Understanding Women's Subjective Sexual Arousal Within the Laboratory: Definition, Measurement, and Manipulation

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ABSTRACT

Introduction: Subjective sexual arousal (SSA) is positive, cognitive engagement in sexual activity. SSA is considered an important aspect of the sexual experience, as it has been found to facilitate sexual activity and, in situations of chronically low or absent arousal, potentially cause distress. Despite the clinical implications of SSA, a thorough review of how to manipulate SSA has yet to be conducted.

Aim: To review the state of knowledge about SSA in women, including its definition, measurement, and the outcomes of studies attempting to manipulate SSA within a laboratory setting.

Method: A comprehensive search of the electronic databases of PubMed and PsycINFO was conducted. The generated list of articles was reviewed and duplicates were removed. Individual articles were assessed for inclusion and, when appropriate, relevant content was extracted.

Main Outcome Measure: The potential effects of various manipulations of SSA in a laboratory setting was the main outcome.

Results: 44 studies were included in this review. Manipulations were grouped into 3 primary categories: pharmacological (n = 16), cognitive (n = 22), and those based on changes to the autonomic nervous system (n = 6). Results suggest that cognitive manipulation is the most effective method of increasing SSA. Altering the relative balance of the 2 branches of the autonomic nervous system (the sympathetic nervous system and the parasympathetic nervous system) also appears to be a promising avenue for increasing SSA.

Conclusion: This review supports the use of cognitive manipulation for increasing women's SSA in a laboratory setting. Avenues for future research and recommendations for clinicians are discussed. **Handy AB, Stanton AM, Meston CM. Understanding Women's Subjective Sexual Arousal Within the Laboratory: Definition, Measurement, and Manipulation. Sex Med Rev 2018;6:201–216.**

Key Words: Subjective Sexual Arousal; Sexual Arousal; Female Sexual Function

DEFINING SUBJECTIVE SEXUAL AROUSAL

Subjective sexual arousal (SSA) has been defined as positive cognitive engagement in response to a sexual stimulus,[1] suggesting that one must be implicitly or explicitly aware of a sexual stimulus, which could be internal (eg, sexual thoughts) or external (eg, a partner), in order to experience SSA. SSA has also been defined as the "emotional"[2,3] or "cognitive"[4,5] state of sexual arousal. These terms, as well as "psychological" or "mental" arousal, are used interchangeably in the literature and are thought to represent a feeling of being "turned on" in one's mind.

Feeling aroused, both in the body and the mind, is an integral component of the sexual experience. Sexual arousal decreases sexual self-restraint[6] and motivates individuals to engage in sexual activity.[7] In fact, feeling sexually aroused is one of the most common reasons why men and women have sex. In a study of over 1,500 undergraduate students, Meston and Buss[7] identified 237 unique reasons why men and women engage in sexual activity; experiencing SSA ("I was horny") was one of the top-10 most frequently cited reasons. It is also thought that increased SSA may enhance pleasure and satisfaction during sexual activity, both of which are linked with engagement in future sexual activity.[8–10] Conversely, chronically low or absent SSA may lead to clinically meaningful distress. Given that sexual arousal can act as both a motivation for sexual activity and a potential cause of distress, understanding how SSA has been manipulated in a laboratory setting has important clinical implications. Thus, this review aims to examine laboratory-based measurement, analysis, and manipulation of SSA.

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MODELS OF SEXUAL AROUSAL AND RESPONSE

Masters and Johnson[11] proposed the first highly cited model of sexual response in 1966. In their model, sexual response is divided into 4 linear phases: excitement, plateau, orgasm, and resolution. Recognizing that these stages only addressed physiological sexual arousal, Kaplan[12] expanded this framework to include sexual desire as a prelude to excitement, maintaining the original model's linear structure. With the expansion of sexuality research in the late 20th century, researchers began to theorize that the female sexual response cycle may not be limited to the specific phases outlined in the Kaplan[12] and Masters and Johnson[11] models. Basson[8] deviated from the linear models to establish a circular model of sexual response, which incorporates both physiological (eg, genital arousal) and subjective (eg, SSA, satisfaction) components, as well as several additional factors, such as the need for intimacy. It has been suggested that women with different levels of sexual function identify with different models of the sexual response cycle. In a study by Sand and Fisher,[13] women were provided with descriptions of 3 models of sexual response (those of Masters and Johnson,[11] Kaplan,[12] and Basson[8]), and they were instructed to endorse the model that they felt best described their own sexual experiences. Though all 3 models were endorsed with equal frequency, the women who endorsed the Basson[8] model had significantly lower levels of sexual function than the women who endorsed either the Masters and Johnson[11] or the Kaplan[12] models. Therefore, it is possible that sexual function plays a role in women's conceptualizations of the sexual response cycle.

