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Examining the time course of genital and subjective sexual responses in women and men with concurrent plethysmography and thermography

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ABSTRACT

Sexual response is a dynamic process, though there is limited knowledge of the time course and relationships among its psychological and physiological components. To address this gap, we concurrently assessed self-reported sexual arousal, genital temperature (with thermography), and genital vasocongestion (with vaginal photoplethysmography [VPP] or penile plethysmography [PPG]) during sexual and nonsexual films in 28 androphilic women (attracted to men) and 27 gynephilic men (attracted to women). Men and women had similarly strong agreement between subjective and genital responses (*sexual concordance*) with thermography, but this agreement was stronger in men than women with PPG/VPP. The time course of changes in self-reported arousal was most similar to changes in genital temperature (i.e., time to onset and peak response). Time-lagged correlations and multilevel modeling revealed changes in the strength of relationships between aspects of sexual response over time. Results highlight the dynamic nature of sexual response and drawbacks of relying on zero-order correlations to characterize sexual concordance.

1. Introduction

Sexual arousal is a multi-dimensional state involving physiological changes, the perception of these changes, subjective experience of arousal, and motivated behaviour (Frijda, 1986; Geer, Lapour, & Jackson, 1993). Based on an information processing model, these aspects of sexual arousal are integrated through positive feedback, such that initial genital responses to a sexual stimulus direct attention to sexual cues, leading to subjective arousal and increased genital responses if stimulation is maintained (Geer et al., 1993; Janssen, Everaerd, Spiering, & Janssen, 2000). Given this integration and feedback over time, it is important to understand temporal changes in sexual response, rather than rely on static estimates of response magnitude. Despite the growing number of measures used to assess genital and subjective sexual responses (Janssen, Prause, & Geer, 2007; Kukkonen, 2014), we know relatively little about the time course of different aspects of sexual arousal, such as differences in onset and peak internal vasocongestion, external genital temperature, and subjective arousal. We also lack a clear understanding of how the relationships between different components of sexual response vary over time. To address these gaps, we concurrently assessed changes in vaginal vasoengorgement, penile circumference, genital temperature, and emotional arousal, and examined the time course and relationships between these different aspects of sexual response using statistical methods that could examine their dynamic nature.

1.1. Assessing sexual response

Heart rate and blood pressure increase with sexual arousal and lead to genital vasocongestion − increased blood flow to the genitals (Levin & Riley, 2007). This blood flow is the result of relaxation of the cavernous muscle of the penis and dilation of the cavernosal artery, or dilation of the capillaries of the vagina (Levin & Riley, 2007). Genital vasocongestion leads to penile erections in men and vaginal lubrication and vulvar/clitoral vasoengorgement in women, and increased temperature of the penis and vulva (Henson, Rubin, Henson, & Williams, 1977; Kukkonen, Binik, Amsel, & Carrier, 2007; Levin, 1998, 2003; Levin & Riley, 2007; Webster & Hammer, 1983). Women's genital responses are most commonly assessed using vaginal photoplethysmography (VPP), which measures changes in vasocongestion in the vaginal epithelium via light reflectance (Geer, Morokoff, & Greenwood, 1974; Sintchak & Geer, 1975). VPP output includes total vaginal blood volume (VBV) or phasic changes (peak-to-trough amplitude) with each heartbeat, termed vaginal pulse amplitude (VPA); changes in VPA are more specific to sexual stimuli (Laan, Everaerd, & Evers, 1995). Men's genital responses are commonly assessed with circumferential penile plethysmography (PPG), which measures changes in penile circumference using a mercury-in-rubber or

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indium-gallium strain gauge (Bancroft, Jones, & Pullan, 1966; Barlow, Becker, Leitenberg, & Agras, 1970). Female and male genital vasocongestion is also assessed with thermographic cameras, which detect infrared energy proportional to the surface temperature of the penile shaft or labia majora (Kukkonen et al., 2007; Kukkonen, Binik, Amsel, & Carrier, 2010). Thermography also allows for the assessment of responses at homologous regions of the vulva and penis (e.g., clitoris and glans), which have only received limited empirical examination to date (see Huberman & Chivers, 2015). Sexual response typically includes an emotional component in addition to physiological changes – i.e., feelings of subjective sexual arousal (Laan & Both, 2008), assessed through self-report (e.g., pre/post-stimulus or continuous measures).

1.2. Relationship between measures of sexual response

1.2.1. Time course of sexual response

There have been few studies comparing the time course of sexual response using concurrent measures (i.e., time to onset or peak response), and those that exist have had small sample sizes ($ns \leq 10$; Henson, Rubin, & Henson, 1979; Henson & Rubin, 1978; Webster & Hammer,1983). Webster and Hammer (1983) found that peak penile circumference occurred earlier than peak penile shaft temperature during a sexual stimulus, suggesting that penile engorgement precedes temperature change. Henson and Rubin (1978) found that vaginal blood volume and labial temperature reached peak with similar latencies, whereas Henson et al. (1979) found that peak vaginal pulse amplitude occurred significantly earlier than peak labial temperature, fitting with evidence that changes in vaginal vasoengorgement begin and peak rapidly (Laan & Janssen, 2007; Lake Polan et al., 2003).

