et al., in preparation) – and it is unknown to what extent these results apply to other populations. Thus, to the extent that social location shapes experiences of sexual pleasure, it may also be meaningful for how T is linked with solitary and dyadic sexuality. I focus on sexual identity and age in my analysis, although of course other social location variables, such as religion, education, SES, race/ethnicity, and disability status, may be equally or more important to experiences of pleasure (e.g., Laumann et al., 1994).

A Qualitative, Phenomenological Approach

The current study explored how queer and heterosexual women across a broad age range defined sexual pleasure during solitary and dyadic situations. To address my research questions, I used a phenomenological approach, meaning that I focused on participants' lived experiences and their interpretations of these experiences (Frost, McClelland, Clark, & Boylan, 2013). Consistent with this approach, I used qualitative methods of data collection (i.e., focus groups) and analysis (i.e., thematic analysis, described further below). These methods are useful for understanding the meanings participants themselves make of their sexual experiences, for

identifying global themes across participants in definitions of sexual pleasure, and for capturing

variation within and across individuals (Frost et al., 2013). Phenomenological methods typically

do not quantify strength or directionality of associations between variables (Frost et al., 2013),

but they are often used to generate hypotheses that can be tested in future quantitative research.

With this approach in mind, the current study addressed the following research questions:

(1a): How do women define sexual pleasure?

(1b): How do women's definitions of pleasure overlap and diverge when considering solitary

versus dyadic sexuality?

(2a): How might experiences of pleasure be similar or different based on sexual identity?

(2b): How might experiences of pleasure be similar or different across age groups?

Method

Participants

Participants were recruited via posters, Craigslist advertisements, and listservs (especially

LGBTQ student and community listservs). To be eligible for the study, women were required to

be comfortable speaking English, to have previous experience with solitary masturbation and

partnered sexuality (defined as contact involving the participant's or partner's genitals), to not

have experienced abuse or intimate partner violence from any current partners, and to be

comfortable discussing sexual topics. I conducted 13 focus groups with a total of 73 participants

(72 women, 1 bigender participant). Participants were diverse by age, sexual identity, and

relationship status and moderately diverse by race/ethnicity, and as a whole they were highly

educated (see Table 3.1). On average, participants reported engaging in masturbation about 8

times in the past month ($M = 7.62$, $SD = 7.45$, $range = 0\text{-}30$) and most participants ($n = 50$) had

at least one current sexual partner.

Table 3.1

Participant Characteristics

Demographic	N (%)
Age	73
18-24	30 (41%)
25-40	22 (30%)
41-64	21 (29%)
Sexual identity	73
Bisexual	12 (16%)
Gay	1 (1%)
Heterosexual	40 (55%)
Lesbian	13 (18%)
Queer	7 (10%)
Race/ethnicity[a]	67
African American/Black	5 (7%)
Asian/Indian	6 (9%)
Latina/Hispanic	2 (3%)
Multiracial	7 (10%)
White	46 (69%)
Other	1 (1%)
Relationship status[b]	72
Single (no sexual or romantic contacts)	12 (17%)
Single (no relationships, some sexual contacts)	9 (13%)
Dating	11 (15%)
Committed relationship	28 (39%)
Married/Common law/Life partnership	12 (17%)
Education	73
High school graduate	1 (1%)
Some college	29 (40%)
Graduated 2-year college	3 (4%)
Graduated 4-year college	12 (16%)
Some graduate or professional school	12 (16%)
Masters, professional, or doctoral degree	16 (22%)

[a]We categorized participants' responses to an open-ended item
[b]Participants indicated their relationship status based on definitions I provided

I made the decision to match groups by age range (18-24, 25-40, or 41+) and sexual identity (Graham et al., 2004). Because of resource constraints, I was limited to offering two sexual identity groups – a lesbian/queer group and a heterosexual group – with bisexual women given the option to select which of these groups they preferred to participate in (or no preference). Thus, I had two groups each of LBQ women ages 18-24 ($n = 7$ and $n = 6$),

heterosexual/bisexual women ages 18-24 (both $n = 9$), LBQ women ages 25-40 ($n = 6$ and $n = 3$), heterosexual/bisexual women ages 25-40 ($n = 5$ and $n = 6$), and LBQ women ages 41+ (both $n = 4$), and three groups of heterosexual/bisexual women ages 41+ (two groups: $n = 4$, one group: $n = 6$)[2,3]. Nine bisexual individuals participated in LBQ groups, and three bisexual individuals participated in heterosexual/bisexual groups.

Procedure

Upon emailing the researchers to express interest in the study, participants were provided with a link to an online background questionnaire, which included items to verify eligibility, demographic questions, and a few items about sexuality and relationships. Eligible participants were invited to participate in a 2-hour focus group session at the University of Michigan Psychology Department. Sessions were moderated by two female graduate students, and for some sessions a female research assistant was also present to facilitate registration and note-taking. Upon arrival, participants read and signed an informed consent form. Each participant was given a nametag and told that she was welcome to use a pseudonym if she preferred. Some focus groups (particularly LBQ sessions) included individuals who were clearly known to one another. Participants were instructed that they were welcome to leave or reschedule if they preferred not to participate with individuals they knew, but no participants opted to reschedule for this reason.

Participants were told that the purpose of the focus group was to gather data on how women define and experience sexual pleasure. Solitary sexuality was defined for participants as being sexual by yourself, with examples of masturbating, fantasizing, or viewing erotica alone.

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[2] I held an additional session for this category because one group ran out of time before moderators addressed all of the main questions.

[3] One 26-year-old participant elected to attend an 18-24 session because she was a current undergraduate student, and one 39-year-old participant attended a 41+ session due to scheduling issues.

Partnered (dyadic) sexuality was defined as anything sexual that involves interaction with another person, with examples of sexual activity with a partner, masturbating or viewing erotica with a partner present, or having a sexual conversation with another person. Discussions followed a semi-structured guide (see Appendix 3.1 for an outline), with general topics including (a) factors participants identified as pleasurable about partnered sexuality, (b) factors participants identified as pleasurable about solitary sexuality, and (c) comparing and contrasting solitary and partnered pleasure. The sequence and wording of questions was flexible and moderators allowed discussions to follow topics generated by participants, which meant that not every question in Appendix 3.1 was necessarily asked in every session. Sessions were recorded using two digital audio recorders.

To facilitate discussion, participants completed a Venn Diagram activity to visually indicate the degree of overlap they experienced between solitary and partnered pleasure. Each participant was asked to arrange two cut-out circles, one labeled "Solitary Sexual Pleasure" and one labeled "Partnered Sexual Pleasure", to represent her answer to the following question: To what extent are the things you find pleasurable about solitary sexuality the same or different as the things you find pleasurable about partnered sexuality? Participants could select one of 11 pre-marked positions, ranging from no overlap to complete overlap between solitary and partnered pleasure. A moderator scored the activities such that *1 = Most overlap* and *11 = Least overlap* (see Appendix 3.1 for an example and visual aid).

At the conclusion of the session, participants were provided with a feedback form on which they were given the option to provide suggestions for future sessions and/or to note any information relevant to the discussion topics that they did not have time to share or were not

comfortable disclosing to the group[4]. Participants were then compensated with $20 or $25 (for age 41+ groups, I increased compensation to facilitate recruitment).

Analysis

Trained research assistants transcribed focus groups using ExpressScribe software. Research assistants were instructed to transcribe the sessions 'verbatim' as much as possible and to avoid editing or 'tidying up' speech. All transcripts were checked at least once for accuracy.

I analyzed the data using thematic analysis, a method for organizing qualitative data into categories, or themes, that describe the data (Boyatzis, 1998; Braun & Clarke, 2006). I followed the inductive approach of Boyatzis (1998), while also incorporating aspects of thematic analysis methods outlined by other authors (Braun & Clarke, 2006; Fereday & Muir-Cochrane, 2008; Frost et al., 2013; Graham et al., 2004). Data analysis began before data collection was completed and thus was an iterative process. First, two authors independently read the first eight transcripts (which included the 18-24 and 25-40 age groups) and summarized participants' responses to each discussion question in each transcript. Both authors compiled a list of preliminary themes based on these summaries, and the two authors compared and discussed their preliminary themes in order to develop a coding scheme for applying themes to specific data extracts. For each theme, the coding scheme included a name, definition, indicators for when the theme occurs, examples, and exclusions (i.e., when not to code for the theme) (Boyatzis, 1998).

During the coding phase, I used NVivo software to assist with coding and organization of data. To establish the reliability of the coding scheme, two authors (one of whom was uninvolved in the initial development of the coding scheme) coded a subset of the transcripts (Fereday & Muir-Cochrane, 2008) and compared their coding after each transcript. This was an

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[4] Participants at one session did not complete feedback forms due to time limitations.

iterative process that involved revision of the coding scheme after each round of coding, ranging from clarification of definitions to restructuring of themes. The two authors coded largely independently, though when new types of content potentially relevant to a theme arose, the authors discussed if/how this content fit into the theme. Coding disagreements were resolved through discussion. After reliability was established for each theme (greater than or equal to 80% agreement on presence, with a participant's turn of speech used as the unit of coding), the first author coded the remainder of transcripts independently. Across themes ($n = 19$), reliability (percentage agreement on presence) averaged 83.6%, with a range of 80.0% to 89.4%.[5]

I made the decision to diversify the sample by including women ages 41+ after data analysis had already begun; overlap of data collection and analysis stages is common and even recommended in focus group research (Morgan, Fellows, & Guevara, 2008). After the five sessions with participants 41+ were completed, the first author read these transcripts to check for the presence of any unique themes not evident in the previous sessions. After discussion with the senior author, I decided to code all transcripts for one additional theme, Shifts Over Time. Two coders established reliability of Shifts Over Time, and the first author then coded this theme across all transcripts and the other themes in the 41+ transcripts independently.

In the final stage of analysis, the first author reviewed the data to create the final thematic map. This process involved selecting which themes to include in the map, developing subthemes where appropriate, and choosing data extracts to present. In the results section, quotations are identified by the participant's sexual identity and the age category of the focus group session they participated in. To aid readability, some brief interjections from moderators or participants

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[5] An exception to this coding method was used to identify segments of discussion relevant to orgasms. Here, I used the Text Search Query function of NVivo to code for the word "orgasm" and synonyms (e.g., climax, come, get off). The first author read excerpts identified by the Text Search Query to eliminate any coding of potential synonyms of orgasm used in other contexts.

(e.g., "mhm", "yeah") have been deleted from quotations. When some of a participant's speech is omitted, […] is used to indicate this.

Results

Quantitative Results: How Similar or Different Are Solitary and Dyadic Pleasure?

Participants' Venn Diagram activities completed at the beginning of the session showed that, on average, participants considered solitary and dyadic pleasure fairly distinct. The mean score on the activity was 8.19 (*SD* = 1.79, *range* = 3-11), where a score of 1 represents complete similarity and 11 represents complete difference, and this mean score significantly differed from the midpoint of 6, $t(71) = 10.41$, $p < 0.001$. Notably, no participants indicated that they felt solitary and dyadic pleasure were completely similar, whereas 12.5% of participants selected option 11, indicating complete difference. Evaluations of the similarity of solitary and dyadic pleasure did not differ by sexual identity group (LBQ or heterosexual/bisexual), $F(1, 66) = 0.83$, $p = 0.366$, $\eta_p^2 = 0.01$, or age group, $F(2, 66) = 2.04$, $p = 0.138$, $\eta_p^2 = 0.06$, nor was there an interaction between the two, $F(2, 66) = 0.62$, $p = 0.540$, $\eta_p^2 = 0.02$. After the focus group discussions, participants indicated significantly more separation between solitary and dyadic pleasure than before, $t(71) = 2.92$, $p = 0.005$, though mean differences from before to after the session were very small (post session: $M = 8.60$, $SD = 1.75$, *range* = 3-11).

Qualitative Results: In What Ways Are Solitary and Dyadic Pleasure Similar and Different?

Figure 3.1 shows the complete thematic map representing participants' definitions of solitary and dyadic pleasure; these themes were common across age and sexual identity groups. In the results that follow, I describe several of the most prominent themes for solitary and dyadic

pleasure in detail. I then briefly discuss nuances in experiences of pleasure by sexual identity and

age.
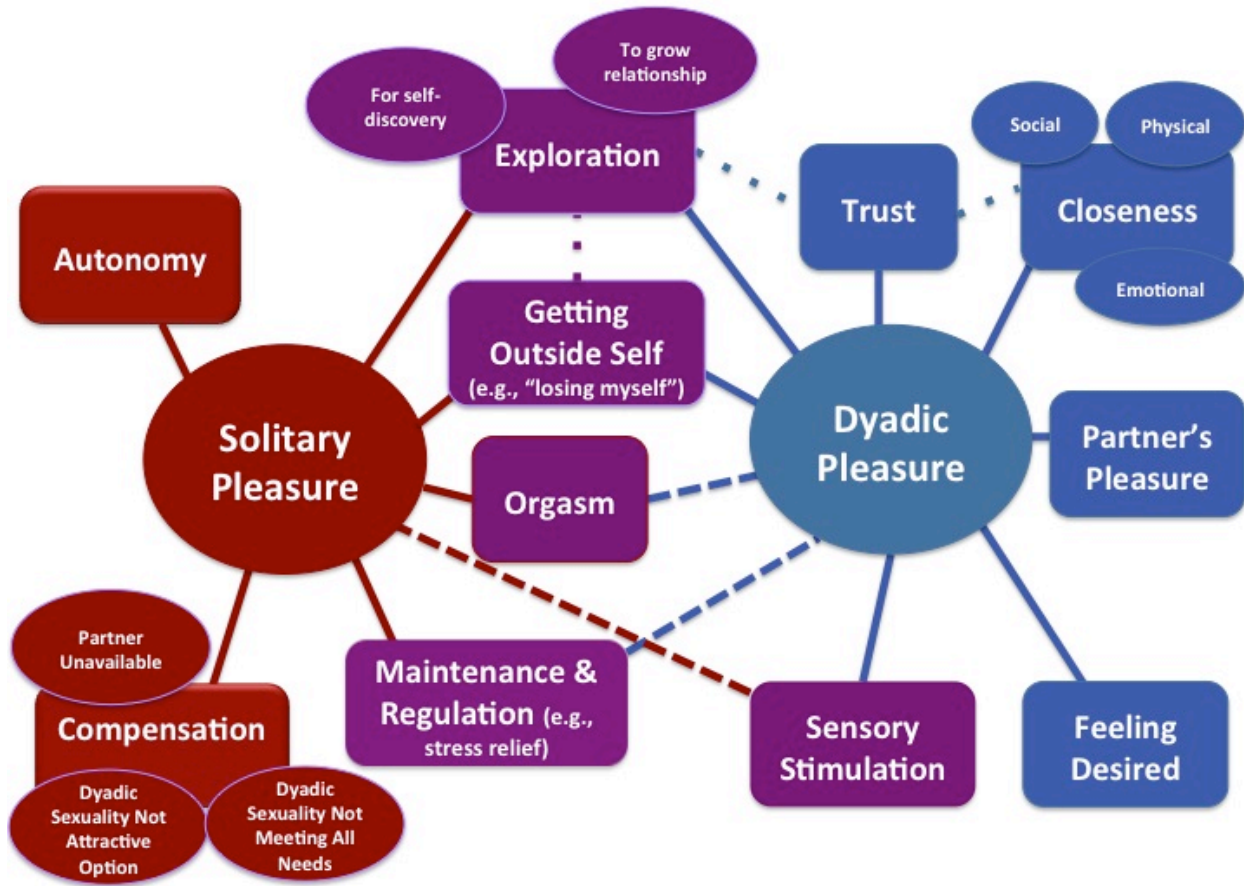
Figure 3.1. *Thematic Map Visually Representing Participants' Definitions of Solitary and Dyadic Pleasure During Focus Group Discussions.* Themes in red were endorsed by participants as uniquely important to solitary pleasure, and themes in blue were endorsed as unique to dyadic pleasure. Themes in purple could apply to both solitary and dyadic pleasure; however, not all applied to solitary and dyadic pleasure equally. Themes in purple connected with a solid line to solitary pleasure and a dashed line to dyadic pleasure (e.g., Maintenance and Regulation) were described as more central to solitary pleasure, and vice versa. Themes connected by dots to each other (e.g., Trust and Exploration) were interconnected and often discussed together by participants.

Solitary Pleasure

"All about me": Autonomy. Across all 13 focus groups, participants described solitary

sexuality as providing complete autonomy in terms of fantasy, use of erotica or toys, type of

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manual stimulation, and length of the experience. For example, a lesbian woman in the 25-40 group explained that solitary sexuality afforded her more freedom than dyadic sexuality in terms of fantasy:

> "Well I love that I can think anything that I want. Like, I actually find that I don't think about the same things. I, I'm always fantasizing even when I'm having sex with a girlfriend, but I think about different things when I'm alone because it feels less wrong…"

Similarly, participants identified the ability to instantly adjust the focus of stimulation, without having to ask for this from someone else, as a unique benefit of solitary sexuality. As one participant said, "I don't have to be mentally telegraphing, 'no, go to the other nipple'" [heterosexual woman, 41+].

Although participants described giving pleasure to a partner as a highly pleasurable aspect of dyadic sexuality (see Dyadic Pleasure below), they emphasized that complete focus on themselves was a key benefit of solitary sexuality. Several participants described this as the ability to be "selfish" (e.g., "You can be like selfish. You don't have to worry if, if your partner's enjoying himself" [heterosexual woman, 18-24]). Solitary sexuality provided relief from the performativity that could accompany dyadic sexuality – "You don't have to put on this image or bolster somebody else's ego" [heterosexual woman, 41+].

Participants explained that this autonomy resulted in consistent and often very intense physical pleasure, as exemplified by the experiences of a bisexual woman in the 18-24 group:

> "…I like that, um, like I can give myself an orgasm […] usually, whenever I want. […] [M]y best orgasms come from like certain kinds of masturbation. Like I've physically given myself an orgasm to the point where my legs and hands were shaking for like three hours afterwards because I used the showerhead on the massage function and like gave myself like four orgasms in the course of like twenty minutes, that like, I was actually just like, 'I need to go sit down!' […] [T]hat's never happened to me like with a partner before."

Some participants also said that solitary autonomy created unique *emotional* qualities: "a sense of freedom" [heterosexual woman, 18-24], "going inwards" [bisexual woman, 25-40], or feelings

of self-reliance (e.g., "knowing that it can happen again tomorrow if I want it to" [heterosexual woman, 25-40]). Overall, participants described solitary sexuality as a realm where they could experience complete control and freedom from the constraints of dyadic sexuality, resulting in reliable, intense genital pleasure and, for some participants, a unique emotional experience as well.

"If you're horny and you don't have anybody": Compensation. In addition to highlighting the role of autonomy in solitary pleasure, participants in all focus groups felt that solitary sexuality was a practical way to meet their own needs when sexual partners were unavailable, when dyadic sexuality was not an ideal option (e.g., "if I don't have enough energy" [heterosexual woman, 18-24]; "when I just don't want to have casual sex" [bisexual woman, 18-24]), or when dyadic sexuality was not meeting all needs. In an example of the latter, a heterosexual woman in the 18-24 group stated that she had used solitary masturbation to supplement dyadic activity when her ex-partner "was just like very concerned about his own pleasure and not about mine". Some participants felt that masturbation served as a substitute for dyadic sexuality (e.g., "for me it's definitely a substitute, because like it's mostly the time or the distance [from my partner]" [heterosexual woman, 18-24]), whereas others felt that for them, the functions of masturbation went beyond standing in for dyadic sexuality. A couple of participants used the word "supplement" to explain the role of masturbation in their sexualities – "I think that it's more like a supplement, like, like partnered sex is the main course and masturbation is the side dish" [heterosexual woman, 18-24].

Additional themes relevant to solitary pleasure. An additional theme primarily relevant to solitary pleasure was Maintenance and Regulation. Participants described solitary sexuality as meeting a basic need for release or regulating negative physical and emotional

feelings (e.g., stress, negative mood, headaches, etc.). Although dyadic sexuality could also be used to regulate mood and stress, this theme was more prominent in discussions of solitary sexuality. Similarly, while orgasm could add to dyadic pleasure (see Social Location below), participants typically described orgasm as the primary (and for some participants, the only) goal of solitary sexuality.

Dyadic Pleasure

"My ultimate goal is to get *them* off": Partner's Pleasure. In contrast to the "all about me" focus of solitary pleasure, participants in all focus groups identified giving a partner pleasure as a key element of dyadic pleasure. A bisexual participant in the 18-24 group explained that, "I think that with a partner, my ultimate goal is to get them off. When I'm by myself, my ultimate goal is to get me off". Similarly, another participant explicitly contrasted the selfishness of solitary pleasure with the selflessness of dyadic pleasure:

> "So for me [solitary sexuality is] a selfish pleasure. Because I can do what I want. […] You do what you want, when it feels right, without embarrassment, without inti-, y'know, intimidation, […] where you want, what you want, when you want it. Um and then with partnered sexuality, um y'know, there's that selflessness. Y'know I wanna make sure that I'm showing my partner what I feel. In hopes that he would do the same for me."
> [heterosexual woman, 41+]

Interestingly, however, not all participants positioned giving a partner pleasure in terms of selflessness. Some participants characterized giving pleasure in terms of empowerment, control, or a sense of achievement, as exemplified by this exchange during an LBQ 18-24 group:

> *Moderator:* So what sorts of things do you find pleasurable about partnered sexuality in particular?
> *P1:* Getting them off.
> *P2:* Mmhmm.
> *P3:* Yeah, pleasuring somebody else, or them.
> *P1:* Knowing that you're the one turning them on (laughter from group).
> *P4:* And just having control over like the pacing of it. Um, like especially when you've been with someone before and you know what they like and. I don't know, I really, I think that's extremely arousing, to like know what you're gonna be doing next, and just like have. I

mean, they're, *it's like incredible how much control you can have over another person's experience* and, enacting that in a way that's just like focused on their pleasure is special and super arousing. [emphasis added]

Thus, some participants identified control as important to dyadic pleasure in addition to solitary pleasure – but in the case of dyadic pleasure, this control was focused on the partner's experience.

