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Review

A review of infrared thermography as applied to human sexual psychophysiology

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ABSTRACT

Infrared thermography (IRT) is a non-contact technique that permits mapping and analysis of the temperature of the body's skin surface. This method has been applied to sexual psychophysiology since the 1980s and its use has been expanding ever since, mainly because it provides several advantages over existing genital response measures. This article presents a review of experimental studies employing IRT to investigate human sexual arousal, with the aim of summarizing the available procedures and evidence so far and to identify important caveats in the literature. The studies reviewed support the feasibility and validity of IRT as a real-time physiological measure of sexual arousal but varied substantially regarding methodology and procedures. The results of this review underscore the value and validity of IRT in sexual psychophysiology and point at the critical need for the standardization of IRT protocols to accommodate the specific needs of applying this methodology to sexual physiology.

1. Introduction

The study of the psychophysiology of human sexual response continues to be a developing field. Over the decades, our understanding of sexual response has expanded and a wide array of measures has been developed to assess the physiological markers of sexual arousal in men and women. However, current instruments used to investigate the physiology of sexual response demonstrate a number of limitations and challenges to its interpretation and usage in different populations. The availability of valid and reliable psychophysiological instruments that can be used in both sexes, across different populations, and with the potential of establishing diagnostic criteria is of crucial importance for both scientific and clinical purposes.

Infrared Thermography (IRT) is a method to measure temperature that is based on the infrared radiation emitted from objects' surface. It provides a map of the distribution of temperatures on the surface of the imaged object and is not related to morphology, like methods such as those relying on the use of X-Rays or MRI (Ammer and Ring, 2012). Infrared thermography has been applied to the study of sexual psychophysiology since the 1980s and provides a number of advantages over alternative measures of genital response.

Studies have shown evidence of the feasibility, reliability, and validity of thermography as a physiological measure of sexual arousal (e.g., Huberman and Chivers, 2015; Huberman et al., 2017; Kukkonen et al., 2007, 2010). Notwithstanding the relevance of these promising results, the heterogeneity of the studies in terms of methodology and measurement procedure warrants a critical interpretation of their findings. The goal of this review is to synthesize and critically discuss the literature on IRT as it has been applied to sexual psychophysiology. Remaining questions and suggestions for future research are also presented.

1.1. Measuring human sexual response throughout time: various measures and inherent limitations

Sexual arousal is a multi-dimensional state that encompasses

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physiological changes dependent on activation of the central nervous system, the perception of these changes, subjective experience of arousal, and motivated behavior (Geer et al., 1993; Rosen and Beck, 1988). Physiological responses specific to sexual arousal include genital responses (erection in men and vaginal lubrication, clitoral, and vulvar congestion in women), with the congestion leading to an increase in pelvic vascular blood flow and resultant pelvic vasocongestion (Levin, 1998, 2003; Levin and Riley, 2007). Genital vasocongestion is also associated with increases in genital skin temperature (Henson et al., 1977; Webster and Hammer, 1983). The different components of sexual arousal are integrated through positive feedback, such that initial genital responses to a sexual stimulus direct attention to sexual cues, inducing subjective arousal and increased genital responses if stimulation is maintained (Barlow, 1986; Geer et al., 1993; Janssen et al., 2000; Rosen and Beck, 1988).

Throughout time, an important focus of sexual psychophysiology has been on the direct measurement of changes in the genitals that are associated with sexual arousal. Extragenital peripheral measures such as skin conductance and heart rate variability have also been studied, but have been found to be indicators of general autonomic arousal and not to be specific to sexual arousal (Zuckerman, 1971).

For men, the most commonly used genital measures include penile volumetric plethysmography (Freund, 1963), mercury and Barlow strain gauges (Bancroft et al., 1966; Barlow et al., 1970), rigiscan monitoring (Bradley et al., 1985; Levine and Carroll, 1994), and penile ultrasonography (Meuleman et al., 1992). For women, vaginal photoplethysmography has become the most widely used measure, with other measures including pelvic magnetic resonance imaging (Maravilla and Yang, 2008; Maravilla et al., 2005), labial thermistors (Henson et al., 1977; Prause and Heiman, 2009), labial and clitoral photoplethysmography (Gerritsen et al., 2009; Prause and Heiman, 2009; Prause et al., 2005), laser Doppler imaging (Styles et al., 2006; Waxman and Pukall, 2009), clitoral ultrasonography (Buisson et al., 2008; Foldes and Buisson, 2009), and heated oxygen electrodes (Beck and Baldwin, 1994; Levin, 2006) also being used. For review of measures of female sexual response see Kukkonen, 2015; for review of both male and female sexual response measures see Janssen, 2001 and Zuckerman, 1971.