Several additional models expanding the understanding of women's sexual response have been proposed. One such model is the Incentive Motivation Model (IMM),[14] which outlines the interconnectedness of subjective, affective, and physiological aspects of sexual arousal. The IMM also describes how the relationships among these components may lead to sexual desire. One aspect of the IMM that may be particularly important to the experience of SSA is the inclusion of perceived genital arousal; recognizing that one is physiologically aroused may influence SSA.[15]

A second theoretical model that has expanded our conceptualization of sexual response and sexual arousal specifically is the Information Processing Model (IPM).[4] The IPM suggests that, in order to experience sexual arousal, one must attend to a stimulus and appraise it as sexual. Sexual information can be processed both implicitly and explicitly. The implicit pathway is thought to be an unconscious detection of a sexual stimulus that triggers physiological changes (eg, lubrication), whereas the explicit pathway represents a conscious application of a sexual meaning to a stimulus that can trigger SSA. Within this framework, individuals learn to associate a sexual meaning with a sexual or non-sexual experience. The IPM is particularly relevant to the present review, as it emphasizes cognitive processes and the experience of SSA.

THE OVERLAP OF SSA AND SEXUAL DESIRE

Researchers have debated the distinction between SSA and sexual desire. Though desire (also referred to as sexual interest or libido) is primarily conceptualized as the *motivation* to engage in a sexual activity,[1] as opposed to the act of being engaged itself, there is evidence to suggest that desire and SSA may be 2 names for the same construct. After conducting a series of focus groups aimed at exploring women's qualitative experience of sexual arousal, Graham et al[16] reported that women frequently used the terms "arousal" and "desire" interchangeably; women were also found to use the term "arousal" to describe both SSA and genital arousal. Furthermore, participants described arousal and desire as being difficult to separate from one another, leading Graham et al[16] to suggest that women may not differentiate between desire and arousal in the same manner as do researchers. It is unclear, however, whether all women in the sample were sexually healthy or had any diagnosed sexual dysfunction; it is possible that a distinction between desire and arousal may be better recognized by women based on their level of sexual function.

Parsing apart these 2 constructs is also complicated by the high rates of comorbidity of desire and arousal dysfunction in women. In 1 study of women diagnosed with hypoactive sexual desire disorder (HSDD), 41% of women in the sample also met criteria for either an arousal (female sexual arousal disorder [FSAD]) or orgasm dysfunction, and 18% met criteria for all three.[17] Sarin and colleagues[18] reported similarly high rates of comorbidity; 53% of women (25 out of 47) in the sample with HSDD also met diagnostic criteria for FSAD. Twenty-two women met diagnostic criteria for HSDD alone and 18 met criteria for FSAD alone. It is important to note that women in the studies noted above were not grouped into the theoretical subtypes of FSAD (ie, genital, subjective, and combined genital and subjective arousal dysfunction[19]). Previous research has indicated that examining women with heterogeneous FSAD masks potential differences in sexual responding that become detectable when grouping women by sybtype.[20,21] Thus, it is possible that the overlap between desire and arousal disorders may have been driven by a single subtype of arousal dysfunction. Also, the high comorbidity of low desire with low arousal does not necessarily mean that desire and arousal dysfunction are one and the same. Many disorders co-occur yet are distinct. For example, the estimated comorbidity of depression and anxiety is 50%,[22] yet there is little disagreement that depression and anxiety are different constructs.