"It's like an orgasm in your heart": Closeness. Participants across all focus groups agreed that closeness was a strong motivator for engaging in dyadic sexuality and a central component of dyadic pleasure. This closeness could be emotional (e.g., "expression of any sort of feeling of friendship or love" [queer woman, 25-40]), physical (e.g., "being intimate and hugging" [lesbian woman, 41+]), or a more social or general form of closeness, often associated with fun or playfulness. One woman described this as follows:

"I think in general it's just fun, like fun being with like another person. It's, it is just kind of like a different hang out (laughter from group). Like, I don't know, it's, it's, it's hanging out in a different way." [heterosexual woman, 18-24]

Although many participants agreed that an emotional connection to a partner enhanced their sexual pleasure, there was substantial variation in the extent to which participants felt that emotional connection was essential to pleasure. Some participants described sexual activity within more versus less emotionally connected partnerships as pleasurable in different ways. For example, a participant in a consensually non-monogamous relationship described her casual sexual interactions as an "extension of masturbation" and her sexual interactions with her long-term partner as an extension of her and her partner's personalities [bisexual woman, 18-24]. Another participant stated that when she was less emotionally intimate with a partner, "I can be more self-focused" [queer woman, 25-40]. Therefore, although participants identified closeness as an important aspect of dyadic pleasure, some participants also explained that within less

emotionally intimate sexual encounters, they could achieve a more self-focused type of pleasure similar to solitary pleasure.

"The shared vulnerability": Trust. Participants explained that trusting a partner was pleasurable because this trust allowed participants to experience a shared, positive vulnerability, as a gay-identified woman in the 18-24 group described:

> "I think, um, only very recently, the something else that is, that partnered has offered that solitary doesn't is, and I, it's this ability to completely let someone, like let go. Not like let someone else necessarily, but like to just be vulnerable, because I have a really really hard time with just letting someone else do things for me, not even just sexually, but like just do things for me. And so being with a partner in a sexual situation, and letting them like kiss you here or do this here, is like, it's one of those things that is like, I don't know, it's kind of a learning tool in general for me, in life…"

Along with this vulnerability, participants explained that trust created the opportunity to be their authentic self with a partner: "…when you trust somebody and your life is really truly y'know enmeshed with theirs […] you can be yourself and you can be comfortable and you're really not y'know uh performing y'know?" [lesbian woman, 41+]. In this way, trust allowed participants' dyadic sexualities to overlap more closely with solitary sexual pleasure; one participant said that over the course of her six-year relationship, she became comfortable sharing "the things that I would think about […] in very solitary ways" with her partner [bisexual woman, 18-24]. Thus, trust was often seen as a pre-requisite for the freedom to be one's authentic self and to explore with a partner.

Additional themes relevant to dyadic pleasure. As other researchers have previously described (Graham et al., 2004), participants in 10 out of the 13 focus groups mentioned feeling desired by a partner (e.g., "having the feedback with somebody of where they obviously find me attractive" [heterosexual woman, 41+]) as enhancing dyadic pleasure. Importantly, physical experiences were not unimportant to dyadic pleasure – participants discussed dyadic sexuality as

involving more varied sensory input (e.g., "skin on skin", smells, tastes, sounds, eye contact) than solitary sexuality.

Overlap Between Solitary and Dyadic Pleasure

"A mix of trying to find myself with others and by myself": Exploration. Although many themes highlighted contrast in participants' definitions of solitary versus dyadic pleasure, exploration was a clear site of overlap between the two. Participants described self-discovery as an important function of solitary sexuality:

> "…when I masturbate I explore, it's not just to get off. Um, like I explore things that, I don't know, with erotica or like with my own imagination, um I think about like what is turning me on, I think about like, I don't know, I like reflect on other times that I've been sexual, and like what really like aroused me then." [bisexual woman, 18-24]

Exploration could also function for self-discovery within dyadic sexuality; for example, some participants described learning about their sexual likes and dislikes via exploring with a partner (e.g., "when I'm with somebody else it's like we can try new things, like oh, I didn't even know I liked that" [heterosexual woman, 18-24]).

A second function of exploration, enhancing the partnered relationship, could also be part of both solitary and dyadic pleasure. For example, a lesbian woman in the 25-40 group said of solitary sexuality, "it kinda gives me an opportunity to explore more of what I like so maybe I can direct my partner there." Exploration together with a partner could enhance a dyadic bond: as a queer woman in the 25-40 group said, "exploring with someone, it's a large part of getting to know someone on a deeper level."

Exploration was often intertwined with the theme of Getting Outside the Self, which was similar in many ways to the theme of escape that Fahs' (2011) participants described as accompanying peak sexual experiences. Participants said that sexual activity allowed them to feel "outside myself" [heterosexual woman, 18-24], to "let all the regular world go"

[heterosexual woman, 41+], or to be someone different than "the person that I am to the rest of the world" [bisexual woman, 18-24].

Summary: Solitary versus dyadic pleasure. Overall, the themes discussed above paint a contrasting picture of solitary and dyadic pleasure, with solitary pleasure characterized by complete autonomy and dyadic pleasure by "give and take" with a partner [heterosexual woman, 41+]. Importantly, whether a particular element was pleasurable could depend on the context as solitary or dyadic: having total control was pleasurable during solitary sexuality, but losing control (and the accompanying positive vulnerability and spontaneity) or focusing control on a partner's pleasure were considered pleasurable during dyadic sexuality. Solitary and dyadic pleasure did share some elements, particularly exploration and a feeling of getting outside oneself. And, dyadic pleasure could become more similar to solitary pleasure in certain contexts – for some participants (or at some times), this was when with a less emotionally intimate partner, whereas for others, this occurred when with a well-known and trusted partner.[6]

Social Location and Experiences of Pleasure

Sexual identity and entitlement to pleasure. The above themes were described in largely similar ways across sexual identity groups, but there were also some specificities by sexual identity in how women discussed their experiences of solitary and dyadic pleasure. Although women of all sexual identities acknowledged cultural stigma surrounding women's masturbation, a minority of younger heterosexual women expressed an additional type of discomfort with masturbation, questioning their entitlement to be sexual without their current partner. For example, a heterosexual woman in the 25-40 group said:

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[6] van Anders (2015) has discussed how the line between solitary and dyadic sexuality can become blurry in interesting ways; for example, is internet sex solitary because it occurs alone or dyadic because it involves interaction with another person? Interestingly, my participants also noted that the boundaries of solitary and dyadic sexuality could blur in contexts such as internet sex and mutual masturbation.

"For me, [orgasm] by myself is easier, but, I dunno, I'm married, and so, being married, for me, changed things, like...I almost feel like I'm cheating on my husband if I were to masturbate, I know that sounds kinda weird, but, so I don't engage in that without…"

Another heterosexual woman described how a previous male partner directly interfered with her ability to engage in solitary masturbation:

"… I didn't masturbate much during my marriage because I didn't wanna get caught, because if I was gonna have an orgasm he wanted to be there for it, so, um, so that was something that was nice to reclaim after that." [25-40]

These narratives, in which masturbation challenged male partners' 'ownership' of women's orgasms, contrasted sharply with queer women's typical responses to whether masturbation was alright when in a relationship (e.g., "Hell yeah"; "It better be!" [bisexual women, 18-24 groups]). Notably, some queer women discussed how their attitude toward their or their partners' solitary masturbation changed as they became more mature (e.g., "I think it's ok now. I mean when I was younger (laughs) I didn't think it was, was ok (laughs)…" [lesbian woman, 41+]).

Like entitlement to solitary pleasure, the level of importance participants placed on their own orgasm during dyadic sexuality also varied by social location. Conceptualizing orgasm as *expected and important* during dyadic sexuality was common among queer women and among heterosexual women in the 41+ age group. For example, a queer woman in the 25-40 group said, "I really do like to orgasm though, and that's a big part of sex for me, like if I um, yeah, I don't, I haven't had any consistent partners that I don't orgasm with and so that's pretty central for me too." The most commonly endorsed view of dyadic orgasm, orgasm as a *nice bonus*, was held about equally by queer and heterosexual women. Here, women stated that orgasm was pleasurable when it occurred, but other elements could compensate for its absence:

"While the orgasm is nice, it's not pinnacle for me. So if, if I don't, then it's no big deal. It's the, it's the whole, the act, and if I, if I felt pleasure during the whole act, if I was able to pleasure her the way she wanted to be, then that's good for me." [lesbian woman, 41+]

Finally, a third perspective on dyadic orgasm, that it was simply *not on the menu*, was endorsed almost exclusively by heterosexual women (e.g., "that's just not an expectation at all for me" [heterosexual woman, 18-24]). Interestingly, a couple of heterosexual participants described how their lack of focus on their own orgasm derived from *their male partners'* fixation on it:

"…it makes me uncomfortable when they're too focused on getting me to orgasm, um, like she said, I've never been able to have an orgasm during sex, I can do it for myself, but I've definitely had partners who have made that their goal, and who have said you know like 'oh you've just never been with me, like I, I (*Another participant interjects*: I've heard that, every guy says that!) can definitely make you' […] and so, after a while you can see their ego starting to crumble and they feel really bad, so I've definitely faked it just to make them not feel bad." [heterosexual woman, 25-40]

"…I, um, fight this battle every time I'm with a partner, um, of, you know, trying not to feel pressure to come. And um, so I end up inverting that and make it about, 'okay, how can I make him come?' Like I, just, I make it all about him. […] And I'm sure, you know, I've been with men who wanted the same thing out of me, but I just can't take, um, I just can't take that feeling, um, and, and I'll never orgasm that way." [heterosexual woman, 25-40]

Additionally, some younger heterosexual women expressed discomfort with receptive oral sex – a behavior that is more closely linked with orgasm for women than penis-vagina intercourse (Richters, de Visser, Rissel, & Smith, 2006). Although some heterosexual women said they enjoyed receiving oral sex, others discussed concerns about appearance (e.g., "does it look weird down there?" [heterosexual woman, 25-40]) or vulnerability, as illustrated by a heterosexual woman in the 25-40 group:

"…I actually feel even more vulnerable when a guy is doing that to me because like, I, I don't know what I'm supposed to be doing at that moment, it's like cause I'm used to like trying to do something to make him feel good, and if I'm just putting myself in this position, he can just be like, 'Well that sucked. Buh bye.' Like, I don't, it just, it makes me feel very vulnerable to do that…"

Thus, as a whole, queer women tended to prioritize their own orgasm as a metric of dyadic pleasure more so than heterosexual women (particularly younger heterosexual women), some of

whom cited concerns about vulnerability during receptive oral sex or their partners' fixations on their orgasms.

Age and shifts over time. Participants, particularly in the 41+ age groups, discussed experiencing shifts in their experiences of sexuality and sexual pleasure over time. Although a few participants mentioned feeling that their desire or pleasure had declined with age or menopause, others, like this heterosexual participant in the 41+ group, discussed positive shifts in body image that enhanced sexual pleasure:

> "I don't want to be 20 again (*Another participant interjects*: I don't either). I mean yeah the rack was a lot nicer […] but honestly, I'm much happier in my skin now than I was, you know, half my age. […] Like yeah fine I've got, you know, the wrinkles, the bumps, and the cellulite and the belly and the whatever and too bad. But you know I'm still a lot better in my skin than before you know so."

Importantly, though I focused on the role of sexual identity and age in my analysis, participants themselves also identified other social location variables such as culture and religion as important to their experiences of sexuality, and especially to their attitudes towards masturbation and solitary sexuality. For example, one participant (who had expressed ambivalence toward masturbation when in a relationship) mentioned the role of her specific cultural and religious background during the session ("I, I think culturally, too. […] I guess in, I dunno, it's not as, how do I say it, uh, masturbation and that sort of fantasy, that kinda stuff, or using a toy, I feel like is a little bit of a taboo…" [heterosexual woman, 25-40]). Thus, as expected, participants' experiences of solitary and dyadic sexual pleasure can best be understood as shaped by multiple intersecting identities, rather than solely by sexual identity and age.

Discussion

By using phenomenological methods to explore how women themselves define sexual pleasure, the current study raises several key points about the nature of sexual pleasure. First,

sexual pleasure is highly multifaceted, encompassing physical experiences (e.g., sensory stimulation), cognitive experiences (e.g., getting outside the self), and emotional experiences (e.g., trust) – as well as experiences that challenge mind-body dualisms (e.g., autonomy, which could facilitate intense genital pleasure and unique emotional experiences). Second, solitary and dyadic pleasure are overlapping but far from identical constructs. Via a quantitative measure (the Venn Diagram activity), women conceptualized solitary and dyadic pleasure as fairly separate, and qualitatively, solitary pleasure was characterized by complete autonomy and dyadic pleasure by placing trust in another individual. Third, most themes were similar across sexual identity and age groups, but social location shaped experiences of pleasure in nuanced ways, with sexual minority women and older women generally experiencing stronger feelings of entitlement to solitary and dyadic sexual pleasure. Below, I discuss the implications of these findings for understandings of T-sexuality links and for sexual-well-being more broadly.

Implications for T-Sexuality Links

My thematic map (see Figure 3.1) supports understandings of sexual pleasure as a 'tricky' context within the S/P Theory, such that pleasure can involve *both* eroticism and nurturance. However, solitary pleasure was characterized by themes that most closely map on to eroticism, such as orgasm and autonomy, which involves power/control and facilitates intense genital pleasure. Autonomy also influences sexual fantasy content, as exemplified by the participant who said her cognitions differed when alone versus with a partner, and this may be relevant for T. Sexual thoughts increase T in women (Goldey & van Anders, 2011), so T responses to sexual activity may be at least partially shaped by internal cognitive experiences. If sexual thoughts can affect T, and women's cognitions differ when alone versus with a partner,

this could at least partially explain why solitary and dyadic sexual desire and behavior are linked with T in different ways.

By contrast, dyadic pleasure was characterized by several themes that at face value map onto nurturance, particularly closeness and trust. Participants often described dyadic sexuality as a way to express their love for a partner or to grow a relationship, and these self-reports are consistent with research showing that sexual activity enhances pair bond formation and maintenance in humans and other species (Insel et al., 1998; Snowdon et al., 2006; Sprecher, 2002; van Anders, Hamilton, Schmidt et al., 2007). However, some themes are trickier to classify as erotic or nurturant, and indeed may involve both. For example, giving pleasure to a partner intuitively seems nurturant – anticipating and responding to a partner's sexual needs could serve a bond maintenance function and might require empathetic responding, which is reduced following T administration (Hermans, Putman, & van Honk, 2006). Yet, some participants explained that when giving pleasure, they felt empowered, in control, confident, and accomplished. In this way, giving pleasure might map onto eroticism via power/control and/or serve a display function rather than a bond maintenance function.

Similarly, some sites of overlap between solitary and dyadic pleasure might be erotic, nurturant, both, or even T-irrelevant. For example, participants described how exploration could help them discover their erotic likes and dislikes, but could additionally make them feel closer to their partners, such that closeness, trust, and exploration were highly intertwined. Maintenance and regulation, which was a more primary element of solitary than dyadic pleasure, might be outside the eroticism-nurturance framework but could also potentially be high-T/erotic, given that relaxing orgasm experiences have been linked with higher T (van Anders & Dunn, 2009) and that sexually-stimulated T responses reduce anxiety-like behavior in nonhuman animals

(Aikey, Nyby, Anmuth, & James, 2002). Taken together, my findings suggest that solitary sexuality may be linked with higher T because it is characterized primarily by eroticism, and dyadic sexuality may be linked with lower T because it often involves nurturance – though dyadic sexuality likely also involves some erotic components (e.g., sensory stimulation, possibly partner's pleasure). Additionally, I identified components of sexual pleasure that are difficult to classify as erotic or nurturant, which suggests avenues for future research. Overall, future quantitative work could further test predictions that higher T is tied to eroticism and lower T to nurturance by combining T sampling with multidimensional questionnaire measures of sexual pleasure. These multidimensional pleasure questionnaires could be used at a trait level to explore between-person associations (e.g., do individuals who report that their dyadic pleasure is highly oriented around *giving* pleasure have higher or lower baseline T relative to others?) or at a state level to explore within-person associations (e.g., would an individual woman have lower T following a dyadic sexual event during which she experiences predominantly nurturant cognitions versus an event during which she experiences predominantly erotic cognitions?).

Links between T and solitary versus dyadic sexuality may be best understood as individual and context-dependent, rather than universal. My data show that social location shapes experiences of sexual pleasure such that, compared with younger heterosexual women, queer women as well as heterosexual women over 40 place greater emphasis on dyadic orgasm and feel more comfortable engaging in masturbation when in a committed relationship. Would more frequent dyadic sexual activity (or higher dyadic sexual desire) still be linked with lower T in queer women and/or midlife and older women, if orgasm is a more frequent (or more desired) outcome of dyadic activity? Similarly, might masturbation be linked with higher T for young heterosexual women because a strong hormonal impetus is required to overcome social and

relational prohibitions on this behavior? Or, if directionality of the T-masturbation link is reversed, perhaps masturbation increases T in this population because it is experienced as a highly agentic behavior.

In addition to social location variables, contextual factors may also shape experiences of pleasure in ways that matter for T responses. Participants described how dyadic pleasure could become more similar to solitary pleasure in casual sexual encounters without strong emotional attachment; yet, sexual interactions with a highly intimate, trusted partner allowed for a level of authenticity that overlapped with solitary pleasure. Thus, dyadic pleasure may be more erotic or more nurturant in some contexts than others; this is supported by my previous finding that being sexually active with a partner was only linked with lower T for pair bonded women, and not for single or casually partnered women (Goldey et al., in preparation). A further nuance is that dyadic sexuality seems to have different effects on T in the short-term versus the long-term: sexual activity with a regular partner acutely increases T in heterosexual women (van Anders, Hamilton, Schmidt et al., 2007), yet more frequent dyadic sexual activity is linked with lower baseline or trait T (Goldey et al., in preparation; van Anders & Goldey, 2010), raising questions about how T responses to discrete sexual events translate to longer-term effects on T. Regardless, my qualitative findings yield the important implication that social location and relationship context shape individuals' experiences of sexual pleasure, and these experiences in turn could affect how sexuality is linked with T.

Implications for Sexual-Well-Being

The potential for sexual pleasure, rather than simply the absence of sexual problems or dysfunction, has been acknowledged as integral to sexual health (World Health Organization, 2006), but a major challenge in incorporating pleasure into sexual health frameworks has been a

lack of knowledge on what sexual pleasure means to individuals themselves (World Health Organization, 2010) (see also Pascoal et al., 2014). My results show that using orgasm presence as a proxy for sexual pleasure drastically oversimplifies how women themselves define pleasure. During solitary sexuality, additional metrics of pleasure might include how in control of the experience an individual felt, how vivid her fantasy was, how relaxed she felt afterward, or the *quality* (rather than simply presence) of orgasm. During dyadic sexuality, factors like closeness or the partner's pleasure may be just as (or more) important to individuals than their own orgasm. Importantly, when research participants or patients in clinical settings are asked if an event was "sexually pleasurable", different individuals may interpret this question in vastly different ways, highlighting the importance of using multidimensional questionnaire measures or asking respondents how they themselves define pleasure.

My results highlight many overarching commonalities in women's definitions of sexual pleasure across age and sexual identity categories, but I found that heterosexual women (especially those in the under 40 age groups) expressed greater ambivalence toward solitary masturbation and dyadic orgasm than queer women. In both solitary and dyadic contexts, this ambivalence stemmed from discourses that placed women's pleasure and orgasm as the purview of their male partners, such that dyadic orgasm became labor women performed for the sake of their partners (Fahs, 2011) and solitary masturbation 'stole' women's orgasms away from their partners. Heterosexual participants in the current study described feeling *pressure* to produce an orgasm for their male partners during dyadic sexuality – and participants stated that this pressure interfered with the likelihood of them *actually* orgasming (e.g., "I'll never orgasm that way"). If women's orgasms are fraught with feelings of pressure and obligation (Braun, Gavey, & McPhillips, 2003; Fahs, 2011; Nicolson & Burr, 2003; Opperman et al., 2014) rather than

desired for intrinsic pleasure, perhaps it is not surprising that some heterosexual women devalued orgasm when defining pleasure. Interestingly, research shows that many lesbian and queer women prioritize non-genital sexual activities, such as kissing, hugging, and cuddling, that alone are unlikely to result in orgasm (Garnets & Peplau, 2006) – yet, lesbian and queer women are more likely than heterosexual women to experience orgasm during dyadic sexual activity (Garcia et al., 2014) and to include orgasm as an important metric of dyadic pleasure. Paradoxically, decentralizing orgasm (and genital sexual activity) and removing the 'orgasm imperative' (Braun et al., 2003; Potts, 2000) may open space for women to more freely experience orgasm and physical pleasure.

A lack of expectation of dyadic orgasm – and discomfort with masturbation – among some heterosexual women may additionally be tied to the coital imperative (McPhillips, Braun, & Gavey, 2001), where penis-vagina intercourse, a behavior that does not reliably result in orgasm for women (Richters et al., 2006), is privileged over other behaviors as the most natural and essential to heterosexuality. Women are more likely to experience orgasm in sexual encounters that include receptive oral sex (Richters et al., 2006), but some heterosexual women in my sample expressed discomfort with this behavior. Research points to ambiguity in scripts around receptive oral sex for women in heterosexual relationships, such that receiving oral sex often requires an active negotiation process, especially during casual sexual encounters (Backstrom, Armstrong, & Puentes, 2012). This may heighten women's feelings of self-consciousness or vulnerability when receiving oral sex.

My research points to the importance of studying positive aspects of sexuality like pleasure in queer and heterosexual women and in women of a broad age range. Much research on LGBQ sexuality is conducted from a risk/vulnerability, stigma, or health disparities

framework (but see Fredriksen-Goldsen et al., 2014); this research is highly important for promoting the health of sexual minority populations, but my findings suggest that the *positive* implications of holding a sexual minority identity for sexual-well-being should not be overlooked.