Although offering important contributions to the physiological study of human sexual response, each of the above-mentioned instruments is associated with a number of problems that limit or hinder its use and that could constrain our understanding of human sexual arousal. One important limitation concerns the fact that most current instruments cannot be used in both men and women, which impedes the comparison between male and female sexual response. Although an anal probe suitable for measuring vascular and muscular activity during sexual arousal for both genders does exist, it has rarely been used in research (Bohlen and Held, 1979; Bohlen et al., 1980; Bohlen et al., 1982) and only one study used a variation of this instrument to compare male and female sexual response (Carmichael et al., 1994). Additionally, the use of these instruments requires direct genital contact or insertion, either by the participant or the experimenter. This constitutes another limitation of these technologies, since their potential intrusiveness may interfere with the activation and experience of sexual arousal and thus influence the outcome measurement (Kukkonen et al., 2006; Prause et al., 2005).

Standardization and between-subjects comparisons are also difficult to establish using the currently available instruments. The absence of an absolute measurement scale or calibration method in the case of techniques such as vaginal and labial photoplethysmography makes it difficult to interpret and compare data between subjects (Janssen, 2001; Prause et al., 2005; Prause and Janssen, 2006). Also, in the case of penile plethysmography and rigiscan monitoring, it is still unclear how strongly the output measures associate with clinically relevant levels of penile rigidity. For these reasons, the task of establishing diagnostic criteria using the current measures has been a challenge, since this requires between-subject comparability and standardization. This holds true in spades for women, since none of the existent measures of physiological sexual arousal have been used to establish diagnostic criteria for female sexual arousal difficulties.

Finally, most existing measures of physiological sexual response do not adequately account for variations in anatomy and physiology, in particular in women. Normal variations in the length of the vagina can lead to positioning differences for the vaginal probes used in plethysmography. Other individual differences in female anatomy and physiological response such as resting levels of vaginal muscular tone and vaginal moistness may also affect the photoplethysmograph signal (Geer and Janssen, 2000). Moreover, participants' movements, including muscle contractions, can easily alter the output of vaginal photoplethysmography. This artifact is even likely to be intensified by the experience of sexual arousal (Janssen, 2001), since muscular activity in and around the vagina increases during sexual arousal (e.g., Bohlen et al., 1982).

1.2. Principles and advantages of infrared thermography as applied to sex research

Infrared thermography (IRT) presents several advantages over existing measures of sexual response, including: (1) the same instrumentation can be used for both men and women, allowing for between-gender comparisons; (2) thermography does not require any genital manipulation or contact; and (3) thermographic output, temperature, is measured on a known absolute scale. The fact that IRT is a remote sensing technique is a particularly important advantage, as the measurement can be carried out without requiring – and thus potentially being affected by – any physical contact.

The use of IRT as a means of assessing sexual arousal relies on three basic principles: (1) that all objects with a temperature above absolute zero constantly emit electromagnetic energy such as infrared radiation at a level proportional to its temperature; (2) that it is possible to detect infrared emission from membranes such as the skin by remote sensing; and (3) that changes in genital temperature are an indirect marker of sexual arousal, by indicating increased genital peripheral blood flow (Bacon, 1976; Kukkonen et al., 2010).

Modern infrared cameras are able to measure the temperature of a body by remotely detecting the infrared radiation emitted as well as to provide a continuous reading of the object in focus through a visual representation (Jones, 1998). These visual representations, called thermograms or temperature “maps”, can be qualitatively and quantitatively analysed, thus making it possible to detect subtle increases or decreases in temperature (Seeley et al., 1980). The current infrared thermographic equipment is able to determine average temperature changes in an area of less than 1 mm of skin with a maximum precision of 50mK in a very short period of time.

Due to all of its advantages, IRT has been established as an effective tool in many different applications (Meola, 2012). In the field of sex research, IRT has been utilized to measure sexual response in both men and women since the 1980s (Abramson and Pearsall, 1983; Abramson et al., 1981a; Abramson et al., 1981b; Beck et al., 1983; Seeley et al., 1980). These initial studies used a technologically limited thermographic equipment and were vastly heterogeneous in study design, populations investigated, and evaluation criteria applied. Still, the results of these studies provided early evidence of feasibility and discriminant validity of IRT as a reliable measure of sexual arousal. These initial studies were followed by a period during which IRT was not used often, but about two decades later this technique gained renewed attention within the field of sex research.

Considering the outlined research, the aim of the present review is to address the gaps in the literature concerning the application of IRT to the assessment of human sexual response, by providing a comprehensive analysis of the empirical data published to date.