Recently, Althof and colleagues[1] proposed additional lines of evidence suggesting that SSA and desire are indeed distinct. In this review, Althof et al[1] discussed correlations between the desire and arousal domains of the Female Sexual Function Index.[23] Specifically, the authors noted that, while the correlation between these 2 domains is high (.76),[23] only 58% of the variance is *shared*. This suggests that, though there is overlap between desire and arousal, they do not represent the same entity. Althof

et al[1] also provided an analysis of SSA in women with low desire, reasoning that if arousal and desire were the same, women should score similarly on both Female Sexual Function Index domains. This was not found to be the case. No differences in SSA emerged between women with and without low desire, which further supports the notion that SSA and desire are separate.

MEASURING SSA IN THE LABORATORY

Psychometrics

In the laboratory, SSA is frequently assessed directly before and after the presentation of a sexually explicit film, though it can also be measured continuously throughout stimulus exposure. One of the most commonly used instruments is the Film Scale,[24] a 7-point Likert scale that has been adapted by many researchers. The Film Scale has been used in over 200 sexuality studies since its introduction in 1983, and it is frequently adapted to meet the needs of a given study. Though these changes preclude the use of reliability or validity statistics, the Film Scale is the measurement of choice for many researchers. A concern regarding the use of retrospective, discrete measures of SSA is that this form of measurement may capture one's current, post-stimulus state rather than one's arousal throughout the course of the film. Similarly, discrete measurement does not allow for the contemporaneous comparison with physiological genital arousal, which is critical for measuring concordance (ie, the relative agreement between genital arousal and SSA).

Researchers have attempted to improve the measurement of SSA by using levers and other apparatuses, and by employing statistical techniques that utilize multiple data points. One such apparatus, termed the "arousometer," has been found to be a valid measure of SSA in sexually functional women.[25] Using continuous measures, SSA can be assessed at the same time as genital arousal and thus compared contemporaneously.

Retrospective, discrete measurement has also been found to be negatively impacted by feelings of social desirability (ie, impression management). In a study conducted by Huberman et al,[26] when SSA was measured discretely, women who scored low on impression management reported greater SSA than those with high impression management, suggesting that women may have modified their responses to conform to societal norms. Continuous assessment, on the other hand, is thought to better capture participants' state during stimulus exposure, thus leading to more accurate reporting. Indeed, Huberman et al[26] failed to find a significant effect of impression management on SSA when SSA was measured continuously. However, both discrete and continuous measures of SSA have effectively differentiated between women with and without sexual arousal concerns.[21] One study found that, regardless of how SSA was measured, women with sexual arousal concerns reported significantly lower levels of SSA than did sexually functional women. This suggests that, though continuous measurement may be less susceptible to impression management, the type of measurement may not impact the results.

There are analytic advantages to continuous assessment of SSA. Statistically, more reliable measurements tend to be obtained from incorporating a greater number of data points into the model. SSA has traditionally been analyzed with statistics that evaluate differences in mean (or maximum) SSA from baseline to stimulus exposure. This form of analysis examines SSA as a single datum, which compromises the statistical advantage of continuous assessment and masks potential patterns in women's arousal over time.

Stimuli Content and Modality Effects

When SSA is assessed in a laboratory setting, participants are typically exposed to a sexually explicit stimulus and are instructed to report their level of SSA. To induce arousal, researchers have employed a variety of stimuli such as audio recordings of sexually explicit narratives, fantasy, sexually explicit images, and sexually explicit video. A limited number of studies have compared the effectiveness of varying types of stimuli in facilitating SSA. One such study examined the additive effects of exposure to visual video (ie, a visual video without the accompanying audio track), audiovisual video (ie, a visual video with the accompanying audio track), and fantasy on SSA in a sample of undergraduate students.[27] When comparing the effects of visual video against audiovisual video, no differences in SSA emerged. However, when women were instructed to fantasize prior to watching the video, ratings of SSA were significantly higher, regardless of whether the video was visual or audiovisual in nature. This is not to say that fantasy is a more potent stimulus than video; rather, the combined effects of fantasy and video was better at facilitating SSA than either medium alone. In a separate study comparing the independent ability of sexual fantasy vs a sexually explicit video at inducing sexual arousal, Laan and colleagues[28] found that the sexually explicit video elicited greater levels of SSA than did fantasy. Similar effects were later reported by Graham et al.[29] To further examine the impact of stimulus type on SSA, Laan and associates[30] examined women's response to male- vs female-produced sexually explicit films. In the study, women exhibited a significantly larger increase in SSA to female-produced sexually explicit films than to male-produced films. A more recent study examining the influence of male- vs female-produced sexually explicit films failed to replicate these findings.[31] In this study, men and women were shown a female-oriented film followed by a male- and female-oriented film in a counterbalanced order. No effect of film or sex of the participant was found.