Similarly, much of the research on aging and sexuality focuses on 'deficits' in sexual desire and function (Hinchliff et al., 2010). Counter to common conceptualizations that link aging with desexualization (especially in women), many of the midlife and older women in my sample acknowledged positive shifts in their sexual-well-being over time, such as improved body image, increased comfort with their own and their partners' solitary sexualities, and a general sense of growth in their sexual selves. These findings point to variation in women's experiences of aging and sexuality and, together with others' results (Sanchez, Crocker, & Boike, 2005; Vares et al., 2007), raise the question of whether stronger endorsement of heteronormative attitudes would predict greater concern about declines in sexual desire and function with age. In these ways, inclusion of a sample diverse by sexual identity and age allowed me to identify many commonalities and some nuances by social location in women's experiences of pleasure – including those that run counter to common assumptions.

Limitations, Future Directions, and Conclusions

My findings should be interpreted within the context of qualitative, phenomenological research, and thus caution is warranted in generalizing the results beyond the current study's sample. However, the consistency with which many themes (e.g., autonomy, partner's pleasure, closeness, etc.) were raised across groups and the alignment of some themes (e.g., feeling desired, getting outside the self) with previous findings (Fahs, 2011; Fahs & Frank, 2014; Graham et al., 2004) points to reproducibility in the results. Furthermore, in keeping with my

phenomenological approach, classification of themes as representative of solitary pleasure, dyadic pleasure, or both was holistic rather than quantitative; future survey research could help quantify the extent to which each theme is exclusively, primarily, or equally characteristic of solitary and dyadic pleasure. Although my sample was diverse in terms of sexual identity and age, it was more homogenous in other factors (e.g., education), and my results leave open questions about the roles of other social identities, such as religion, race/ethnicity, SES, and disability status – some of which participants themselves mentioned as important to their experiences – in definitions of sexual pleasure. Finally, because I did not hold separate focus group sessions for bisexual women, I was less able to tease out differences between bisexual, lesbian, and queer women's experiences, which is problematic (van Anders, 2012a). My findings raise questions about whether sexual minority women's stronger feelings of entitlement to sexual pleasure are more tightly linked to holding a sexual minority identity, to the gender(s) of their current or past partners, or (most likely) a combination of these.

In sum, by asking women how they defined sexual pleasure, I found that solitary and dyadic sexual pleasure were each highly multifaceted but largely distinct from one another. Via the S/P Theory, participants' descriptions of solitary pleasure primarily mapped onto eroticism, whereas several themes relevant to dyadic pleasure mapped onto nurturance, providing a potential explanation for why solitary sexual desire and behavior have been linked with higher T, but dyadic sexual desire and behavior with lower T, as predicted (van Anders, 2013). My findings suggest that solitary and dyadic pleasure are qualitatively different experiences for women in ways that may have implications for their associations with T. Furthermore, social location and context (e.g., sexual identity, age, relationship context) can shape these experiences of pleasure, such that these variables are important to consider in studies with T. These results

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have important implications for understanding how *experiences* of sexuality could underlie

bidirectional T-sexuality links and for promoting women's sexual-well-being broadly, and my

study provides an example of how individuals' narratives of their sexual experiences can be used

to better understand hormonal findings.

Outline of Focus Group Discussion Guide

1. What are some things about being sexual that make you feel pleasure? These could be
   pleasurable aspects of solitary sexuality, partnered sexuality, or both.

2. Venn Diagram activity: Each participant was asked to arrange two cut-out circles to represent
   her answer to the following question: To what extent are the things you find pleasurable
   about solitary sexuality the same or different as the things you find pleasurable about
   partnered sexuality? The lack of overlap in (a) would represent that the participant
   considered solitary and partnered pleasures very different, and the overlap in (b) would
   represent that she considered them very similar. Participants selected one of 11 pre-marked
   positions, and a moderator scored the activities such that *1 = Most overlap* and *11 = Least
   overlap*. Thus, (a) would be scored as 10 and (b) would be scored as 2.

3. What do you find pleasurable about partnered sexuality?

4. What are some motivations or reasons for engaging in partnered sexuality?

5. How do your feelings toward your partner affect your pleasure?

6. How do you measure your degree of pleasure in partnered situations?

7. When you engage in partnered sexuality, do you plan it and look forward to it? What do you look forward to? Is the anticipation itself pleasurable?

8. Are there circumstances that make partnered sexuality especially pleasurable for you?

9. What do you expect to get out of partnered sexuality?

10. What do you find pleasurable about solitary sexuality?

11. What are some motivations or reasons for being sexual by yourself?

12. Would there be a reason to engage in masturbation without orgasm? If so, what reason?

13. Do you feel that masturbation is ok when you are in a relationship or have a regular sexual partner? Why or why not? Have you felt this way in all of your relationships?

14. How do you measure your degree of pleasure in solitary situations?

15. When you engage in solitary sexuality, do you plan it and look forward to it? What do you look forward to? Is the anticipation itself pleasurable?

16. Are there circumstances that make solitary sexuality especially pleasurable for you?

17. What do you expect to get out of solitary sexuality?

18. Are there times or situations when you would prefer to engage in solitary activity rather than partnered activity? If so, what are those situations?

19. Are there times or situations when you would prefer to engage in partnered activity rather than solitary activity? If so, what are those situations?

20. What is the role of fantasy in pleasure? Is this important during solitary situations, partnered situations, or both?

21. Can use of erotica contribute to pleasure? Is this the case for solitary sexuality, partnered sexuality, or both?

22. Are there things you identify as similarly pleasurable about both solitary and partnered sexuality?

23. What is one positive thing in terms of pleasure that you get from solitary sexuality that you don't get from partnered sexuality?

24. What is one positive thing in terms of pleasure that you get from partnered sexuality that you don't get from solitary sexuality?

25. Venn Diagram activity repeated (to see if participants' feelings have changed during the course of the discussion)

26. Following recap from moderator's notes: Have we missed anything, or are there any other thoughts that you would like to share?

CHAPTER 4

IDENTIFICATION WITH STIMULI MODERATES WOMEN'S AFFECTIVE AND TESTOSTERONE RESPONSES TO SELF-CHOSEN EROTICA

Introduction

Sexual stimuli bring about testosterone (T) release in many vertebrate species including humans, and this rapid T release may function to direct behavior toward the pursuit of sexual activity (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008). While more research has examined sexually-modulated T in men and male non-human animals, studies show that women's T is highly responsive to sexual cues. For example, sexual activity with a partner increases T in women, as does anticipation of sexual activity (Dabbs & Mohammed, 1992; Hamilton & Meston, 2010; van Anders, Hamilton, Schmidt et al., 2007). Furthermore, sexual thoughts in the absence of external sensory stimuli are sufficient to increase women's T (Goldey & van Anders, 2011). However, three separate studies have shown that viewing erotic films is not associated with a statistically significant change in women's T (Hamilton et al., 2008; Heiman et al., 1991; van Anders et al., 2009). Why would erotic films not increase women's T when just *thinking* about a sexually arousing situation is sufficient?

Presumably, viewing erotic films elicits some degree of sexual cognitions and arousal and, indeed, erotic films typically elicit higher genital and self-reported sexual arousal than fantasy alone does in women (Bloemers et al., 2010; Graham, Janssen, & Sanders, 2000; Laan, Everaerd, Van Aanhold, & Rebel, 1993; Laan, Everaerd, van Berlo, & Rijs, 1995). Thus, absent or very low arousal to films could not explain the absence of T responses. However, a crucial

confound between sexual thoughts and erotic films in past studies that measured T is autonomy in stimulus selection: in the sexual thoughts study, participants self-defined a sexually attractive partner and situation (Goldey & van Anders, 2011), whereas in the studies using film stimuli, participants viewed films chosen by researchers (Hamilton et al., 2008; Heiman et al., 1991; van Anders et al., 2009). Here, I test whether self-chosen erotica yields higher T responses than researcher-chosen erotica, and I hypothesize that two key variables will account for higher T in women who view self-chosen erotica: higher identification with stimuli and lower negative affect.

Identification With Stimuli

Because previous research has almost exclusively relied on the paradigm of measuring participants' responses to films selected by researchers, little is known about women's cognitive and emotional responses to erotic films they choose themselves. However, there is reason to believe that identification, defined as taking the perspective of actors in the film (Bossio, Spape, Lykins, & Chivers, 2014; Cohen, 2001), would be stronger to self-chosen stimuli. Women are more likely to imagine themselves as participants in the film when they view preferred stimuli (i.e., stimuli depicting two women for same-sex attracted women; stimuli depicting a woman and a man for other-sex attracted women) than non-preferred stimuli (Bossio et al., 2014). Similarly, women are more likely to 'become' the woman in the video, imagine themselves participating in the sex, and feel involved when they view erotic films produced by and for women (i.e., 'women-centered' films) compared to films designed for men (Mosher & MacIan, 1994). However, while 'women-centered' erotica that depicts participants' preferred genders/sexes increases identification, even these stimuli may not map onto each individual woman's erotic preferences as women are not a unitary group. Indeed, women may default to viewing as

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detached, passive observers when they view women-centered erotica chosen by researchers (Both, Laan, & Everaerd, 2011). Thus, a close fit between stimulus characteristics and individual attractions and preferences – which would presumably be maximized when women choose their own stimuli – should yield high levels of identification. In turn, identification is a clear positive predictor of women's self-reported sexual arousal, both in correlational studies and in experimental studies that have manipulated identification via instructional prompts (Bossio et al., 2014; Both et al., 2011; Janssen, Carpenter, & Graham, 2003; Koukounas & McCabe, 1997; Sheen & Koukounas, 2009).

The above findings suggest that autonomy in choosing preferred stimuli should maximize identification and thus increase arousal, but would identification matter for T? Unlike when fantasizing about a self-defined attractive partner, women watching erotic films chosen by researchers may be unable to imagine actors in the films as potential partners, both because the actors may not match their individual preferences for attractiveness and because of the scripted unrealistic nature of the interactions (Goldey & van Anders, 2015). The presence of a potential partner – real or imagined – may be an important cue for T release, as evidence suggests that T responds to evaluations of partner quality in women (Lopez et al., 2009) and in non-human females (Correa et al., 2011; Gwinner et al., 2002; Marshall et al., 2005). In support of a role for identification in T responses, women's T increased in response to films of romantic 'courtship' interactions when they were explicitly instructed to imagine themselves as the woman in the film (Lopez et al., 2009). Although the role of identification in T responses to erotic rather than romantic films has not been tested, these results suggest that visual stimuli can increase women's T when women imagine themselves as part of the film and imagine a film character as a potential partner. Additionally, perhaps differences in identification at least partially explain why viewing

erotica increases men's T (Hellhammer et al., 1985; Pirke et al., 1974; Redoute et al., 2000; Stoleru et al., 1993, 1999) but not women's, given that men are more likely to adopt an involved, emotional attentional focus when viewing erotica (Both et al., 2011).

Finally, although previous research has not examined the role of identification in T responses to sexual stimuli specifically, a growing body of research demonstrates the importance of cognitive evaluations in moderating T responses to competition (Oliveira et al., 2013; Salvador, 2005), suggesting that similar factors could play a role in sexually-modulated T. For example, losing a competition against an unfamiliar opponent increased T only when participants evaluated the competition as threatening (Oliveira et al., 2013). Similarly, factors like motivation to win and attribution of the outcome to personal performance versus luck seem to more clearly predict T responses than contest outcome (i.e., victory versus defeat) (reviewed in Salvador, 2005). If T is sensitive to cognitive appraisals in competitive contexts, it may respond to analogous parameters, like identification with stimuli, in sexual contexts.

In sum, identification may amplify T responses to sexual stimuli, and identification may be far from maximal when women view researcher-chosen erotica. Thus, I predict that self-chosen erotica should increase identification due to a stronger match between stimuli and preferences and, that to the extent that self-chosen erotica increases identification, it should increase T.

Negative Affect and Erotica

A majority of women report some degree of ambivalent affect, or a mix of positive and negative emotions, in response to erotic films (Peterson & Janssen, 2007). Furthermore, while erotic films elicit higher genital and self-reported arousal than sexual fantasy, they also elicit higher levels of negative emotions, such as aversion and shame (Laan et al., 1993, 1995) –

though even self-directed stimuli like sexual thoughts can bring about small but significant increases in negative affect (Goldey & van Anders, 2012a). Do erotic films universally elicit ambivalent affect in women, or does heightened negative affect result from the typical laboratory paradigm in which women view researcher-chosen stimuli? Negative affect is alleviated, though not eliminated, when women view women-centered films as opposed to films created for a male audience, suggesting that stimulus content modulates negative affect (Laan, Everaerd, van Bellen, & Hanewald, 1994; Mosher & MacIan, 1994). Additionally, to the extent that self-chosen stimuli increase identification, they may decrease negative affect (Koukounas & McCabe, 1997), though manipulations that increase identification have clearer enhancing effects on positive affect than inhibitory effects on negative affect (Sheen & Koukounas, 2009). Thus, it seems plausible, but as yet unclear, that self-chosen erotica could alleviate negative affect via a closer match between stimuli and preferences.

On the other hand, autonomy in choosing erotic stimuli may be fraught with contradictions for women, given that solitary sexual behaviors – like viewing erotica alone – remain some of the most stigmatized sexual behaviors for women (Alexander & Fisher, 2003; Petersen & Hyde, 2011). Similar to sexual agency more generally, autonomy in erotic stimulus selection could represent a "double-edged sword" (Bay-Cheng, 2015), such that higher autonomy carries the cost of self-blame for any negative outcomes. By this line of reasoning, choice might be expected to *exacerbate* negative affect already associated with viewing erotica, due to an increased 'responsibility' for stimulus selection.

In addition to gaps in knowledge regarding effects of autonomy on negative affect, whether negative affect plays a role in predicting T responses to sexual stimuli is ambiguous, as research has tended to focus on links between hormone responses and arousal. In competitive

contexts, negative affect is often presumed to mediate declines in T upon losing, but findings on whether negative affect actually predicts T changes are mixed (Gonzalez-Bono, Salvador, Serrano, & Ricarte, 1999; Mazur & Lamb, 1980; McCaul, Gladue, & Joppa, 1992) (reviewed in Salvador, 2005). Given past findings that erotica elicits ambivalent affect and inconsistent findings on T and negative affect, I sought to clarify whether self-chosen erotica would alleviate (or exacerbate) negative affect and whether this would have implications for T responses.

The Current Study

I was interested in the implications of this research for understanding how context modulates sexual stimulation of T and sexual responses more generally. Specifically, the goals of the current study were twofold. First, I characterized women's self-reported arousal and cognitive/emotional responses (identification, enjoyment, and negative affect) to erotica conditions varying in the autonomy participants could exert over the choice of stimuli. To do so, I randomly assigned women to a neutral film condition or one of three erotica conditions: high choice (self-chosen erotica from participants' own sources), moderate choice (self-chosen erotica from a small collection of films preselected by sexuality researchers), and no choice (erotica assigned by researchers). The high and moderate choice conditions both involved self-chosen erotica, and the moderate and no choice conditions both involved erotica preselected by researchers, so my design allowed me to tease out effects of choice versus stimulus source. I hypothesized that self-chosen erotica (in the high and moderate choice conditions) would increase self-reported arousal, identification, and enjoyment and decrease negative affect compared to researcher-chosen erotica (the no choice condition), and that effects would be especially strong in the high choice condition.

Second, I tested whether erotic films would increase T when participants could autonomously choose stimuli. I hypothesized that self-chosen erotica would increase T, especially in the high choice condition, compared to researcher-chosen erotica. Furthermore, I hypothesized that identification would moderate effects of choosing erotica on T (i.e., self-chosen erotica would only increase T to the extent that it increased identification), and I explored whether negative affect also would moderate effects of choosing erotica on T (i.e., whether self-chosen erotica would only increase T to the extent that it decreased negative affect).

Method

Participants

Participants were recruited via posters and online advertisements on websites such as Craigslist. To be eligible for the study, participants were required to be women 18 years or older, have previous experience and comfort with viewing erotic videos, have Internet access at home, and not have conditions or be using medications affecting hormones (including hormonal contraceptives). Participants first completed a baseline session in the laboratory and then completed the experimental portion of the study at home. Of the 221 participants who completed the baseline session, 189 completed the at-home portion. Of those 189 participants, I excluded those who reported taking medications or having medical conditions affecting T (including hormonal contraceptive use in the past 3 months) ($n = 18$), who did not follow instructions (e.g., provided both saliva samples before watching the video, engaged in masturbation or partnered sexual activity during the video, had their partner present during the study) ($n = 23$), or who had technical difficulties with the online questionnaire or video that compromised the validity of their data ($n = 18$). Because the study was designed to only include women with experience using visual erotica, I additionally excluded 13 women who reported "not at all" for their

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frequency of erotic video use (plus one nonresponder). This left 116 participants (115 women, 1

bigender participant; $M_{age} = 23.03$, $SD = 7.10$) for analyses. Demographic characteristics of the

participants are shown in Table 4.1.

Table 4.1
Participant Characteristics

Demographic	N (%)
Age	114
18-20	49 (43%)
21-30	57 (50%)
31-40	1 (1%)
41-50	5 (4%)
51-60	2 (2%)
Occupation status	116
Student only	42 (36%)
Student & employed (part- or full-time)	57 (49%)
Employed non-student	15 (13%)
Unemployed non-student	2 (2%)
Length of time living in United States	116
Entire life	89 (77%)
More than 10 years	12 (10%)
10 or fewer years	15 (13%)
Race/ethnicity[a]	113
African American/Afro-Caribbean/Black	10 (9%)
Asian	19 (17%)
Hispanic/Latina/Mexican American	3 (3%)
Middle Eastern	2 (2%)
Multiracial	12 (11%)
Native American	1 (1%)
South Asian/Indian	6 (5%)
White	60 (53%)
Sexual identity[a]	116
Between Lesbian and Bisexual	1 (1%)
Bisexual	7 (6%)
Heterosexual	86 (74%)
Lesbian	6 (5%)
Mostly Heterosexual/Qualified Heterosexuality	5 (4%)
Pansexual	3 (3%)
Queer	8 (7%)
Relationship status[b]	116
Single	44 (38%)
Dating	12 (10%)
Committed relationship	53 (46%)
Committed relationship and dating other people	7 (6%)

Frequency of erotic video use	116
Once or twice per year or less	33 (28%)
Once every couple months	22 (19%)
Once per month	18 (16%)
2-3 times per month	23 (20%)
1-3 times per week	16 (14%)
4-6 times per week	3 (3%)
Once per day	1 (1%)

[a]I categorized participants' responses to an open-ended item

[b]Participants indicated their relationship status based on definitions I provided (van Anders & Goldey, 2010)

Design

Participants were randomly assigned to one of the four film conditions described below:

High choice erotica. In this condition, participants chose an erotic video from their own sources (e.g., the Internet). "Erotic video" was defined for participants as "a video that is oriented around explicit sexual acts with the goal of being sexually arousing." Participants were instructed to choose the video based on their preferences (e.g., from a website or producer they like), but to avoid choosing a video or scene they had seen before if possible, in order to avoid the confound of novel content in the other conditions but not the high choice condition. Participants were instructed to watch the video for about 10 minutes, but that they could stop at an appropriate point (e.g., when a scene ended). Participants were allowed to skip around within a video, watch scenes from multiple videos, or choose a new video if they disliked their initial choice, all of which helped to maximize the high autonomy of this condition.

Moderate choice erotica. In this condition, participants chose an erotic video from a collection of eight researcher-selected films hosted on a secure website accessible only to study participants. I chose the films in this condition based on recommendations from sexuality researchers for films to use in a study with women as participants. Some researchers suggested specific films, whereas others suggested producers (e.g., Candida Royalle, Erika Lust). Clips

were edited to approximately 10 minutes (range = 8.53 to 11.00 min). Six films depicted

interactions between a woman and a man, whereas two films depicted interactions between two

women. Although the specific sexual activities varied somewhat between video clips, most

showed a range of behaviors (e.g., kissing, cunnilingus, fellatio, penis-vagina intercourse, dildo-

vagina intercourse). Please see Appendix 4.1 for a list of the films used in this condition.

Participants were instructed to choose a video from the secure website based on their

preferences. The homepage of the website provided a descriptive title for each video along with

five still images from the video (which rotated in .gif form) to help participants make their

selection. Similar to the high choice condition (and to maximize the moderate autonomy of this

condition), participants were instructed that they could skip around within a video, watch scenes

from different videos, or choose a new video if they disliked their initial choice, and that they

should watch for about 10 minutes total and stop at an appropriate point.

No choice erotica. In this condition, participants viewed an erotic film that the researcher

assigned. All participants in this condition watched the same video clip, which was one of the

eight video clips included in the moderate choice condition. I selected this particular clip for the

no choice condition because it was from a film produced by Candida Royalle (1998), whose

work is used widely as stimuli in sexuality research (e.g., Both, Spiering, Everaerd, & Laan,

2004; Brotto & Yule, 2011; Janssen et al., 2003; Laan et al., 1994; Ter Kuile, Vigeveno, & Laan,

2007). The video was 10.13 minutes long and depicted an interaction between a woman and a

man involving kissing/touching, cunnilingus, and penis-vagina intercourse. Participants were

provided with a link to a secure website similar in layout to the moderate choice website but

containing only this one video. Participants were instructed to watch this video from beginning

to end in sequence (i.e., not to skip around or watch scenes out of order) to maximize the lack of autonomy in this condition.

Neutral. In the neutral condition, participants watched a 9.85-minute clip from a travel documentary about the history of Scotland (Hinshelwood, 1997). I have used this film previously as a neutral or time-filler activity that does not induce changes in T (Goldey & van Anders, 2011). Participants were given a link to a secure website similar in layout to the moderate and no choice erotica websites, but containing only the documentary film. Participants were instructed to watch this travel video from beginning to end in sequence.

Materials

Health and background questionnaire. This questionnaire included demographic items to help describe the sample and questions about potential confounds with T (e.g., medication use, medical conditions affecting hormones, nicotine use, height and weight to calculate body mass index [BMI]).

Relationships and sexuality questionnaire. This questionnaire was included to help describe the sample in terms of variables relevant to relationships and sexuality. Participants indicated their relationship status based on definitions I provided (van Anders & Goldey, 2010). When controlling for relationship status in my analyses, I coded responses as single (not romantically involved with anyone), casually partnered (dating or committed and dating), or in a committed relationship (van Anders & Goldey, 2010). Participants self-identified their sexual identity in an open-ended item, and they responded to questions about their experiences with sexual media, including their frequency of erotic video use (on a scale from *0 = Not at all* to *8 = More than once per day*).