A comprehensive understanding of the dynamics of sexual response includes examining both the time course of *increases* during sexual arousal and *decreases* during resolution of sexual response, when the sexual stimulus is withdrawn (i.e., return-to-baseline [RTB]). Some studies have found that women's self-reported arousal decreased more rapidly than their genital responses (VPA or labial temperature; Henson et al., 1979; Henson & Rubin, 1978). Others have reported rapid decreases in both vaginal vasoengorgement and subjective arousal during RTB (within 1-min; Lake Polan et al., 2003).

1.2.2. Relationship between genital and subjective sexual responses: sexual concordance

Considerable research has evaluated the agreement between physical and psychological aspects of sexual response, termed *sexual concordance*. A meta-analysis found that men's sexual concordance was positive and large (average $r = 0.69$, $n = 987$, $k = 45$) whereas women's concordance was smaller (average $r = 0.33$, $n = 1170$, $k = 56$, based on studies reporting exact correlations; Chivers, Seto, Lalumière, Laan, & Grimbos, 2010), albeit varying from strongly negative to strongly positive. Women's concordance was significantly stronger in the few studies that assessed genital temperature (average $r = 0.55$ with thermography, $n = 97$, $k = 6$; Chivers et al., 2010). An additional study reported no gender differences in concordance with thermography for the latter 10 min of a 15-min stimulus; during the first 5 min, men's concordance was stronger than women's (Kukkonen et al., 2010). These findings suggest that changes in women's genital temperature may relate more closely to their subjective sexual arousal than changes in vaginal vasoengorgement, whereas men's subjective arousal is strongly related to both changes in penile circumference and temperature.

Studies examining the relationship between genital and subjective sexual responses typically use zero-order (simultaneous) correlations, either between-subject (i.e., group variation in responding) or within-subject (i.e., individual variation in responding; Chivers et al., 2010). Multilevel or hierarchical linear modeling (MLM or HLM; see Page-Gould, 2016) may be more appropriate for analyzing sexual concordance, as it allows between-subject comparisons of within-subject effects (i.e., the extent of individual variation in responding may be examined and compared across groups; Rellini, McCall, Randall, & Meston, 2005). MLM may be particularly useful for understanding the dynamic nature of sexual response, as temporal changes in the magnitude of concordance throughout sexual response may be examined. Time-lagged cross-correlations would also facilitate examining asynchronous relationships between physiological and psychological aspects of sexual responses (see Prause & Heiman, 2010).

1.2.3. Relationships between genital responses

Changes in penile circumference or vaginal vasoengorgement should, theoretically, be highly correlated with changes in genital temperature, given that changes in each result from increased genital blood flow. Change in penile shaft temperature during sexual response was shown to positively correlate with changes in penile circumference ($rs > 0.76$; Webster & Hammer, 1983). Examinations of the relationship between women's labial temperature, assessed with surface thermistors on the labia minora, and changes in vaginal vasoengorgement, assessed with VPP, has yielded mixed results (Henson & Rubin, 1978; Prause & Heiman,2009).

Most studies examining the relationships between measures of genital response have used zero-order within-subject correlations to assess individual variation in responding across a stimulus. Given that sexual response involves integration/feedback between its components, and that changes in vaginal vasoengorgement may occur more quickly than changes in genital temperature (Henson et al., 1979), zero-order correlations may be inadequate to quantify the dynamic relationship between aspects of genital response. For similar reasons, emotion researchers have argued that stimulus onset may not be an appropriate point of synchronization among aspects of emotional response, given that the time course of emotional components varies (Hollenstein & Lanteigne, 2014). Time-lagged cross-correlations may better capture the relationship between components of sexual response, allowing an examination of time series data shifted by lags (Prause & Heiman, 2010).

1.3. Current study and hypotheses

The current study examined the relationships between different aspects of concurrently assessed sexual responses, including the time course of these responses, relationship between genital and subjective responses, and relationship between genital responses. Gynephilic men (i.e., sexually attracted to women) and androphilic women (i.e., sexually attracted to men) viewed sexual and nonsexual films while sexual responses were assessed with PPG or VPP, thermography, and self-report. Drawing from the information processing model and past research, we predicted the following (see Table 1 for a summary):

1.3.1. Time course of sexual response

We predicted that time to onset and peak penile circumference and VPA would be shorter than for genital temperature or self-reported arousal, with VPA having the shortest time to onset and peak response (i.e., changes in women's VPA would occur more rapidly than changes in men's penile circumference). We did not predict gender differences in time to onset or peak response for changes in genital temperature or self-reported arousal. During return-to-baseline (RTB), we predicted that changes in self-reported arousal would precede genital changes, and that changes in VPA and PPG would precede changes in genital temperature.

1.3.2. Relationship between genital and subjective sexual responses: sexual concordance

We predicted that genital responses would be positively related to self-reported arousal, but that sexual concordance would be: (a) significantly stronger for men than women when assessing penile