Film Scale (Heiman & Rowland, 1983). The Film Scale is commonly used to measure self-reported state arousal and affect before and after presentation of sexual stimuli (Hamilton, Rellini, & Meston, 2008; Kuffel & Heiman, 2006; Lorenz & Meston, 2012; van Anders et al., 2009). I modified the scale by adding two items measuring state desire ("a desire to masturbate", "a desire for sexual activity with a partner" (Graham et al., 2000)) and two items from the Sexual Arousal and Desire Inventory ("happy", "good" (Toledano & Pfaus, 2006)). My version included 39 items on a scale from *1 = Not at all* to *7 = Intensely*. Participants responded to this scale at three timepoints: 1) pre-film, 2) immediately post-film (post), and 3) approximately 15 min post-film (final). At Times 1 and 3, participants were asked to rate how they felt currently; at Time 2, participants rated how they felt during the video.

Because the scoring of the Film Scale varies across studies, I conducted a principal components analysis to resolve the items into subscales. I used absolute change scores from pre- to post-film (Time 2 – Time 1) in the principal components analysis because I was most interested in *changes* in arousal and affect from pre- to post-film. The items resolved into five subscales: Sexual/Positive Psychological Arousal and Desire (abbreviated Psychological Arousal; 18 items; e.g., attracted, sensuous, interested, happy, a desire for sexual activity with a partner), Perceived Physiological Arousal (11 items; e.g., genital wetness or lubrication, faster breathing than normal), Anxiety (3 items: worried, anxious, angry), Disgust (2 items: disgusted, offended), and Guilt/Embarrassment (2 items: guilty, embarrassed). Each item was assigned to the subscale on which it loaded the highest, and the items "incompetent," "inhibited," and "masculine" were discarded because they failed to load above 0.4 on any subscales. Internal consistency was adequate to high for all subscales, though somewhat lower for subscales with fewer items as might be expected (Cronbach's alpha = 0.960 for Psychological Arousal, 0.957

for Perceived Physiological Arousal, 0.580 for Anxiety, 0.520 for Disgust, and 0.692 for Guilt/Embarrassment). I computed mean subscale scores for each timepoint, and then absolute change scores for each subscale from pre- to post-film (Time 2 – Time 1) and pre-film to final (Time 3 – Time 1).

Enjoyment. Participants rated their enjoyment of the video using a single item ("Please rate the extent to which you enjoyed the video you watched") on a scale from *1 = Not at all* to *7 = Very much*.

Identification Scale (Cohen, 2001). This 10-item scale was based on the items suggested by Cohen (2001) for measuring identification with media characters, and I adapted the items to be relevant to erotic films. Items focused on absorption (e.g., "While viewing the video, I felt as if I was part of the action"), sharing the feelings of the characters (e.g., "When the character(s) experienced pleasure, so did I"), sharing the perspective of the characters (e.g., "During viewing, I felt I could really get inside the character(s)' head(s)"), and internalizing the goals of the characters (e.g., "While viewing the video, I wanted the character(s) to succeed in achieving their goals"). Participants responded to each item on a scale from *1 = Strongly Disagree* to *7 = Strongly Agree*, and I computed a mean score for the 10 items (Cronbach's alpha = 0.936). Only participants in the erotica conditions completed this scale, as the items would have been irrelevant to the neutral condition because there were no 'characters' in the neutral film.

Video details questionnaire. In this questionnaire, participants in the high choice condition were asked to provide a brief description and/or title/link of the video(s) they watched if they were comfortable doing so. Participants in the moderate choice condition were asked to indicate which video(s) they watched from a list of the possible selections for this condition. Participants in all conditions were asked whether they watched one or multiple videos, for how

many minutes they watched the video, if they had engaged in any sexual behaviors (e.g., masturbation, intercourse, oral sex, etc.) since beginning the at-home survey, and whether they had been alone since beginning the survey.

        Saliva samples. I measured T through saliva samples, which provide a number of advantages over blood sampling, such as increasing participant comfort, minimizing invasiveness, and enabling participants to collect and store samples at home (for review, see van Anders et al., 2014), all of which were essential to the design of the current study. Participants were instructed to refrain from eating, drinking (except water), brushing their teeth, chewing gum, or smoking for one hour prior to providing saliva samples. Saliva samples were provided by spitting into 17mL polystyrene tubes, and participants were instructed to freeze their saliva samples as soon as possible after providing them. Our lab has successfully used this procedure for self-collection and storage of saliva samples in the past (van Anders, Hamilton, Schmidt et al., 2007; van Anders et al., 2014). Participants were instructed to keep their samples frozen using icepacks during transport to the lab if possible. If samples arrived unfrozen, this information was recorded; to minimize variation in the number of freeze-thaw cycles, all samples that arrived at the lab frozen were freeze-thawed once prior to assay. Samples were stored in the lab at -20 °C for 1-6 months until assayed in duplicate at the Core Assay Facility at the University of Michigan using enzyme immunoassay kits from Salimetrics. Salimetrics reports the sensitivity of the assay as < 1.0 pg/mL. Inter-assay CVs were 8.63% for high T and 26.04% for low T, and intra-assay CV was 9.21%. Samples with high intra-assay CVs between the duplicates were re-run. In cases where only one sample from a given participant (pre-film or post-film) was re-run and the original and re-run T values had a CV greater than 20%, I averaged

the original and re-run values to avoid exaggerating differences between pre-film and post-film samples due to inter-assay variation.

Procedure

All procedures were approved by the University of Michigan Institutional Review Board. Data were collected between May and November 2013. Participants first attended a baseline session in the laboratory, where they completed an informed consent form, the background and demographics questionnaire, and the relationships and sexuality questionnaire[1]. Participants also provided a saliva sample for practice and received materials and instructions for completing the at-home portion of the study.

Participants were instructed to complete the at-home portion of the study in a private place (i.e., with no one else in the room) and to refrain from any sexual activities (including masturbation) during this portion of the study so that I could isolate effects of viewing erotica from masturbation. Because of the potential for effects of masturbation or partnered sexual activity on T (Exton et al., 1999; van Anders, Hamilton, Schmidt et al., 2007), participants who reported engaging in these activities or having their partner present during the study (*n* = 9, plus two nonresponders) were excluded from analyses as described above.

Participants were given a link to an online questionnaire, which guided them through study procedures. First, participants provided a pre-film saliva sample while completing the Film Scale. Then, participants received instructions about viewing a video corresponding to their randomly assigned condition (see Design above). To avoid differential anticipatory effects on T

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[1] In the interest of fully reporting, I also note that the following measures were collected but not analyzed in the present study: the Sexual Desire Inventory (Spector, Carey, & Steinberg, 1996), the Sociocultural Attitudes Towards Appearance Questionnaire (Thompson, van den Berg, Roehrig, Guarda, & Heinberg, 2004), the Personal Attributes Questionnaire (Spence & Helmreich, 1978), the Brief Mosher Sex Guilt Scale (Janda & Bazemore, 2011), the Female Sexual Subjectivity Inventory (Horne & Zimmer-Gembeck, 2006), the Attitudes about Dating and Relationships Measure (Ward, 2002), and the Feminist Beliefs and Behavior Measure (Zucker, 2004).

or arousal, participants were unaware of their condition assignment until this time. In all conditions, participants were instructed to watch the video with sound if possible, and not to engage in any other activities such as checking email while watching the video.

Immediately after watching the video, participants completed a second Film Scale and the enjoyment item (along with a few additional items about experiences viewing the video not included in the current analyses). Participants then viewed a slideshow of landscape pictures for 12 minutes as a time-filler, as effects of sexual and other social stimuli on T are typically evident after a 10-20 minute delay (van Anders et al., 2014). After the time-filler activity, participants provided their post-film saliva sample and completed the third Film Scale. Participants were instructed to finish the post-film saliva sample before proceeding to the Identification Scale (for participants in the erotica conditions only) and the video details questionnaire. Approximately 24 hours after viewing the video, participants completed an additional brief questionnaire with measures unrelated to the current analyses (sexual desire and sexual behaviors during the 24-hour period post-film). Upon completion of the study, participants were compensated with $25.

Analyses

To measure changes in T from pre- to post-film while accounting for variation in baseline T, I computed a percent change in T (T%: (post-film T – pre-film T) / pre-film T) as is common in research with T (van Anders et al., 2014). I excluded T outliers (over 3 SD from the mean and/or visually) from analyses involving T. Three participants were outliers for pre-film T, four for post-film T (two of whom were also outliers for pre-film T), and four for T%. An additional participant's pre-film T could not be determined due to insufficient sample volume.

I checked whether the following potential confounds were associated with T% and, if so, whether controlling for them changed the pattern of results: age, nicotine use, BMI, relationship

status, time of day of testing, and date of testing (van Anders et al., 2014). Compared to other potential sources of variation in T, menstrual variation is relatively small, and menstrual phase does not need to be controlled in studies with T unless it is of particular interest (Dabbs & de La Rue, 1991; van Anders et al., 2014); thus, participants were tested in all phases of their menstrual cycle and I did not control for menstrual phase. I used analyses of variance (ANOVAs) to test for effects of condition on self-report variables and T%, and analyses of covariance (ANCOVAs) when controlling for factors or testing for potential moderators. For ease of interpretation, I used absolute change scores (Time 2 – Time 1 or Time 3 – Time 1) in analyses with the Film Scale variables. I followed up significant effects with least significant difference (LSD) post-hoc tests or contrasts.

Results

Film Selections

All 27 participants in the high choice condition reported choosing a video from the Internet; among the 11 participants in this condition who reported the specific website hosting the video they chose, pornhub.com was the most frequent choice (n = 5). Sixteen participants in the high choice condition provided a description of the video they chose (see Table 4.2 for a summary of these descriptions). In the moderate choice condition, there was variation in the frequency with which each of the eight video options was selected; the most popular video was viewed by 17 participants, whereas the least popular video (the same video used for the no choice condition) was viewed by two participants. On average, participants in the high choice condition reported taking longer to choose a video (M = 5.20 min, SD = 5.49) than participants in the moderate choice condition (M = 1.90 min, SD = 1.23), $t(56)$ = 3.26, p = 0.002, but watching videos for a similar amount of time (high choice: M = 12.60 min, SD = 4.46; moderate choice: M

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= 11.13 min, SD = 3.81), $t(55)$ = 1.34, p = 0.187. Ten participants in the high choice condition

and seven in the moderate choice condition reported watching scenes from more than one video.

In all conditions combined, all but four participants (two each in the high choice and moderate

choice conditions) reported watching the video with sound.

Table 4.2
Description of Content of Videos Chosen by Participants in the High Choice Condition[a]

Content Characteristic	Number of Participants Mentioning Characteristic/ Number of Participants Who Provided Data on Characteristic
Number and genders of actors	
One woman, one man	12/13
Two women, one man	2/13
Sexual behaviors	
Kissing	1/12
Oral sex on woman	4/12
Oral sex on man	6/12
Oral sex (unspecified)	4/12
Intercourse	12/12
Woman masturbating with sex toy	1/12
Described coercion or power differential between characters[b]	3

[a]Data are available from 16 participants who provided a description of their video (out of 27 participants in the high choice condition).
[b]Three participants indicated in their descriptions that the male actor had control or power over the female actor, and/or that the film depicted a coercive scenario (e.g., male employer and female employee).

Effects of Film Conditions on Arousal and Cognitive/Emotional Parameters

      Film Scale. Overall, film condition significantly affected absolute changes in arousal and

affect from pre- to post-film (Time 2 – Time 1) as measured by the Film Scale, *multivariate*

$F(15, 299)$ = 8.56, p < 0.001, η_p^2 = 0.28. There were significant univariate effects of film

condition for all subscales (all p's < 0.008; η_p^2 = 0.48 for psychological arousal, 0.50 for

perceived physiological arousal, 0.14 for disgust, and 0.10 for guilt/embarrassment) except

anxiety (p = 0.791, η_p^2 = 0.01), and I followed up these significant effects with LSD post-hoc

tests (see Figure 4.1 for change scores; see Table 4.3 for means and SDs for all dependent

variables by experimental condition).

Table 4.3

Means ± SD of Film Scale Variables, Enjoyment, Identification, and Testosterone by Experimental Condition

			High Choice Erotica	Moderate Choice Erotica	No Choice Erotica	Neutral
Film Scale	*Psych Arousal*	*T1*	3.07 ± 0.89	2.99 ± 0.86	2.81 ± 0.89	3.38 ± 1.26
		T2	4.62 ± 1.20	4.20 ± 1.44	3.74 ± 1.29	1.86 ± 0.66
		T3	2.44 ± 0.99	3.09 ± 1.50	2.32 ± 0.80	1.89 ± 0.82
	Physio Arousal	*T1*	1.39 ± 0.46	1.47 ± 0.61	1.38 ± 0.42	1.62 ± 0.59
		T2	4.16 ± 1.47	3.59 ± 1.42	3.14 ± 1.44	1.19 ± 0.38
		T3	1.60 ± 0.85	2.01 ± 1.30	1.37 ± 0.72	1.12 ± 0.39
	Disgust	*T1*	1.28 ± 0.81	1.06 ± 0.17	1.16 ± 0.52	1.21 ± 0.41
		T2	1.93 ± 1.44	1.31 ± 0.65	1.31 ± 0.78	1.05 ± 0.15
		T3	1.33 ± 1.03	1.03 ± 0.18	1.24 ± 0.68	1.07 ± 0.29
	Guilt/Embarrass	*T1*	1.46 ± 1.22	1.50 ± 0.96	1.26 ± 0.56	1.28 ± 0.59
		T2	2.02 ± 1.52	1.40 ± 0.78	1.29 ± 0.73	1.03 ± 0.19
		T3	1.35 ± 0.83	1.00 ± 0.00	1.10 ± 0.39	1.05 ± 0.29
	Anxiety	*T1*	1.78 ± 1.05	1.86 ± 1.09	1.83 ± 0.68	1.69 ± 0.89
		T2	1.52 ± 0.79	1.34 ± 0.66	1.44 ± 0.57	1.26 ± 0.54
		T3	1.57 ± 0.74	1.65 ± 1.05	1.58 ± 0.75	1.20 ± 0.48
Enjoyment			4.63 ± 1.69	4.61 ± 1.76	3.38 ± 1.40	2.64 ± 1.42
Identification			4.30 ± 1.38	4.17 ± 1.60	3.49 ± 1.40	N/A
Testosterone (pg/mL)		*T1*	46.94 ± 16.73	45.64 ± 18.86	38.83 ± 15.95	46.06 ± 20.09
		T2	45.74 ± 17.92	39.33 ± 14.66	38.42 ± 11.63	43.35 ± 21.47

Note. "Psych Arousal" = Sexual/Positive Psychological Arousal and Desire; "Physio Arousal" = Perceived Physiological Arousal; "Guilt/Embarrass" = Guilt/Embarrassment. T1, T2, and T3 correspond to Time 1 (pre-film), Time 2 (post-film), and Time 3 (final).
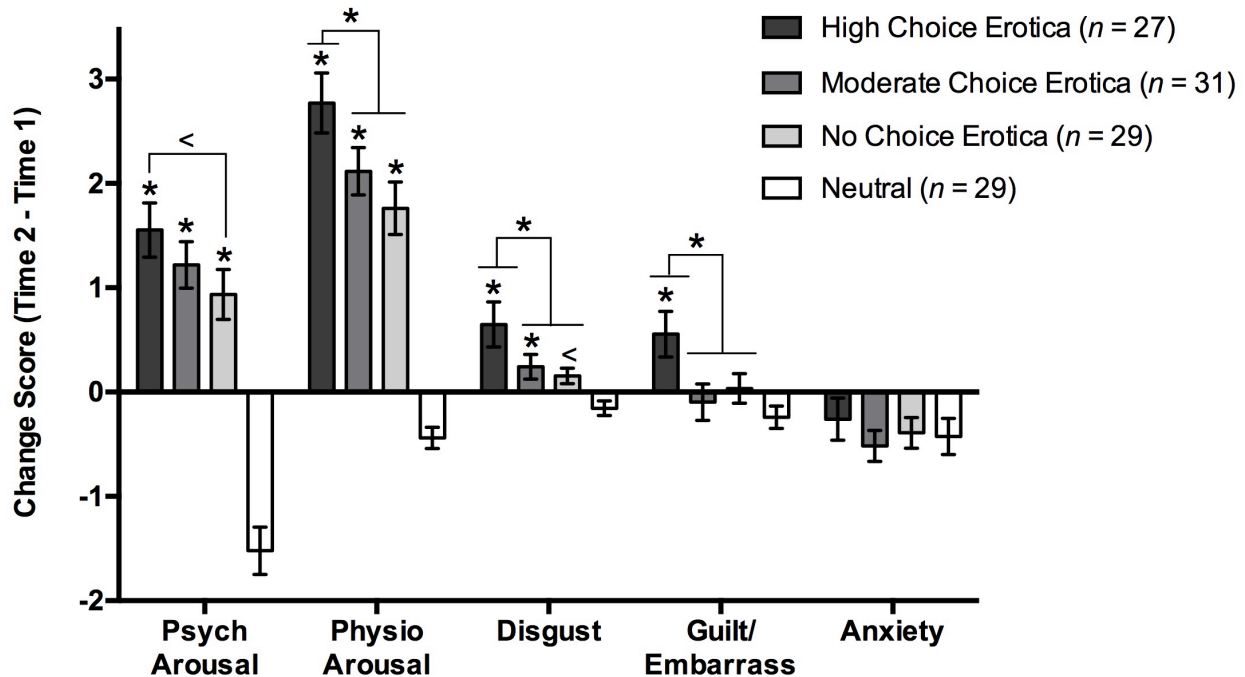
Figure 4.1. *Effects of Film Conditions on Changes in Film Scale Subscales From Pre- to Post-Film.* "Psych Arousal" = Sexual/Positive Psychological Arousal and Desire; "Physio Arousal" = Perceived Physiological Arousal; "Guilt/Embarrass" = Guilt/Embarrassment. "*" indicates a significant difference at $p < 0.05$, and "<" indicates a trend at $p < 0.10$. "*" or "<" immediately above a bar indicates a difference compared to the neutral condition.

As expected, women in all erotica conditions showed significant increases in psychological arousal and perceived physiological arousal compared to women in the neutral condition (all p's < 0.001). Furthermore, women in the high choice condition had significant increases in perceived physiological arousal over women in the moderate choice ($p = 0.043$) and no choice ($p = 0.002$) conditions, and marginal increases in psychological arousal over women in the no choice condition ($p = 0.072$). Unexpectedly, however, women in the high choice condition also reported significant increases in disgust and guilt/embarrassment compared to women in the moderate choice and no choice conditions (all p's < 0.031). Relative to women in the neutral condition, disgust significantly increased among women in the high choice condition ($p < 0.001$) and the moderate choice condition ($p = 0.030$), but only marginally so among women in the no choice condition ($p = 0.093$). Additionally, women in the high choice condition ($p = 0.001$), but

not in the moderate choice condition ($p = 0.528$) or no choice condition ($p = 0.238$), reported

significant increases in guilt/embarrassment compared to the neutral condition. Overall, self-

chosen erotica from participants' own sources increased perceived physiological arousal, but

additionally increased disgust and guilt/embarrassment, compared to erotica preselected by

researchers (see Figure 4.1).

Some effects of conditions on Film Scale scores were still evident when considering

absolute changes from pre-film to the final timepoint (Time 3 – Time 1), *multivariate F*(15, 299)

$= 3.65$, $p < 0.001$, $\eta_p^2 = 0.14$. Significant univariate effects at the final timepoint were limited to

psychological arousal ($p < 0.001$, $\eta_p^2 = 0.26$) and perceived physiological arousal ($p < 0.001$, η_p^2

$= 0.20$), and I followed up these effects with LSD post-hoc tests (see Figure 4.2).

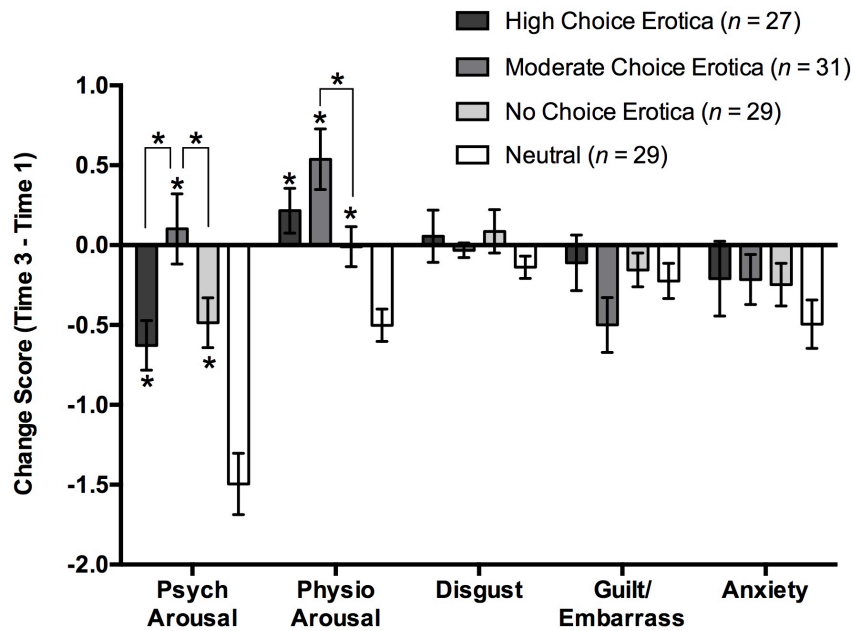**Figure 4.2.** *Effects of Film Conditions on Changes in Film Scale Subscales From Pre-Film to Final.* "Psych Arousal" = Sexual/Positive Psychological Arousal and Desire; "Physio Arousal" = Perceived Physiological Arousal; "Guilt/Embarrass" = Guilt/Embarrassment. "*" indicates a significant difference at $p < 0.05$. "*" immediately above or below a bar indicates a significant difference compared to the neutral condition.

From pre-film to the final timepoint, women in all erotica conditions showed significant increases in psychological arousal and perceived physiological arousal compared to women in the neutral condition (all p's < 0.02), though psychological arousal had dropped below pre-film levels for women in the high and no choice conditions. Women in the moderate choice condition reported significant increases in psychological arousal compared to women in the high choice condition ($p = 0.006$) and significant increases in both psychological arousal ($p = 0.024$) and perceived physiological arousal ($p = 0.008$) compared to women in the no choice condition. Thus, arousal remained elevated at the final timepoint for women in the moderate choice condition relative to those in the other erotica conditions (see Figure 4.2). Because changes from pre-film to final were overall less pronounced than from pre- to post-film, I focus on pre- to post-film changes in subsequent analyses with the Film Scale.

Enjoyment. Film condition significantly affected enjoyment of the video, $F(3, 111) = 10.91$, $p < 0.001$, $\eta_p^2 = 0.23$, such that the high and moderate choice conditions elicited significantly more enjoyment than the no choice condition (p's < 0.005) (see Figure 4.3 for means). Erotic films were rated as more enjoyable than the neutral film (p's < 0.001 for high and moderate choice conditions vs. neutral; $p = 0.081$ for no choice vs. neutral). Thus, participants enjoyed erotic films more when they chose the film themselves, either from their own sources or a preselected pool, compared with having a film assigned.
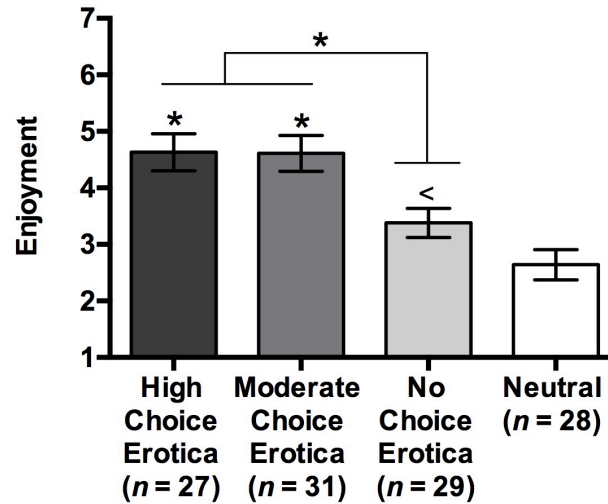
Figure 4.3. *Effects of Film Conditions on Enjoyment.* "*" indicates a significant difference at $p < 0.05$, and "<" indicates a trend at $p < 0.10$. "*" or "<" immediately above a bar indicates a difference compared to the neutral condition.

Identification. Counter to predictions, the erotica conditions only had a marginally significant effect on identification, $F(2, 84) = 2.52$, $p = 0.087$, $\eta_p^2 = 0.06$. Post-hoc tests showed that compared with women in the no choice condition, identification was higher for women in the high choice condition ($p = 0.042$) and marginally higher for women in the moderate choice condition ($p = 0.077$). However, ratings of identification were near the midpoint for each of the three erotica conditions (see Table 4.3 for means). (Participants in the neutral condition did not respond to the identification scale.)

In sum, evidence for an overall 'positive' effect of self-chosen erotica on viewing experiences was mixed: self-chosen erotica increased enjoyment but only marginally increased identification with the film. Compared with erotica preselected by researchers, self-chosen erotica from participants' own sources increased perceived physiological arousal, but also increased disgust and guilt/embarrassment, from pre- to post-film.

Did identification moderate effects of self-chosen erotica on negative affect? Because the high choice condition increased guilt/embarrassment and disgust but only marginally

increased identification, I was interested in whether self-chosen erotica might have elicited especially strong levels of guilt/embarrassment and disgust when participants weakly identified with their chosen stimuli. To test this, I conducted ANCOVAs with guilt/embarrassment (Time 2 – Time 1) (or disgust Time 2 – Time 1) as the dependent variable, and erotica condition, identification, and the condition x identification interaction as predictors.

Identification moderated the effects of erotica condition on guilt/embarrassment, $F(1, 81)$ = 3.76, $p = 0.028$, $\eta_p^2 = 0.09$ (see Figure 4.4). To follow up the significant interaction, I conducted post-hoc contrasts to test for differences in guilt/embarrassment between conditions at three levels of identification: low (25th percentile, corresponding to an identification score of 2.9 on the 1-7 scale), moderate (50th percentile, corresponding to a score of 4), and high (75th percentile, corresponding to a score of 5.1), following common practices. At low or moderate levels of identification, women in the high choice condition had increased guilt/embarrassment compared to those in the moderate choice (p's < 0.004) and no choice conditions (p's < 0.04). However, at high levels of identification, there were no significant differences between the erotica conditions in guilt/embarrassment (all p's > 0.30). Identification was a significant negative predictor of guilt/embarrassment in the high choice condition, $\beta = -0.33$ ($SE = 0.15$), $t = -2.18$, $p = 0.039$, but was not significantly linked with guilt/embarrassment in the moderate choice condition, $\beta = 0.11$ ($SE = 0.11$), $t = 1.03$, $p = 0.311$, or the no choice condition, $\beta = 0.08$ ($SE = 0.11$), $t = 0.75$, $p = 0.462$. Thus, self-chosen erotica from participants' own sources increased guilt/embarrassment only when participants weakly or moderately identified with their chosen stimuli (see Figure 4.4).
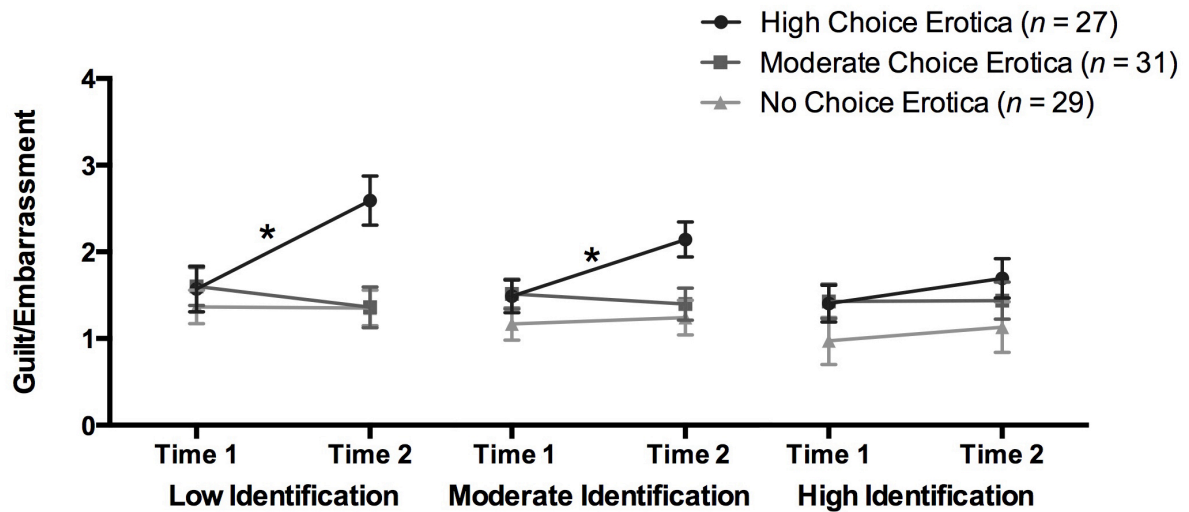
Figure 4.4. *Identification Moderated Effects of Self-Chosen Erotica on Guilt/Embarrassment.* The figure shows effects of erotica conditions on the change in guilt/embarrassment from pre-film (Time 1) to post-film (Time 2) at low (25th percentile), moderate (50th percentile), and high (75th percentile) levels of identification. Note that low identification corresponded to a mean score of 2.9, moderate identification to a mean of 4, and high identification to a mean of 5.1 on a scale from 1-7. Guilt/embarrassment was measured on a scale from *1 = Not at all* to *7 = Intensely.* My statistical analyses used change scores (Time 2 – Time 1) in guilt/embarrassment as the dependent variable, but I show means at Time 1 and Time 2 here for ease of interpretation. "*" indicates a significant difference in change scores between the high choice condition and both the moderate and no choice conditions at $p < 0.05$.

Identification did not significantly moderate effects of erotica condition on disgust, $F(2, 81) = 1.70$, $p = 0.190$, $\eta_p^2 = 0.04$, but there was a significant main effect of identification on disgust across erotica conditions, $F(1, 81) = 9.01$, $p = 0.004$, $\eta_p^2 = 0.10$, such that higher identification predicted lower disgust, $\beta = -0.17$ ($SE = 0.06$), $t = -3.04$, $p = 0.003$. Thus, the increase in guilt/embarrassment associated with self-chosen erotica from participants' own sources was ameliorated at higher levels of identification, and higher identification predicted lower disgust across erotica conditions.

Exploratory analyses. To help clarify the unexpected results regarding increased guilt/embarrassment and disgust in the high choice condition, I conducted post-hoc analyses to

further explore possible explanations for this finding. Among participants in the high choice condition, changes in disgust and guilt/embarrassment from pre- to post-film were similar for those who provided a description and/or title/link of their video ($n = 18$; disgust: $M = 0.72$, $SD = 1.27$; guilt/embarrassment: $M = 0.53$, $SD = 0.99$) and those who did not provide this information ($n = 9$; disgust: $M = 0.50$, $SD = 0.79$; guilt/embarrassment: $M = 0.61$, $SD = 1.45$), t's < 0.5, p's > 0.6, suggesting that self-consciousness about providing information about the video was not a driving factor of negative affect. I checked whether less experienced erotica users were skewed to the high choice condition, and this was not the case; there were no significant differences between the four conditions in frequency of erotic video use, $F(3, 112) = 0.16$, $p = 0.926$, $\eta_p^2 = 0.004$. Frequency of erotic video use was negatively, but not significantly, correlated with time to choose a video in the high choice condition, $r(25) = -0.29$, $p = 0.144$, and these two variables were not significantly correlated in the moderate choice condition, $r(29) = -0.03$, $p = 0.869$. In turn, time to choose a video was not significantly correlated with changes in disgust, $r(25) = -0.22$, $p = 0.263$, or guilt/embarrassment, $r(25) = -0.22$, $p = 0.262$, for women in the high choice condition. For women in the moderate choice condition, time to choose a video was not significantly correlated with guilt/embarrassment, $r(29) = 0.23$, $p = 0.215$, but taking more time to choose a video predicted marginally lower disgust, $r(29) = -0.32$, $p = 0.084$.

I also explored whether arousal and enjoyment, in addition to identification, might moderate or predict negative affect in the erotica conditions. Neither psychological arousal, perceived physiological arousal, nor enjoyment significantly moderated effects of erotica conditions on guilt/embarrassment or disgust (all p's for interaction terms > 0.10). However, across erotica conditions, higher enjoyment predicted lower disgust, $\beta = -0.18$ ($SE = 0.05$), $t = -3.70$, $p < 0.001$, as did higher psychological arousal, $\beta = -0.16$ ($SE = 0.06$), $t = -2.58$, $p = 0.012$.

Interestingly, neither enjoyment nor psychological arousal significantly predicted guilt/embarrassment (p's > 0.8), but higher perceived physiological arousal predicted marginally *higher* guilt/embarrassment, $\beta = 0.14$ ($SE = 0.08$), $t = 1.80$, $p = 0.076$. Thus, identification, but not arousal or enjoyment, moderated effects of erotica conditions on guilt/embarrassment, although arousal and enjoyment did predict disgust across erotica conditions.

Effects of Film Conditions on T

Film condition did not significantly affect T%, $F(3, 102) = 0.32$, $p = 0.811$, $\eta_p^2 = 0.01$. I checked whether controlling for age, nicotine use, BMI, relationship status, time of day of testing, or date of testing changed the pattern of results, and none did (date of testing, $F(1, 101) = 3.30$, $p = 0.072$, and BMI, $F(1, 100) = 3.44$, $p = 0.067$, each had marginally significant effects on T%, but neither changed the pattern of results with condition and T%).

Identification and negative affect as moderators of T%. Although there was no significant difference in T% between film conditions overall, I tested whether identification would moderate effects of self-chosen erotica on T%, in addition to moderating effects of self-chosen erotica on guilt/embarrassment as shown above. I also explored whether guilt/embarrassment or disgust would moderate effects of erotica conditions on T%. I used ANCOVAs with T% as the dependent variable, and condition, the relevant moderator variable (i.e., identification, guilt/embarrassment, or disgust), and the condition x moderator variable interaction as predictors[2].

Identification moderated effects of self-chosen erotica on T%, $F(2, 71) = 3.40$, $p = 0.039$, $\eta_p^2 = 0.09$ (see Figure 4.5). Decomposing the interaction showed that among women who

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[2] I excluded the neutral condition from these analyses because parameters in the neutral condition differed greatly from the other conditions (e.g., T% at high levels of disgust would not make conceptual sense in the neutral condition, because high levels of disgust did not occur in the neutral condition); further, the Identification Scale was only completed by participants in the erotica conditions.

reported low levels of identification, those in the moderate choice condition showed decreased T compared to those in the no choice condition ($p = 0.037$). However, this difference in T% between the moderate choice and no choice conditions was not present at moderate ($p = 0.583$) or high ($p = 0.325$) levels of identification. The pattern for the high choice condition versus the no choice condition was similar; that is, T% tended to be lower for women in the high choice condition compared to women in the no choice condition at lower levels of identification (see Figure 4.5); however, there were no significant differences via the post-hoc contrasts (all p's > 0.21). In the moderate choice condition, higher identification significantly predicted higher T%, $\beta = 4.81$ ($SE = 1.99$), $t = 2.41$, $p = 0.023$, but identification was not a significant predictor of T% in the high choice condition, $\beta = 2.35$ ($SE = 3.02$), $t = 0.78$, $p = 0.444$, or the no choice condition, $\beta = -3.99$ ($SE = 2.82$), $t = -1.42$, $p = 0.170$. Collapsing the high and moderate choice conditions into one 'self-chosen' condition also yielded a significant interaction between identification and condition, $F(1, 73) = 6.38$, $p = 0.014$, $\eta_p^2 = 0.08$, suggesting a similar pattern of results in the high and moderate choice conditions. Self-chosen erotica marginally decreased T at low ($p = 0.073$) but not high or moderate levels of identification. Thus, higher levels of identification may have offset a decrease in T associated with self-chosen erotica, especially in the moderate choice condition. And, higher identification predicted higher T% for participants in the moderate choice condition specifically.
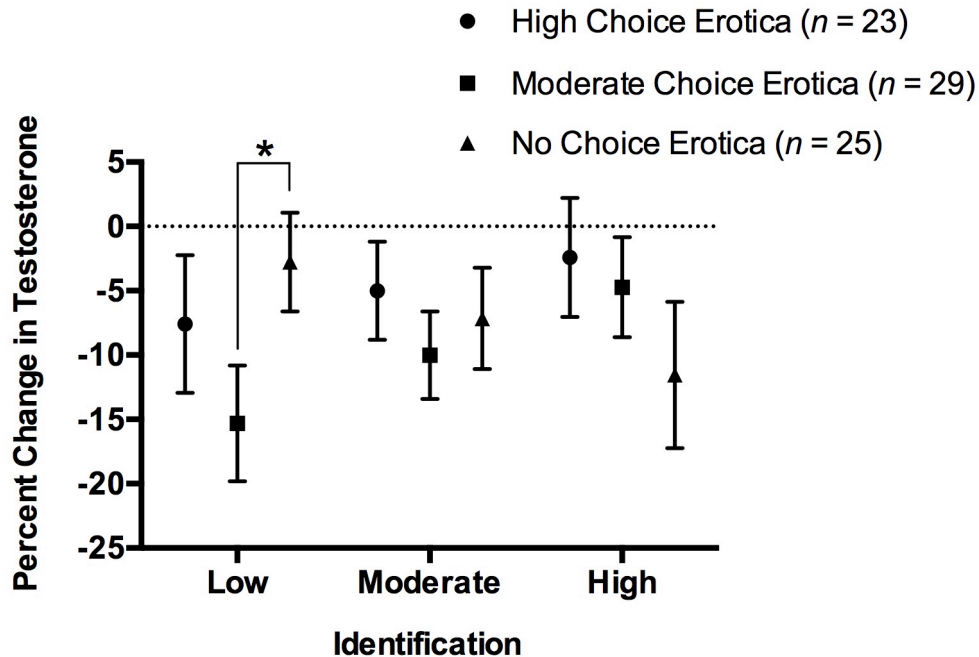
Figure 4.5. *Identification Moderated Effects of Self-Chosen Erotica on Testosterone.* The figure shows effects of erotica conditions on the percent change in testosterone (T%) from pre- to post-film at low (25th percentile), moderate (50th percentile), and high (75th percentile) levels of identification. "*" indicates a significant difference at $p < 0.05$.

Neither guilt/embarrassment (interaction term: $F(2, 71) = 1.51$, $p = 0.227$) nor disgust (interaction term: $F(2, 71) = 0.25$, $p = 0.778$) significantly moderated the effects of self-chosen erotica on T%.

I checked whether controlling for BMI or date of testing, the two covariates that were linked with T%, changed the above pattern of results. When controlling for BMI, the interaction between condition and identification became non-significant ($p = 0.127$, $\eta_p^2 = 0.06$; $p = 0.052$, $\eta_p^2 = 0.05$ with high and moderate choice conditions collapsed), but the overall pattern of results was the same, with lower T% for women in the moderate choice condition than for women in the no choice condition at low levels of identification ($p = 0.048$; $p = 0.071$ with high and moderate choice conditions collapsed). Controlling for date of testing made the positive link between identification and T% in the moderate choice condition a trend, $\beta = 4.18$ ($SE = 2.07$), $t = 2.02$, p

= 0.054. Otherwise, controlling for BMI or date of testing did not change the overall pattern of results.

Discussion

The current study is the first to compare women's arousal, cognitive/emotional responses, and T responses to self-chosen versus researcher-chosen erotica. I predicted that self-chosen erotica would increase identification with stimuli and ameliorate negative affect, and in turn lead to higher T responses. However, my results demonstrate that the effects of autonomously choosing erotica are more complex. Although self-chosen erotica increased perceived physiological arousal and enjoyment, it also increased disgust and guilt/embarrassment – and the latter effect was especially pronounced when participants did not strongly identify with their chosen stimuli. Mirroring the pattern of results with guilt/embarrassment, self-chosen erotica *decreased* T, but only at low levels of identification. These findings highlight the importance of internal cognitive and emotional experiences in shaping T responses to external sexual stimuli.

Effects of Self-Chosen Erotica on Arousal and Cognitive/Emotional Responses

In line with my predictions, self-chosen erotica increased self-reported arousal and enjoyment compared with researcher-chosen erotica. Previous research demonstrated that attempting to tailor film selection to participants' characteristics (e.g., using films chosen by research assistants with similar demographic backgrounds to participants) increased self-reported arousal (Janssen et al., 2003; Janssen, Goodrich, Petrocelli, & Bancroft, 2009; Laan et al., 1994; Mosher & MacIan, 1994), and my study extends this research by showing that self-chosen erotica from participants' own sources increased perceptions of physiological arousal immediately post-film over and above self-chosen erotica preselected by researchers. An alternative explanation is that by exercising choice over stimulus selection, participants may

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have felt more obligation to be aroused, and thus reported higher arousal regardless of their actual experience of arousal. However, other self-report findings in the high choice condition ran counter to expectations (see below), suggesting that the results with arousal are unlikely an artifact of demand characteristics.

A more puzzling finding was that self-chosen erotica from participants' own sources only marginally increased identification and significantly exacerbated negative affect, specifically disgust and guilt/embarrassment, compared to the other erotica conditions. Although I had predicted that erotica from one's own sources would more closely match personal preferences and thus maximize identification, it is possible that the characteristics of most erotica available online are not conducive to identifying closely with the stimuli. For example, a vast majority of the actors in free online pornography are white (Gorman, Monk-Turner, & Fish, 2010; Vannier, Currie, & O'Sullivan, 2014), which could make it difficult for racial/ethnic minority participants to identify with this material. Commonly-available pornography often includes heteronormative portrayals of bodies and sexual behaviors, with an emphasis on penetration rather than behaviors oriented around women's pleasure (e.g., cunnilingus) (Gorman et al., 2010; Morrison & Tallack, 2005; Vannier et al., 2014), and this includes much of so-called 'lesbian' pornography, which is often targeted at a heterosexual male audience (Morrison & Tallack, 2005). Furthermore, in an open-ended item in the current study, several participants in the high choice condition used words like "fake" or "unrealistic" to describe the videos they watched (see also Parvez, 2006). Therefore, it is possible that stimuli from participants' own commonly-available sources are at least as challenging to identify with as the 'women-centered' stimuli commonly used in sexuality research.

Self-chosen erotica from participants' own sources may have increased disgust and guilt/embarrassment for similar reasons. Although I recruited for participants comfortable with erotica, the stigma associated with women's visual erotica use may become even more salient when women choose erotica themselves as opposed to watching erotica assigned to them by researchers. Indeed, viewing erotica chosen by someone else (e.g., a relationship partner) may be more socially sanctioned for women than viewing erotica for the purpose of solitary masturbation or arousal (Bridges & Morokoff, 2011; Hald, 2006; Lawrence & Herold, 1988; Traeen, Nilson, & Stigum, 2006), such that choosing erotica from one's own sources exacerbates the guilt, embarrassment, and disgust already conditioned to this stigmatized behavior.

The increase in guilt/embarrassment in the high choice condition was ameliorated at high levels of identification however, indicating that viewing self-chosen visual erotica does not unequivocally lead to guilt and embarrassment in women. Rather, a woman who chooses erotica but then does not identify with her chosen stimulus may experience a dissonance between her lack of identification with the film and the knowledge that she herself *chose* it, thus increasing guilt and embarrassment. Additionally, the time investment required to choose erotica (which was larger in the high choice than moderate choice condition) could elicit negative affect when that investment fails to result in high identification with stimuli. Alternatively, guilt or embarrassment in response to self-chosen films might inhibit the ability to identify with the stimulus. My findings thus point to identification as an important predictor of women's affective responses to self-chosen erotica and raise questions about the directionality of this link.

A further implication of my results is that negative affect and sexual arousal can co-occur when women view self-chosen erotica in their home environments, in addition to when viewing researcher-chosen erotica in the laboratory (Peterson & Janssen, 2007). Despite increasing

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disgust and guilt/embarrassment, the high choice condition elicited the highest post-film increases in perceived physiological arousal. Together with previous findings (Peterson & Janssen, 2007; Vilarinho et al., 2014), my results suggest that the presence of positive emotions – like enjoyment, which increased in response to self-chosen erotica – may be more predictive of sexual arousal than the absence of negative emotions. In addition, it is possible that disgust, guilt, and embarrassment increased *because* women noticed themselves becoming physiologically aroused to explicit sexual stimuli (Peterson & Janssen, 2007), given the stigma surrounding pornography use for women. This interpretation is supported by my finding that higher physiological arousal predicted marginally higher guilt/embarrassment across erotica conditions. Finally, it is important to note that while the increases in negative affect observed in the high choice condition were statistically significant compared to the other conditions, they were relatively small in magnitude (less than 1 point on a 7-point scale). Therefore, while self-chosen erotica increases negative affect compared to erotica preselected by researchers, it does not necessarily result in 'high' levels of negative affect.

What do my results mean for researchers interested in increasing the ecological validity of studies involving erotic films? If the goal is to maximize self-reported arousal and enjoyment but minimize negative affect, a design similar to the moderate choice condition may be most appropriate. This condition allowed participants some autonomy in stimulus selection, while the film screening process eliminated degrading content or content expected to be offensive to many participants (e.g., female actors depicted in low power positions and coercive sexual situations, as reported by three participants in the high choice condition) – perhaps explaining why this condition did not increase guilt/embarrassment compared to the neutral condition. Although the moderate choice condition elicited lower post-film perceived physiological arousal than the high

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choice condition, this difference was transient, with the moderate choice condition eliciting longer lasting effects on self-reported arousal and similar levels of enjoyment. Thus, allowing participants to choose from a small collection of films prescreened by researchers may be an optimal way to balance participants' individual preferences with experimental control (Janssen et al., 2009). A further consideration is that participants were tested at home, which increases women's genital and self-reported arousal to erotic films compared to the laboratory setting (Bloemers et al., 2010). The home environment may therefore allow participants to experience maximally positive effects of film choice on enjoyment and arousal.

Effects of Self-Chosen Erotica on T

Overall, self-chosen erotica did not increase T compared to viewing researcher-chosen erotica or a neutral film, but self-chosen erotica failed to elicit the intended effects on negative affect and identification. However, even though self-chosen erotica did not significantly increase identification or T, identification was an important predictor of T responses. Specifically, at low levels of identification, self-chosen erotica decreased T (especially in the moderate choice condition), but this was not the case at moderate or high levels of identification. Thus, choosing erotica and not identifying with what has been chosen may elicit a decrease in T alongside an increase in negative affect.

In the contexts of cortisol responses to stress and T responses to competition, researchers have argued that cognitions and emotions elicited by a stimulus, rather than the stimulus itself, trigger hormone responses (Dickerson et al., 2004; Oliveira et al., 2013; Salvador, 2005; Salvador & Costa, 2009). This possibility has been less thoroughly explored in relation to sexual stimuli, and my findings suggest that effects of stimulus source or content on T responses may be secondary to effects of cognitive and emotional reactions. Furthermore, previous work on stress

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suggests that hormones respond to specific cognitive or affective states (e.g., shame) rather than more general ones (e.g., general negative affect or distress) (Dickerson et al., 2004). In the case of sexual stimuli, identification appears to be one such specific parameter important for T. As neither guilt/embarrassment nor disgust moderated T responses to erotica, the link between identification and T does not appear to be secondary to effects of negative affect on T. It is possible that the 10-item measure of identification was simply more nuanced than the guilt/embarrassment measure, and that a more comprehensive measure of guilt/embarrassment (or disgust) could have yielded different results. However, there are specific reasons to believe that identification is an important trigger for T responses in sexual contexts.

Previous studies that have found T responses to sexual or mating-relevant stimuli in the absence of sexual behavior in women have employed conditions that encouraged identification – instructing participants to imagine engaging in sexual activity with a self-defined attractive partner (Goldey & van Anders, 2011) or to imagine themselves as the female character in a videotaped courtship interaction (Lopez et al., 2009). And, research in female birds suggests that females' T responds to cues that indicate higher partner quality (Correa et al., 2011; Gwinner et al., 2002; Marshall et al., 2005); in the context of viewing sexual stimuli in humans, it may be unlikely that individuals will imagine actors in the film as potential partners if they cannot imagine *themselves* as part of the film. More broadly, identification may increase participants' focus on sexual aspects of the film and their own physiological and mental arousal and reduce their focus on external, non-sexual distractions (Barlow, 1986). In this way, identification may facilitate engagement in positive sexual fantasies stimulated by film content – and perhaps it is actually this fantasy aspect that increases T (Goldey & van Anders, 2011). An alternative possibility is that women who typically have lower T responses to sexual stimuli may experience

sexual interactions as less rewarding and as a result identify less strongly when viewing erotic films. By highlighting the importance of identification in predicting T responses to erotica, my results suggest new avenues for future research. For example, attempting to manipulate identification via instructional prompts (Both et al., 2011; Sheen & Koukounas, 2009) would address the question of whether identification facilitates T responses or vice versa.

Only the moderate choice condition showed a statistically significant association between identification and T, although when I combined the moderate and high choice conditions together into one 'self-chosen' condition, the interaction between identification and condition remained significant, with self-chosen erotica marginally decreasing T at low levels of identification compared to researcher-chosen erotica. This suggests that the overall pattern was similar in the moderate and high choice conditions, and my study may have had inadequate power for the effect of identification on T to reach statistical significance in the high choice condition. The moderate choice condition did differ from the high choice condition on several parameters as discussed above (e.g., the moderate choice condition elicited lower levels of disgust and guilt/embarrassment), and perhaps identification is especially likely to be linked with T responses when negative affect is lower.

Although higher identification may offset a decrease in T associated with self-chosen erotica, self-chosen erotica never elicited *higher* T responses compared to researcher-chosen erotica or a neutral film. This raises the question of whether offsetting a decrease in T is analogous to increasing T; maintaining T at stable levels in comparison to a decline in T (e.g., as often occurs in control conditions due to circadian fluctuations) is often interpreted as conceptually similar to an increase in T (Dabbs & Mohammed, 1992; Miller & Maner, 2010). Yet, my results suggest that even relatively higher levels of identification when viewing visual

erotica do not predict an *increase* in T compared to a neutral control. It may be that visual stimuli are simply a less strong stimulus for women's T than sexual fantasy or partnered sexual behavior, or, perhaps engaging in fantasy or partnered sexual behavior elicits identification in a qualitatively different way than viewing commercially or freely available pornography. Visual imagery during fantasy or visual stimuli from a partner during real-life sexual interactions may provide more salient cues for women's T than visual erotica. And, the interaction between identification and erotica condition explained a relatively small proportion of variance in women's T responses, suggesting that other unexplored individual and stimulus factors likely contribute to variation in women's T responses to erotica.

Going forward, future research could build on my findings to further disentangle stimulus modality from identification and autonomy in terms of effects on T. For example, would sexual fantasy still increase T if participants were given explicit instructions about what to fantasize about? Is there a role for identification with auditory stimuli in sexually-modulated T, even though the visual aspect of audiovisual sexual stimuli is typically assumed to be primary? Additionally, my findings raise important questions about the downstream consequences of decreases in T in response to self-chosen audiovisual stimuli at low levels of identification. If up-regulating T increases the reward value of a sexual stimulus as previous researchers have hypothesized (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008; van Anders & Watson, 2006), would experiencing a *decrease* in T in response to a sexual stimulus decrease the likelihood of seeking out similar stimuli in the future? Just as an increase in T may direct energy toward pursuit of sexual activity (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008; van Anders & Watson, 2006), a decrease in T could function to discourage the pursuit of sexual situations that could be costly or unpleasurable. Perhaps the widely-held assumption that women

are less oriented toward visual sexual stimuli than men stems from women experiencing their interactions with erotica as unrewarding due to a lack of identification with the stimuli and an accompanying decline in T.

Limitations

Increasingly, sexuality researchers are recognizing the importance of developing more ecologically valid paradigms for assessing physiological and self-reported responses to sexual stimuli (Bloemers et al., 2010; Janssen et al., 2009; Paterson, Jin, Amsel, & Binik, 2014; van Lankveld et al., 2014). However, a tradeoff of my focus on ecological validity is decreased experimental control, especially in terms of participants' video selections in the high choice condition. Participants' selections varied in the number and genders/sexes of actors and the types and intensities of sexual behaviors depicted. Furthermore, there was variation among participants in the high and moderate choice conditions in the duration and number of films viewed. Especially because many participants in the high choice condition did not report information about their chosen videos, it is difficult to pinpoint exactly what factors (e.g., differences in time to choose a video, stimulus intensity, or types of sexual behaviors depicted, versus the act of choosing erotica per se) contributed to differences in negative affect and arousal between the high choice condition and other erotica conditions. However, my findings suggest that factors like stimulus content, erotica use habits (e.g., time to choose a film, switching films), and perceived authenticity (e.g., perception of the film as "fake") could be important variables to address to understand effects of self-chosen erotica on arousal, identification, and negative affect.

On the other hand, some ways in which my experimental design imposed control over participants' erotica use experiences are also worth noting. To avoid the confound of novel

content in the moderate and no choice conditions but not the high choice condition, participants were instructed to try to choose a video they had not seen before, which may have made it more challenging for participants to find stimuli they identified with. Participants were also instructed not to masturbate in order to isolate effects of visual erotica on T. Viewing erotica while alone without masturbating may have been a novel experience for some women, and novelty has been linked with T responses to sexual stimuli (Rupp & Wallen, 2007)[3]. Thus, my results may apply to the specific context of viewing unfamiliar erotic stimuli without masturbation, rather than to all of women's experiences with self-chosen erotica.

Conclusion

Although self-chosen erotica increased perceived physiological arousal and enjoyment, it also increased guilt and embarrassment and decreased T at lower levels of identification. The current study demonstrates that cognitive/emotional factors, specifically identification, are important for T responses to sexual stimuli. However, self-chosen erotica does not reliably maximize identification, perhaps because of the stigma associated with viewing erotica for women and the problematic characteristics of much of the erotica available online (e.g., focus on men's rather than women's pleasure, lack of authenticity). Based on my findings, researchers seeking to increase the ecological validity of sexuality research paradigms could preselect multiple erotic films to increase participants' autonomy while minimizing negative affect. My results underscore the importance of cognitive and emotional experiences, over and above stimulus modality, in shaping physiological responses to sexual stimuli, and the importance of social context for sexual and hormonal research.

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[3] Importantly, including participants' typical masturbation habits when using erotic videos (from 0 = Never to 6 = Always/Every time) as a covariate did not change the interaction between identification and condition to affect T%, $F(2, 70) = 3.90$, $p = 0.025$, mitigating concerns about the role of novelty in my results.

APPENDIX 4.1

Film Selections in the Moderate Choice Erotica Condition

1. Lust, Erika (Director). (2010). *Life Love Lust [Scene 1: Life]*. Spain: Lust Films and Publications of Barcelona.

2. Royalle, Candida (Director and Producer). (1997). *The Gift.* USA: Femme Productions.

3. Trouble, Courtney (Director). (2009). *Roulette.* USA: No Fauxxx Productions.

4. Royalle, Candida (Producer). (1984). *Urban Heat.* USA: Femme Productions.

5. Royalle, Candida (Director and Producer). (1998). *Eyes of Desire.* USA: Femme Productions.[a]

6. Sundahl, Debi (Director and Producer), & Kinney, Nan (Director and Producer). (1989). *Hungry Hearts.* USA: Fatale Media.

7. Hottentot, Venus (Director), & Royalle, Candida (Producer). (2006). *Afrodite Superstar.* USA: Femme Productions.

8. Lust, Erika (Director). (2010). *Life Love Lust [Scene 2: Love]*. Spain: Lust Films and Publications of Barcelona.

[a]This film was also used for the No Choice Erotica Condition.

CHAPTER 5

GENERAL DISCUSSION

Synthesis

Testosterone (T) is often studied for its role in causally influencing (male) sexual behavior, but this perspective captures only part of the story of T-sexuality interactions. Research in females and males from a variety of species demonstrates clear evidence for the 'reverse relationship', i.e., effects of sexual stimuli and behaviors on T (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008). An important feature of sexually-stimulated T responses is their variability, such that T does not respond the same way to every sexual situation, even when the same or similar sensory stimuli are present (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008). What accounts for this variability in sexually-stimulated T is not well-characterized, and this remains a major unanswered question in research on sexual modulation of T (Nyby, 2008).

In women, sexual cognitions in the absence of external stimuli are sufficient to increase T (Goldey & van Anders, 2011), as is anticipation of sexual activity (Hamilton & Meston, 2010; van Anders, Hamilton, Schmidt et al., 2007). These findings suggest that one source of variability in sexually-stimulated T may be how an event is experienced *internally*, i.e., cognitively, perceptually, and affectively. In my dissertation, I examined how internal experiences shaped sexual modulation of T and bidirectional T-sexuality links in women. I addressed how solitary sexuality (i.e., being sexual alone) and dyadic sexuality (i.e., being sexual

with a partner) created distinct experiences for women in ways that have implications for associations with T.

First, I demonstrated that, among young heterosexual women, T was associated with solitary sexual behavior differently than with dyadic sexual behavior. Specifically, women's T was about 25% higher when they had recently engaged in masturbation than when they had not, but T was about 25% *lower* during periods of dyadic sexual activity than during periods of dyadic inactivity. Whereas associations between solitary activity and T were consistent across partnering statuses, dyadic activity and T were only associated when women were currently pair bonded, and not when single or casually partnered. These results add to a larger body of findings from women showing positive associations between T and solitary sexuality and negative (or occasionally null) associations between T and dyadic sexuality (van Anders, Hamilton, & Watson, 2007; van Anders, Hamilton, Schmidt et al., 2007; van Anders & Dunn, 2009; van Anders et al., 2009) (reviewed in van Anders, 2012b). They also clarify for the first time that negative links between dyadic sexual behavior and T are specific to pair bonded women.

Why were solitary and dyadic sexuality linked with T in different ways, when sexuality is often assumed to be one phenomenologically whole 'high-T' category? To address this question, I turned to women's own descriptions of their solitary and dyadic sexual experiences. During focus group discussions, women defined solitary and dyadic sexual pleasure in overlapping but far from identical ways. Solitary pleasure was focused on autonomy and orgasm, whereas dyadic pleasure was focused on parameters like closeness, trust, and giving pleasure to a partner. Thus, solitary sexuality may be associated with higher T because it is primarily oriented around eroticism, whereas dyadic sexuality may be associated with lower T because it can be oriented

around nurturance, supporting predictions of the Steroid/Peptide Theory of Social Bonds (van Anders et al., 2011; van Anders, 2013).

Individual and contextual variables shaped how women defined solitary and dyadic sexual pleasure, such that not all women defined pleasure in the same way, and individual women acknowledged that their definitions of pleasure varied based on context. Compared to younger heterosexual women, queer women as well as older heterosexual women expressed stronger entitlement to solitary pleasure and tended to place greater emphasis on orgasm as a metric of dyadic pleasure. Solitary and dyadic sexuality might therefore represent especially distinct experiences for young heterosexual women (the group in whom T-sexuality associations were studied in Chapter 2), such that solitary sexuality may require particularly high levels of agency to overcome social proscriptions, and dyadic sexuality may be relatively unlikely to be oriented around orgasm. In terms of contextual influences, participants emphasized that the extent to which dyadic pleasure was characterized by nurturance varied based on context. For some (but not all) participants, dyadic pleasure was less oriented around nurturance during casual sexual encounters than during sexual activity with a relationship partner. This is consistent with my finding that dyadic sexual behavior was linked with lower T when women were pair bonded, but not when they were single or casually partnered. In these ways, attention to variation in women's narratives of their solitary and dyadic sexual experiences informed interpretations of variation in T-sexuality links.

In my final study, I examined a factor women identified as key to solitary sexual pleasure – autonomy – more deeply in relation to solitary sexual modulation of T. Would differences in autonomy explain previous findings that sexual thoughts increased women's T but visual sexual stimuli did not (Goldey & van Anders, 2011; Hamilton et al., 2008; Heiman et al., 1991; van

Anders et al., 2009)? Previous studies had confounded stimulus modality with autonomy in stimulus selection, such that women chose the content of their sexual thoughts but visual stimuli were chosen by researchers. I hypothesized that higher autonomy in stimulus selection would facilitate women's T responses to visual sexual stimuli. Specifically, I predicted that viewing *self-chosen* erotic films would increase T compared to viewing erotic films chosen by researchers.

Contrary to my hypothesis, overall, there were no differences in T between women who viewed self-chosen versus researcher-chosen films. Attention to how autonomy in stimulus selection was actually experienced by study participants helped clarify this finding. I had expected that autonomously choosing stimuli would be a positive experience for women; i.e., that women given autonomy over stimulus selection would feel less disgust, guilt, and embarrassment and more strongly identify with the stimuli they chose. In actuality, women who chose stimuli from their own sources felt *more* disgusted, guilty, and embarrassed, and they reported only marginally higher identification with the stimuli. Given the stigma associated with pornography use for women (Alexander & Fisher, 2003; Petersen & Hyde, 2011), autonomy in stimulus selection may have been experienced as *responsibility for* stimulus selection. Perhaps for this reason, choosing erotica exacerbated guilt and embarrassment, especially when participants did not identify with the stimuli they chose. Importantly, although the experimental conditions did not have the intended effects on identification, identification was associated with T responses. For women who weakly identified with stimuli, self-chosen erotica *decreased* T compared to researcher-chosen erotica, but this difference disappeared for women who more strongly identified with stimuli. Thus, the cognitive/emotional variable of identification predicted

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how T responded to visual sexual stimuli, but choice of stimuli did not clearly translate to higher identification, perhaps because choice was intertwined with responsibility.

Taken together, these results point to several overarching themes that have important implications for theoretical understandings of sexuality and T as well as for sexual-well-being and clinical practice. First, my results provide empirical evidence supporting conceptualizations of solitary and dyadic sexuality as distinct components of sexuality – hormonally and experientially. Second, my findings reinforce understandings of sexuality-T links as dynamic and bidirectional, rather than the causal arrow only going from T to sexuality. Finally, these results address gaps in research on sexual modulation of T by demonstrating the importance of the internal context (e.g., cognitive, perceptual, and affective experiences) in predicting T responses. Below, I discuss each of these themes and their implications in more detail, and I conclude by describing open questions generated by my findings.

Solitary and Dyadic Sexuality Are Distinct Components, Hormonally and Experientially

Sexuality is typically conceptualized as a uniformly 'high-T' behavioral category, and this idea persists even despite comparative evidence that higher T does not always correspond to more sexual behavior and vice versa. Wingfield and colleagues (1990) proposed that variations in males' circulating T have more to do with male-male competition than with sexual behavior per se, and research in nonhuman primates generally supports this prediction (Beehner et al., 2006; Cavigelli & Pereira, 2000; Muller & Wrangham, 2004; Rangel-Negrin et al., 2011; Strier et al., 1999, 2003). Furthermore, across species, sexual stimuli and behavior do not always increase T (Goldey & van Anders, 2015). As just one example of variation in how sexuality modulates T, in California mice, about half of males increased T in response to a courtship interaction, whereas half displayed a *decrease* in T (Gleason & Marler, 2010). Although research

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on the social role of T in nonhuman females is limited, some studies in female primates and birds do suggest that, as in males, higher levels of androgens correspond to periods of heightened competition for resources or mates (Beehner, Phillips-Conroy, & Whitten, 2005; Cain & Ketterson, 2012; Langmore, Cockrem, & Candy, 2002), and not necessarily to sexual behavior or motivation (Sannen et al., 2005; Wallen, 2001). In sum, comparative research clearly suggests that higher T maps more closely onto *competition* than to sexuality, and that sexuality is sometimes but certainly not always a high-T behavioral context. Yet, the assumption that sexuality and high-T unambiguously co-occur persists: one need only refer to the plethora of studies examining T administration as a treatment for sexual dysfunction in women to see the pervasiveness of this assumption[1].

Counter to assumptions that sexuality is a uniformly high-T category, and in line with comparative perspectives, my findings strongly indicate that sexuality is not one phenomenologically whole category. This is true when considering findings with T as well as how sexuality is experienced by women themselves. My results show that one (of perhaps many) important distinctions is whether sexuality is solitary or dyadic, i.e., whether it occurs alone or together with a partner. Periods of engagement in solitary masturbation are associated with higher T, whereas periods of engagement in dyadic sexual activity are associated with *lower* T for pair bonded women specifically. In addition to their differential associations with T, women characterize solitary and dyadic sexual pleasure differently: solitary pleasure is primarily oriented around autonomy and orgasm, whereas dyadic pleasure is oriented around closeness, trust, and giving pleasure. Therefore, solitary and dyadic sexuality are distinct not only hormonally but also experientially.

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[1] Reis and Abdo (2014) identified 80 articles on T treatment for hypoactive sexual desire disorder in women published between 1988 and 2012. This review only included studies on middle-aged and older women, such that 80 may be an underestimate.

These findings support predictions of the Steroid/Peptide Theory of Social Bonds (S/P Theory) (van Anders et al., 2011; van Anders, 2013), which proposes that the social phenomenology of T can be best understood within the framework of *competition* and *nurturance*. High T is associated with competition (i.e., resource acquisition or defense) and low T with nurturance (i.e., warm, loving, supportive care). Sexuality is difficult to classify in that it could fall into competition *or* nurturance depending on the individual and context. Competitive sexuality (or *eroticism*) could involve genital/erotic pleasure, orgasm, jealousy, power/control, etc.; nurturant sexuality could involve closeness, pair bond formation or maintenance, comforting oneself or a partner, etc. (van Anders, 2013). Because solitary sexual behavior was linked with higher T, the S/P Theory yielded the prediction that solitary sexuality would be experienced as erotic. My qualitative data supported this: women described solitary pleasure as oriented around autonomy (which might map onto power/control) and orgasm. Together, my qualitative and hormonal data support understandings of solitary sexuality as a high-T erotic context for women.

Findings on dyadic sexuality and T have been more mixed than those with solitary sexuality. I found that dyadic sexual behavior was linked with lower T, but only when women were pair bonded; when women were single or casually partnered, dyadic sexual behavior did not significantly predict T. Similarly, some past findings have linked dyadic sexual desire with lower T, but others found null associations (reviewed in van Anders, 2012b; van Anders, 2013). Adding further nuance, dyadic sexual activity *acutely* increases T in women (i.e., from pre- to 15-min post activity) (van Anders, Hamilton, Schmidt et al., 2007). My qualitative data help resolve these findings by positioning dyadic sexuality as a non-uniform context that could involve both eroticism (e.g., erotic sensory stimulation) and nurturance (e.g., closeness, trust).

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Participants described dyadic pleasure as context-dependent, such that it might be more oriented around eroticism than nurturance and vice versa at some times (or with some partners) than others. Thus, studies on dyadic sexuality and T may have yielded mixed findings because dyadic sexuality involves *both* eroticism and nurturance, which are linked with T in different ways. Additionally, the pair bond context is an important moderator of how T and dyadic sexuality are linked, perhaps because dyadic sexuality may be experienced as especially nurturant within a pair bond. In support, some of my focus group participants described dyadic pleasure as more strongly oriented around trust (which has been theorized as key to long-term social affiliations in primates (Dunbar, 2010)) and closeness with long-term partners than with casual partners.

My results, which show that pair bond status and dyadic sexual activity interact to shape women's T profiles, have implications for fundamental questions about the role of sexual activity in pair bonds. Researchers have argued that non-conceptive sexual activity functions to promote pair bond formation and maintenance (particularly following challenges to the pair bond) in humans and in socially monogamous nonhuman primates (Snowdon, 2001; Snowdon et al., 2006). Data from humans supports this assertion: dyadic sexual activity increases feelings of intimacy (van Anders, Hamilton, Schmidt et al., 2007) and sexual satisfaction is highly intertwined with relationship satisfaction and commitment (Sprecher, 2002). However, findings also point to an 'intimacy paradox', such that dyadic sexual activity with a pair bonded partner acutely increases women's T, and T inhibits nurturance (van Anders et al., 2011). How can dyadic sexual activity increase T but still promote nurturance within pair bonds? Although one potential pathway may involve sexual modulation of oxytocin (van Anders et al., 2011), my findings suggest that differential effects of dyadic sexual activity on T in the short-term versus long-term may additionally help resolve this paradox. When women are pair bonded, dyadic

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sexual activity acutely increases T (van Anders, Hamilton, Schmidt et al., 2007) but predicts lower baseline T later on. This pattern of T secretion – lower baseline T with high responsiveness to social stimuli – may be adaptive for pair bonded individuals in balancing the costs and benefits of T (Wingfield et al., 1990). Relatedly, my results point to dyadic sexual activity as a crucial mechanism for maintaining pair bonded women's lower T: pair bonded women only had lower T than single or casually partnered women *when they were dyadically sexually active*. Thus, dyadic sexual activity may be the key behavior that regulates women's T expression in relation to tradeoffs between competition for new partners and nurturance within pair bonds.

Dyadic sexual activity predicting lower baseline T when women are pair bonded fits neatly within the competition-nurturance framework of the S/P Theory, such that sexuality within pair bonds may serve nurturant relationship formation and maintenance functions. Links between higher T and solitary sexual activity are perhaps less intuitive within this framework. Higher T is linked with *competition*, and solitary sexuality involves no direct potential for acquisition or defense of resources. van Anders (2013) has theorized that orgasm and genital/erotic pleasure may be linked with high T because they are proximate cues that *could* signal access to a reproductive opportunity. Ironically, women may be more likely on average to experience orgasm and genital/erotic pleasure during solitary sexuality than during sexual activity with a partner. Thus, links between solitary sexuality and T may be a 'side effect' or byproduct of selection for T to respond to proximate cues that could signal reproductive opportunities (van Anders, 2013). Future studies could test this hypothesis by examining whether dyadic sexual events that include orgasm are more likely to increase T in women than dyadic events that do not involve orgasm (but see van Anders, Hamilton, Schmidt et al., 2007), and

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whether events that include orgasm are more likely to be accompanied by behaviors or feelings that could facilitate resource acquisition (e.g., feelings of confidence). Similarly, feelings of control may commonly occur during competition for resources (sexual or otherwise), and thus experiencing feelings of autonomy or agency during solitary sexuality may predict higher T even though no actual 'competition' is occurring.

My findings have important implications for theoretical understandings of sexuality, pair bonding, and T, but they have practical implications as well. First, my results suggest that assuming low T is the culprit when women report concerns with dyadic sexual desire or function may be misguided. Over 90% of women who obtain a clinical diagnosis of hypoactive sexual desire disorder are in committed romantic relationships (Rosen et al., 2012), and my research suggests that engaging in dyadic sexuality is linked with *lower* T for committed women. Of course, clinical and non-clinical populations may differ in how T and sexuality are linked (van Anders, 2012b), but my findings question whether T administration would be effective or advisable for pair bonded women who report concerns with sexual desire or function. That is, if women with higher dyadic desire have *lower* T (van Anders, 2012b) and pair bonded women have *lower* T when dyadically sexually active, this suggests that administering T may not result in enhanced dyadic desire or more frequent dyadic activity for pair bonded women. And, T administration could potentially have undesired effects on nurturance within romantic relationships, given that women's T is negatively associated with their own and their partners' relationship commitment and satisfaction (Edelstein et al., 2014). Although directly testing these predictions via T administration would be logistically difficult, future research could examine the extent to which women's erotic and nurturant fantasy content predicts T and dyadic desire over time. For example, if women's nurturant fantasy content increased alongside decreases in T over

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time in a committed relationship, this would support predictions that dyadic sexual activity is linked with lower T in pair bonds because it is especially likely to be oriented around nurturance. This methodology could also be used to explore whether erotic or nurturant fantasy content more strongly predicts dyadic desire in women; I would hypothesize that women would have higher dyadic desire when they reported a greater proportion of *nurturant* relative to erotic fantasy content. The implication would be that dyadic desire is more strongly related to nurturance (and lower T) than to eroticism (and higher T) as is typically assumed.

Secondly, as sexual pleasure – and especially women's sexual pleasure – increasingly becomes a focus of popular discourse around egalitarianism in relationships, it is important to recognize diversity and context-dependence in meanings of sexual pleasure to women themselves. Sexual pleasure is often implicitly assumed to mean *dyadic* sexual pleasure, but for many of the women I interviewed, solitary sexuality was an important and distinct source of pleasure, providing a level of autonomy difficult to achieve during dyadic interactions. Furthermore, definitions of pleasure differed based on the sexual context as solitary or dyadic, such that total control was pleasurable during solitary sexuality but allowing oneself to give up control (and trust a partner) was pleasurable during dyadic sexuality. Within dyadic contexts, definitions of pleasure further differed based on whether the experience occurred with a long-term partner or casual partner. Although there may be no 'one size fits all' definition of sexual pleasure, my findings do point to some commonalities across women *within* a given sexual context, such as the importance of closeness, trust, and erotic sensory stimulation to women's dyadic pleasure. Thus, when women report dissatisfaction with dyadic sexual pleasure, this may reflect relational issues that involve both partners (e.g., concerns with trust or intimacy) rather than issues with genital arousal or orgasm (Basson, 2003; Tiefer, Hall, & Tavris, 2002). On the

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other hand, researchers and clinicians should be cautious of inaccurately essentializing women's dyadic pleasure as *exclusively* or inherently nurturant (Meana, 2010), given that women also prioritized factors such as erotic sensory stimulation. Taken together, my findings highlight the value of examining both hormones and individuals' narratives of their own experiences to understand solitary and dyadic sexual pleasure as multifaceted constructs.

T-Sexuality Links Are Bidirectional and Dynamic

My findings support understandings of solitary and dyadic sexuality as distinct in terms of their associations with T. However, one commonality between solitary and dyadic sexuality is that links with T appear bidirectional in both contexts, meaning that sexual behavior can predict future T and not just vice versa (see Figure 5.1). Specifically, dyadic sexual behavior predicts future T more strongly than T predicts future dyadic sexual behavior, and masturbation and T are tightly linked in time (such that T predicts masturbation during the current month, but not the previous or next month). In the short-term, viewing visual sexual stimuli leads to downstream changes in T that depend on participants' identification with the stimuli and the degree of choice they are given over stimulus selection. In addition to establishing bidirectionality in T-sexuality links, my data help resolve controversies on pair bonding and T by showing these links are bidirectional as well. Lower T predicts future pair bonding, but pair bonding also predicts changes in T, such that women in new relationships experience an increase in T. Together, these findings reinforce understandings of T as responsive to social stimuli and behavior, rather than solely a causal influence on behavior. Although hormone-behavior links are widely understood to be bidirectional (Gleason et al., 2009; van Anders & Watson, 2006), my results provide some of the first longitudinal evidence that links between T and both pair bonding and sexuality are bidirectional in women.
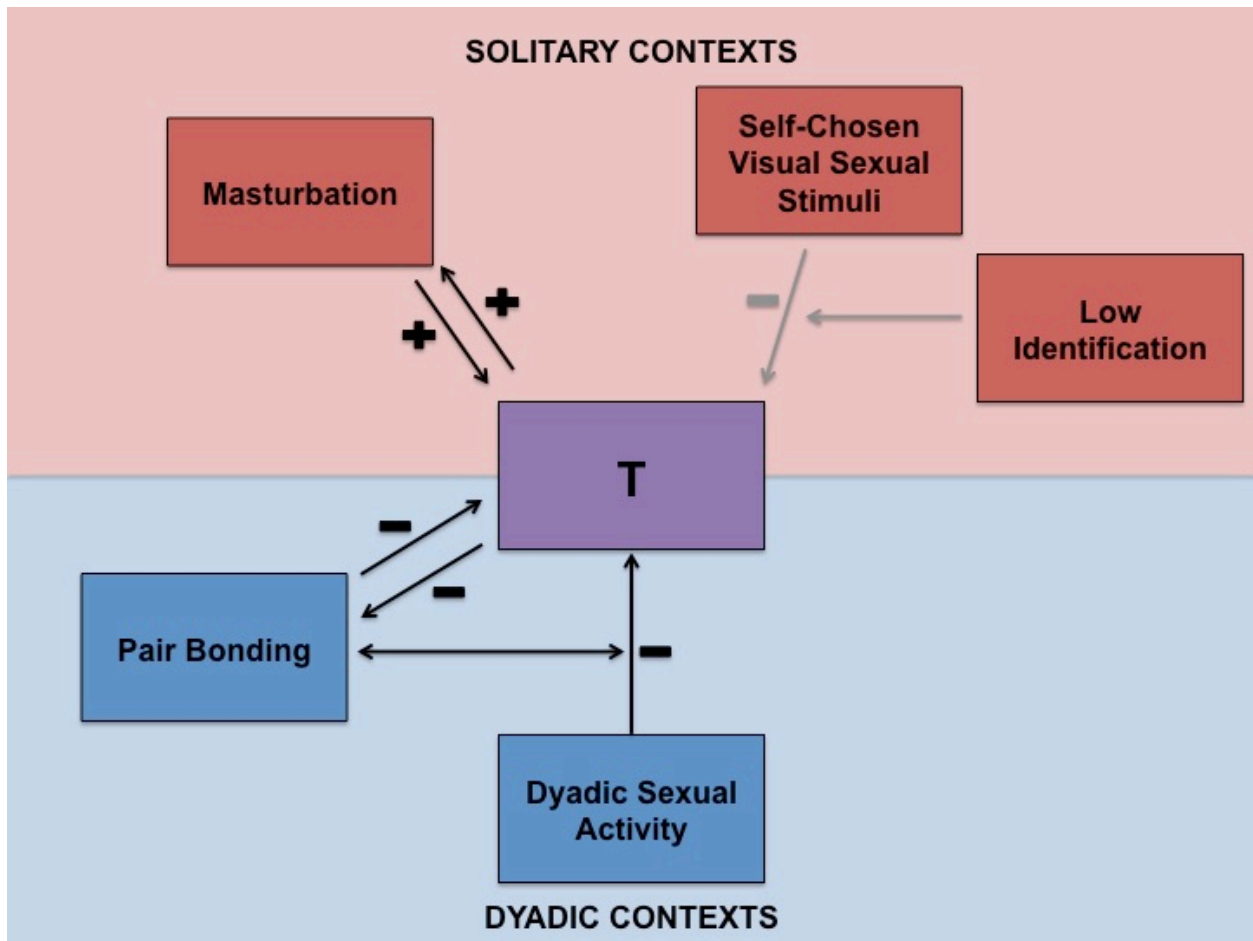
Figure 5.1. *Summary of Bidirectional Associations Between Testosterone, Sexuality, and Pair Bonding.* Symbols and arrows in black represent longer-term associations (i.e., month-to-month associations between T and behavior), whereas symbols and arrows in gray represent shorter-term associations (i.e., acute T responses). Within solitary contexts: Associations between masturbation and T are positive and likely bidirectional (associations are tightly linked in time). Solitary viewing of self-chosen visual sexual stimuli decreases T when participants weakly identify with their chosen stimuli. Within dyadic contexts: Dyadic sexual activity and pair bond status interact to predict T, such that dyadic sexual activity predicts lower T when women are pair bonded. Women have lower T when pair bonded than when single (if they engage in dyadic sexual activity), and pair bonding-T associations are bidirectional. (Note that negative links between T and pair bonding are qualified by increased T among women in new relationships.)

In addition to bidirectionality (i.e., that T predicts future behavior and behavior predicts future T), my results show that T and behavior are dynamically linked, meaning that T changes as sexual behaviors change on a within-person level. This is important given that T can sometimes show different patterns of associations with behavior within- versus across-subjects.

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For example, T and aggression were not significantly associated across subjects in female hybrid baboons (*Papio* spp.), but within subjects, females' T increased during periods of heightened aggression (Beehner et al., 2005). Within-individual changes in T may sometimes be more meaningful for behavior than absolute levels compared to other individuals, given individual differences in receptor densities (van Anders et al., 2014). In the case of solitary and dyadic sexuality in women, within-person associations with T showed largely similar patterns to past findings on between-person associations (van Anders, Hamilton, Schmidt et al., 2007; van Anders & Goldey, 2010; van Anders, 2012b). My findings clarify that masturbation is associated with higher T both across and within women (i.e., women with higher T engage in more frequent masturbation, and women have higher T during periods of engagement in masturbation). Similarly, more frequent dyadic sexual activity is associated with lower T across women, and engagement in dyadic sexual activity is associated with lower T within women – though the latter is the case only when women are pair bonded. Thus, my results clarify for the first time that solitary and dyadic sexual behaviors are associated with T on a within-person level, and not only a between-person level, in women.

My findings speak to both bidirectionality and dynamic within-person associations with regards to T-social behavior links, but caution is warranted in making firm statements about causality based on my longitudinal findings. Although I controlled for potential confounds including hormonal contraceptive use, it is possible that other variables covaried with masturbation and/or dyadic sexual activity on a within-person level in ways that had implications for T. However, my within-person findings are informative because they suggest that previous between-person associations between sexuality and T are unlikely to be explained by stable

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individual difference variables. Instead, my findings show that T and sexual behavior can fluctuate together within an individual woman over time.

Internal Stimuli Shape Sexual Modulation of T and Bidirectional T-Sexuality Links

My findings and those of others demonstrate that sexual stimuli and behavior can affect T (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008), but a related contribution of my dissertation is to highlight the importance of the internal context (i.e., cognitive, perceptual, and affective experiences), over and above external stimuli or behaviors, in shaping sexual modulation of T and bidirectional T-sexuality links. Taken together, the findings of my first two studies suggest that solitary and dyadic sexuality may be differentially associated with T because they are experienced so differently (e.g., solitary sexuality involves complete autonomy in terms of fantasy, whereas dyadic sexuality does not). In my final study, identification, or the extent to which participants took the perspective of film characters, moderated women's T responses to self-chosen versus researcher-chosen erotica. These findings suggest that internal cognitive and emotional experiences may drive sexual modulation of T and underlie bidirectional T-sexuality links.

In several ways, my findings on sexuality and T parallel established findings from the literature on stress physiology. As with sexuality, 'stress' was traditionally assumed to be one uniform category in terms of its effects on physiology, such that any psychological or physical stressor should elicit a similar cascade of reactions in the autonomic nervous system, hypothalamic-pituitary-adrenal (HPA) axis, and immune system (Kemeny, 2003). However, it has become clear that not all stressors elicit cortisol release or other physiological changes (Kemeny, 2003), just as not all sexual situations increase T. Only specific types of stressors – in particular, those that are uncontrollable or have the potential to elicit social-evaluative threat

(i.e., negative judgment by others) – reliably increase cortisol (Dickerson & Kemeny, 2004; Kemeny, 2003). In these situations, acute cortisol responses could promote submission, disengagement, or withdrawal behaviors and thus could be part of an adaptive physiological and behavioral response for mitigating effects of social rejection in uncontrollable situations (Dickerson et al., 2004). Thus, both sexuality and stress are non-uniform contexts in terms of their effects on physiology (e.g., solitary and dyadic sexuality are linked with T in different ways, and different stressors affect cortisol in different ways).

A closer look at *how* different stressors elicit specific physiological responses is informative for understanding how sexual contexts might differentially affect T. External contextual parameters such as controllability of the stressor or the presence of an evaluative audience predict whether stressors will increase cortisol, but these effects appear secondary to effects of cognitive appraisals on cortisol and other physiological markers. For example, stressors that are actually uncontrollable elicit less pronounced immune alterations if they are perceived as controllable (reviewed in Kemeny, 2003); how the situation is appraised seems to override the external contextual parameters in terms of how cortisol responds. Kemeny (2003) summarized these findings as follows: "First, depending on the nature of the eliciting conditions, different patterns of physiological response can occur. Second, when cognitive appraisals of conditions are manipulated, distinctive physiological effects can be observed within the same context. Therefore, *the way the individual thinks about the situation* may override the impact of the specific nature of the conditions themselves" (p. 128; emphasis added). These conclusions about the role of cognitive appraisals in modulating stress physiology show clear parallels with my results on sexuality and T. An external contextual parameter – choice versus no choice over erotic stimulus selection – by itself did not lead to differences in sexually-stimulated T

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responses. However, choice over stimulus selection interacted with a cognitive parameter, identification, to predict T responses. Thus, external conditions may be meaningful for sexually-modulated T to the extent that they shape how the sexual situation is perceived or experienced.

A further relevant finding in the stress physiology literature is that, although cognitive appraisals and affective experiences seem to drive physiological responses, specific emotional or cognitive states (rather than *all* or *any* emotional or cognitive states) are associated with physiological changes (Dickerson et al., 2004). For example, perceptions of being evaluated but not other appraisals (e.g., task difficulty) and shame but not other negative emotions (e.g., anger, sadness, general distress) predict stronger cortisol and immune responses to stressors (Dickerson et al., 2004; Dickerson, Mycek, & Zaldivar, 2008; Dickerson, Gable, Irwin, Aziz, & Kemeny, 2009). This too is analogous to my findings on sexual modulation of T, such that identification but not disgust or guilt/embarrassment moderated T responses to visual sexual stimuli. Altogether, my findings suggest that principles from the stress physiology literature can be adapted to model sexual modulation of T in humans, although the specific external and internal parameters that trigger hormone release differ between stressful and sexual contexts. For example, choice over stimulus selection may be an important external variable and identification an important internal variable for sexual modulation of T (as opposed to evaluative audiences and shame for stressful modulation of cortisol). In Figure 5.2, I propose a model where the external context shapes internal cognitive and emotional experiences, and these internal experiences are the key stimuli driving sexual modulation of T. In Figure 5.3, I make predictions about factors that should increase or decrease T in a broader comparative context.
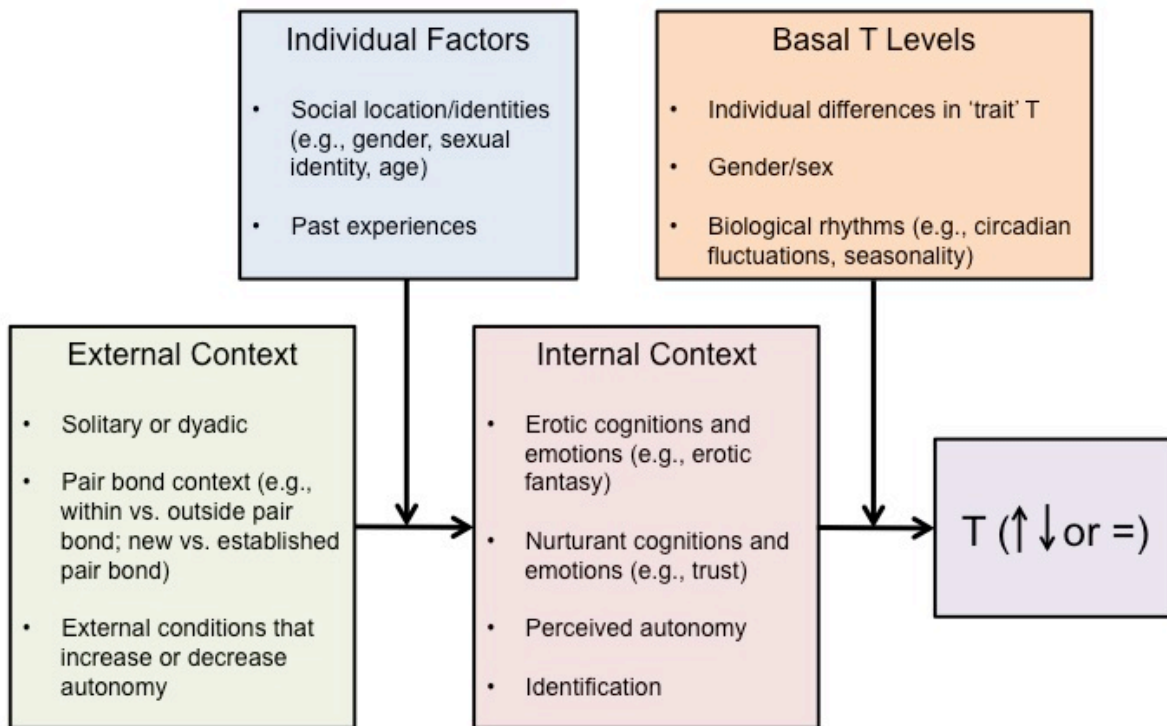
Figure 5.2. *Model Proposing a Pathway From External Context to Testosterone (T) via the Internal Context (i.e., Cognitions, Perceptions, and Emotions).* External contextual factors such as whether sexuality occurs alone or with a partner, whether sexuality occurs within or outside of a pair bond, and conditions that affect the degree of autonomy (among other potential external contextual factors) influence internal contextual parameters. Internal parameters include erotic cognitions and emotions, nurturant cognitions and emotions, perceived autonomy, and identification, among others. The model proposes that it is these cognitions and emotions that determine whether T will increase, decrease, or remain unchanged in response to sexual stimuli. Individual factors like social identities and past experiences can affect how the external context is translated to the internal context, and therefore how sexuality modulates T. For example, gender-specific socialization experiences may affect how external conditions that increase autonomy over erotic stimulus selection are perceived (i.e., as autonomy versus responsibility) and therefore shape T responses. Finally, basal differences in T can influence the extent to which cognitions, perceptions, and emotions translate to a change in T. For example, two individuals may experience a situation as equally erotic, but the individual with lower basal T may show a larger increase in T because T has more 'room' to increase in response to social stimuli. See Kemeny (2003) for a similar model of how cognitive appraisals drive physiological responses to stressors.
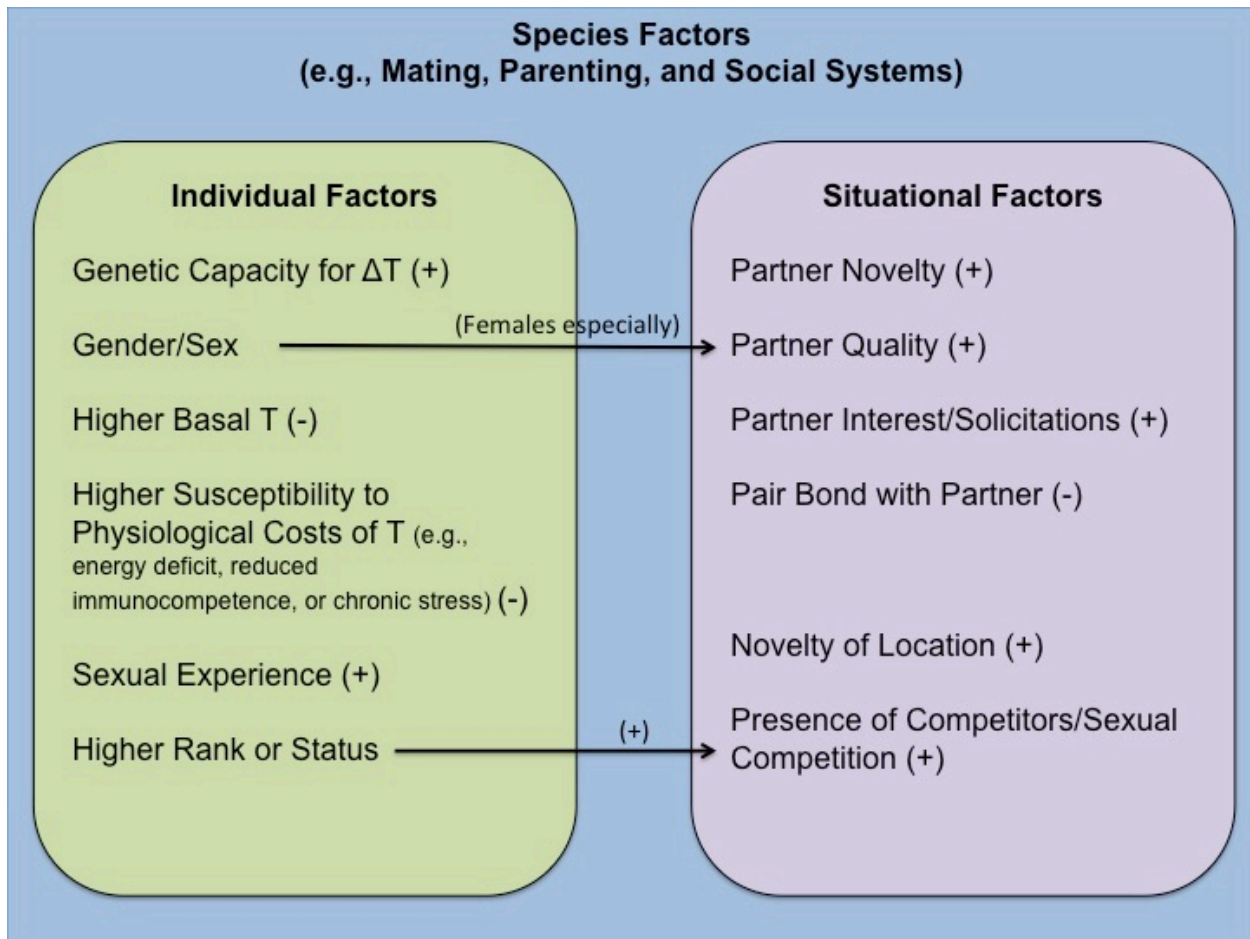
Species Factors
(e.g., Mating, Parenting, and Social Systems)

Individual Factors

Genetic Capacity for ΔT (+)

Gender/Sex ——— (Females especially) → Partner Quality (+)

Higher Basal T (-)

Higher Susceptibility to
Physiological Costs of T (e.g.,
energy deficit, reduced
immunocompetence, or chronic stress) (-)

Sexual Experience (+)

Higher Rank or Status ——— (+) →

Situational Factors

Partner Novelty (+)

Partner Quality (+)

Partner Interest/Solicitations (+)

Pair Bond with Partner (-)

Novelty of Location (+)

Presence of Competitors/Sexual
Competition (+)

Figure 5.3. *Hypothesized Effects of Individual and Situational Factors on Sexually-Modulated Testosterone (ΔT).* The figure makes predictions about conditions that are expected to increase or decrease T, based on a cross-species review (Chapter 1) and the findings of this dissertation. (+) indicates that factor is expected to increase ΔT, and (-) indicates the factor is expected to decrease ΔT. Effects of individual and situational factors on ΔT occur against a backdrop of species-specific factors, so hypothesized effects represent overarching patterns but may not be consistent across all species. Figure adapted from Goldey & van Anders (2015), *Adaptive Human Behavior and Physiology.*

Context-specific responses to stressors are thought to be adaptive because different stressors (e.g., the potential for physical harm versus social rejection) require different behavioral coping responses (Dickerson et al., 2004). Likewise, sexual behavior can be directed toward multiple different adaptive goals (e.g., pair bond maintenance versus resource acquisition), such that one stereotyped hormonal response may be less beneficial than context-specificity in hormonal responses. Tying T responses to cognitions and emotions rather than simply to external

stimuli may allow for even greater flexibility in T responses, such that individuals can integrate the current situation with their past experiences (Toates, 2009). Cognitions may also serve as incentive stimuli that motivate behavior in the absence of external cues (Kavanagh, Andrade, & May, 2005; Toates, 2009).

Conceptualizing sexually-modulated T as a function of internal stimuli, and not just external stimuli, has broad implications for the fields of social and behavioral neuroendocrinology. The importance of internal cognitive and emotional states to social modulation of physiology is widely accepted in the stress literature and increasingly so in the competition literature (Dickerson et al., 2004; Kemeny, 2003; Salvador & Costa, 2009), and my findings indicate that this approach is useful for sexuality as well. Together, my findings on sexuality and those of others on stress and competition highlight the malleability of biology, such that T responds not only to the external social environment but also to how individuals perceive the social environment. An important implication is that changing the way an individual thinks about a social situation could change physiological responses, even if the external situation is unaltered. On a broad level, my results suggest the potential for a physiological pathway by which the way an individual thinks about an event might actually shape future outcomes. For example, could imagining oneself winning prior to a competition increase T, and could this T response increase the likelihood of *actually* winning? Could the degree of pleasure one anticipates from a sexual situation influence T expression and feelings of pleasure during the actual sexual event? Future studies are needed to test these assertions, but my findings raise exciting questions about the extent to which individuals may have the ability to harness cognitions to influence their own physiology and behavior (see also Carney, Cuddy, & Yap, 2010; Cook & Crewther, 2012).

Future Directions

Would Priming Different Cognitions Affect Sexually-Modulated T?

A key implication of my findings is that altering how individuals think about a situation could affect T responses, even if external factors are held constant. There is evidence that the content of sexual thoughts is linked with T responses in men, with higher inclusion of nurturant content predicting stronger decreases in T (Goldey et al., 2014). However, researchers have yet to experimentally test whether priming different types of fantasy content would affect T responses to sexual thoughts. For example, future studies could prime participants to imagine primarily erotic or primarily nurturant content (e.g., via different instructional prompts or priming with erotic or nurturant images), and then measure T responses to sexual thoughts. Future work could also examine how priming different appraisals would influence T responses to external sexual stimuli. For example, would T responses to erotic films differ if participants were explicitly instructed to imagine themselves as part of the film (encouraging identification) versus to watch as a casual observer? Would T responses to dyadic sexual activity differ if participants were instructed to focus on erotic stimulation versus feelings of closeness, or on their own pleasure versus their partner's?

One important caveat is that experimental manipulations are not always effective at eliciting the desired cognitive or emotional experiences. For example, in Chapter 4, I intended that varying autonomy over stimulus selection would affect identification, but it did not reliably do so. I also have pilot data suggesting that instructional prompts intended to encourage or discourage identification are not effective at influencing women's actual identification with self-chosen erotic films (Goldey & van Anders, 2013). This raises questions about the extent to which identification is a relatively stable individual difference variable versus a function of

stimulus characteristics; perhaps identification would be more malleable in response to instructional prompts for some individuals than others (e.g., for those who are closer to the midpoint on 'trait' identification). These findings highlight the importance of manipulation checks to ensure that instructional prompts have the intended effects on cognitions and emotions in studies of sexually-modulated T.

Although internal cognitions and emotions seem to ultimately be more important than sensory stimulus modality for sexual modulation of T, it is possible that there are nuances in *how* cognitions and emotions affect T based on stimulus modality. For example, instructional prompts might be more effective at changing cognitive/emotional experiences (and thus at modulating T) for some stimulus modalities than others. With visual stimuli, attempts to increase identification may prove ineffective because commercially available erotic stimuli typically contain interactions that are perceived as inauthentic by women (Parvez, 2006) and are thus challenging to identify with. Would instructional prompts be more effective at altering identification for auditory stimuli, where participants might be able to employ more mental imagery, than for visual stimuli?

In general, the role of auditory cues has been neglected in research on sexual modulation of T in humans and other primates, even though auditory cues may be important for sexual arousal and pleasure (e.g., participants in my focus groups reported that auditory cues heightened pleasure). There is some evidence that *baseline* T predicts arousal to auditory sexual stimuli in men (Dabbs, 1997) and attention bias for auditory sexual stimuli in a subset of women with lower baseline T (Alexander & Sherwin, 1993). However, it is unknown whether auditory sexual cues would *affect* T, and what role identification would play. A follow-up study could compare women's T responses to visual sexual stimuli alone (without audio), auditory sexual stimuli

alone (without visuals), and audiovisual stimuli. Participants in each sensory condition could further be randomly assigned to high or low identification instructional prompts. I hypothesize that instructional prompts would affect identification most strongly in the audio alone condition because of greater potential for mental imagery. I would expect the strongest identification and largest T increases in the high-identification prompt audio condition relative to the other conditions.

What Are the Neural Pathways From Cognitions to T?

A further open question generated by my dissertation research is what specific neural mechanisms connect cognitive and affective experiences to T release. Presumably, sensory stimuli are initially integrated with cognitive appraisals of the meaning of the stimuli via connections between the thalamus and prefrontal cortex (Dickerson & Kemeny, 2004). The prefrontal cortex then sends inputs to the amygdala and hippocampus, which generate emotional reactions and in turn send connections to the hypothalamus (Dickerson & Kemeny, 2004). Finally, the hypothalamus triggers the HPG or HPA cascades, culminating in T release from the ovaries or adrenal glands (Feldman, Conforti, & Weidenfeld, 1995) (as reviewed in Dickerson & Kemeny, 2004).

Within the prefrontal cortex, one candidate for appraising the meaning of sexual stimuli is the orbitofrontal (ventromedial prefrontal) cortex (OFC) (Toates, 2009). The OFC is involved in the conscious experience of pleasure and is activated during pleasant mental imagery (Costa, Lang, Sabatinelli, Versace, & Bradley, 2010; Kringelbach, 2005; Toates, 2009). It receives input from all five sensory modalities and has reciprocal connections with the hypothalamus, making it a prime candidate to integrate and elaborate upon sensory information and potentially trigger hormone release (Kringelbach, 2005). The OFC is also androgen-sensitive (Berridge &

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Kringelbach, 2008; Finley & Kritzer, 1999), suggesting this area could *respond* to T release in a reciprocal fashion.

In addition to the OFC, the anterior cingulate cortex (ACC) could be involved in appraising sexual situations; this structure is implicated in adjusting reward-seeking behavior in response to changing conditions (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001). The ACC is activated in response to both cognitively demanding stimuli (in the dorsal portion) and emotionally charged stimuli (in the ventral portion) (Allman et al., 2001). Importantly, one PET study found the ACC was activated when young men recalled a previous pleasant sexually arousing situation (Rauch et al., 1999), so there is evidence that this area can respond to sexual thoughts. The ACC's connections with other neural structures, including the amygdala and hypothalamus, also support a potential role in sexual modulation of T.

Although establishing causality in neural pathways to T release would be difficult in humans, future research could benefit from combining functional magnetic resonance imaging (fMRI) with hormone measurements in studies of sexual modulation of physiology. I hypothesize that activation in the OFC and ACC would positively correlate with T responses to positive sexual mental imagery. A further direction would be to establish whether associations between T and neural activation in these areas is sexuality-specific or common to other social rewards (e.g., competitive victory: Rauch et al., 1999), as well as how T-neural activation associations might differ for primarily erotic versus primarily nurturant sexual imagery.

What Are the Functions of Sexually-Modulated T (If Any)?

Hormone responses are typically understood to feed back on behavior in an iterative fashion (Goldey & van Anders, 2015; van Anders & Watson, 2006), and the bidirectionality of T-behavior associations in my data supports an iterative pattern. Therefore, one important

question generated by my research is what the downstream consequences of sexually-stimulated T responses are. Previous authors have hypothesized a number of potential functions for acute sexually-stimulated T responses, including facilitating approach or orientation toward sexual cues, signaling to or evaluating a potential partner, coordinating behavior within a bonded pair, or promoting learning or reward processes associated with sexuality (Gleason et al., 2009; Goldey & van Anders, 2015; Nyby, 2008; van Anders & Watson, 2006).

An additional hypothesis is that sexually-stimulated increases in T might function to decrease anxiety (Gleason et al., 2009; Nyby, 2008; van Anders & Watson, 2006). The anxiolytic effects of sexual behavior have been documented in both male and female rodents (Aikey et al., 2002; Edinger & Frye, 2007; Nyuyki, Waldherr, Baeuml, & Neumann, 2011), although in females, these effects may be dependent on the ability to "pace" or control the timing of sexual stimulations (Nyuyki et al., 2011). Sexual stimuli and behavior may reduce anxiety in humans as well. In addition to self-reports of stress relief as a motivation for sexual activity (Graham et al., 2004) and a component of sexual pleasure (see Chapter 3), experimental studies show that cortisol responses to a psychosocial stress task are attenuated by physical intimacy (massage) in women and by exposure to visual sexual stimuli in men (Creswell, Pacilio, Denson, & Satyshur, 2013; Ditzen et al., 2007). This sexuality-induced anxiolysis could be adaptive: successful sexual behavior requires overcoming the anxiety that might otherwise be associated with novel partners or contexts (Gleason et al., 2009; Nyby, 2008), and the experience of anxiolysis itself could be rewarding and reinforce sexual behavior or cues associated with it (van Anders & Watson, 2006).

Research in rodents and humans points to anxiolytic effects of sexual activity, but the mechanism for these effects remains elusive. Progesterone and oxytocin are often suggested as

potential mediators of intimacy-induced anxiolysis in women and nonhuman females (Aikey et al., 2002; Ditzen et al., 2007; Nyuyki et al., 2011), whereas T has been suggested as a potential candidate in males (Gleason et al., 2009; Nyby, 2008). However, T represents a potential unexplored mediator in women as well as in men, given that some sexual stimuli acutely increase T in women (and overall, there are stronger effects of sexual stimuli on T in women than in men (van Anders, 2013)). Importantly, T has anxiolytic properties, which may be mediated by the agonistic actions of its metabolites on $GABA_A$ receptors (Aikey et al., 2002). In sum, there is evidence that sexual behaviors and stimuli reduce anxiety, that some sexual stimuli acutely increase T, and that T has anxiolytic properties. Based on this evidence, I would test the hypotheses that: (1) sexual thoughts and activity buffer against physiological and psychological stress responses in women and (2) T responses to sexual thoughts and activity mediate their anxiolytic effects.

To test these hypotheses, I could first compare women's cortisol responses and self-reported stress responses to a commonly used social-evaluative stressor (the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993)) following either dyadic sexual activity or a control condition (e.g., time with their partner without physical contact). In a second study, I could use a similar design to compare women's responses to the stressor after sexual thoughts versus control conditions (e.g., positive non-sexual social thoughts). Examining effects of sexual activity and thoughts would clarify whether potential stress-buffering effects of sexual activity extend to sexual thoughts in the absence of external cues, or whether physical touch is required for these effects. Findings would have implications for elucidating the functions of sexually-stimulated T responses as well as important health implications. For example, perhaps sexual intimacy plays an important role in the protective effects of long-term pair bonds for health

(Robles, 2014), or perhaps even intimacy-related thoughts might have some protective effects against stress-related health concerns.

Thus far, I have discussed potential functions of acute *increases* in T in response to sexual stimuli, but one clear finding from my dissertation is that sexual stimuli do not always increase T. Rather, sexual stimuli may sometimes predict *decreases* in T in the short-term (e.g., to self-chosen erotic films at low levels of identification) or the long-term (e.g., dyadic sexual activity predicting lower baseline T). What might be the downstream consequences of these decreases in T? I would predict that sexually-stimulated declines in T would have different effects in the short-term versus the long-term. In the long-term, lower T is expected to facilitate nurturance within a pair bond (van Anders et al., 2011); this is supported by my finding that pair bonded women who are dyadically sexually active have lower T than singles, and by research showing that women with lower T display higher empathy during conflict discussions with a partner (Schneiderman, Kanat-Maymon, Zagoory-Sharon, & Feldman, 2014). In the short-term, effects of sexually-stimulated decreases in T are unclear, but I have hypothesized that acute T decreases might discourage future engagement with similar sexual stimuli in some contexts (e.g., unrewarding interactions with pornography) (see Chapter 4). In general, future research on downstream consequences of sexually-modulated T could benefit from considering nuances in the pattern (i.e., increase versus decrease in T) and time course of T responses.

Conclusion

In this dissertation, I report that women's T is linked with solitary and dyadic sexual behavior in different ways, such that women have higher T during periods of engagement in solitary sexual behavior, but lower T during periods of engagement in dyadic sexual behavior. The latter finding on dyadic sexual behavior is specific to pair bonded women, indicating that the

pair bond context is an important moderator of how T and dyadic sexuality are linked. Solitary and dyadic sexuality may be linked with T in different ways because they represent qualitatively different experiences for women: women define solitary sexual pleasure as oriented around autonomy, and dyadic sexual pleasure as oriented around nurturant intimacy (among other components). Finally, cognitive and emotional experiences have implications for women's acute T responses to external sexual stimuli, such that identification (i.e., taking the perspective of film characters) moderates women's T responses to self-chosen versus researcher-chosen visual erotica.

Taken together, these findings highlight the bidirectional and dynamic nature of T-sexuality links. Sexuality and pair bonding predict future T in addition to vice versa, and fluctuations in T are linked with changes in sexual behaviors on a within-person level. Moreover, results point to the importance of internal cognitive and emotional experiences, over and above external sensory stimuli, to sexual modulation of T and bidirectional T-sexuality associations. Drawing from my findings and from the stress physiology literature (e.g., Kemeny, 2003), I propose that external contextual parameters (e.g., whether sexuality occurs within or outside of a pair bond) modulate T via their effects on internal cognitions and emotions. In this way, my findings demonstrate the power of even subtle internal cues – i.e., cognitive, perceptual, and affective experiences of social situations – to shape physiology. Building on these results, important directions for future research include: (a) testing whether priming different cognitions would affect sexually-modulated T, (b) characterizing the neural pathways that link cognitive and affective experiences to T responses, and (c) elucidating the functions of sexually-modulated T.

Finally, my results highlight the value of asking participants about their individual experiences to inform understandings of hormone-behavior associations. Using qualitative methods to ask women what solitary and dyadic sexuality were *like* for them generated insights about how and why solitary and dyadic sexuality were differentially linked with T. My studies provide an example of how hormonal and qualitative data can be used together to better understand the phenomenology of sexuality and the evolved social role of T. Within sexuality research, merging phenomenological and biological methods is perhaps especially important in order to avoid falsely dichotomizing sexuality into biological versus social influences, evolution versus culture, or body versus mind (Mah & Binik, 2001; Tolman & Diamond, 2001; van Anders, 2013). The integration of qualitative and hormonal methods is relatively uncommon in neuroscience research, but valuable, as neuroscientist Gillian Einstein argues:

> "…I would argue that neuroscience…really must ask (however it can) the organisms being studied what it is *like* for them. After all, we are trying to learn something about the experience – which presumably doesn't only take place in the brain, and is textured by context." (Einstein, 2012, p. 157)

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