Researchers have also examined the effects of sexual stimuli content, such as relationship characteristics, sexual activities, and sexual orientations, on SSA (for a review, see Chivers[32]). Chivers and Timmers[33] assessed whether the type of relationship between the characters within the stimulus impacts SSA. In their study, participants listened to 3 audio recordings of sexually explicit narratives depicting sexual activity between strangers, friends, or long-term partners. Though genital arousal was lower in narratives depicting sexual activity between friends than between strangers or long-term partners, no differences in SSA emerged.[33]

SSA does differ based on the type of sexual activity depicted in the sexually explicit stimulus. For example, women report significantly lower levels of SSA to audio recordings depicting non-consensual and/or violent sexual activity than to consensual, non-violent sexual activity.[34] Additionally, SSA has been shown to vary based on women's interest in masochism.[35] Women interested in masochism showed similar levels of SSA to masochistic and non-masochistic sex, whereas women who were not interested in masochism reported significantly higher SSA to non-masochistic sex than to masochistic sex.[35]

There also appears to be an effect of sexual orientation on SSA measured in the laboratory. Women with same-sex attraction report greater levels of SSA to same-sex couples engaging in sexual activity than to opposite-sex couples. This does not appear to be the case for women with opposite-sex attraction; these women demonstrate similar levels of SSA to films depicting same-sex couples and films depicting opposite-sex couples. A recent review by Chivers[32] explores this phenomenon, positing explanations for these differences that range from sexual plasticity to protective evolutionary mechanisms to in utero androgen exposure.

THE RELATIONSHIP BETWEEN SSA AND PHYSIOLOGICAL SEXUAL AROUSAL

A considerable amount of research on sexual arousal has examined the concordance between physiological arousal (eg, vaginal pulse amplitude [VPA]) and SSA. Concordance is determined by correlating VPA with SSA; greater concordance is generally thought to be indicative of healthy sexual function.[36] Research has posited that concordance may vary greatly from woman to woman, and that concordance may also differ based on the method of measuring SSA. Rellini and colleagues[25] found significant correlations between continuously measured SSA and VPA in 16 out of 22 of the women in their sample, with a range of $r = .08-.79$. When examining the individual correlations of discretely measured SSA and VPA in the same sample of women, no significant correlations emerged. Others, however, have suggested that measurement may not play a large a role in concordance. A meta-analysis indicated that correlations between SSA and VPA are generally low, regardless of whether SSA is measured discretely ($r = .29$) or continuously ($r = .30$).[2] Researchers have attempted to explain these discrepancies in concordance in several ways. For example, it has been hypothesized that women's attitudes toward sex and sexual stimuli, cultural messages women receive to inhibit sexuality, and an inability to perceive genital responses may play a role in concordance. However, research has largely failed to support these hypotheses.[30,37]

Alternatively, the variability in concordance rates could be related to the way in which *genital* arousal is measured. In addition to vaginal photoplethysmography, genital arousal can be measured through labial thermistors, thermographic cameras, ultrasound, magnetic resonance imaging, laser Doppler imaging, and clitoral photoplethysmography (for a review of measurement techniques, see Kukkonen[38]). However, a limited number of studies have examined correlations between SSA and physiological sexual arousal using these techniques. Thermographic cameras, which measure changes in genital temperature rather than changes in blood flow, are becoming increasingly popular in laboratory research, as they do not come into direct physical contact with the genitals. The average correlation between SSA and genital arousal measured through thermographic cameras is .55,[2] which is notably greater than the correlations that are associated with VPA. These studies suggest that the form of genital arousal measurement may have a greater influence on concordance than the form of SSA measurement.

AN OVERVIEW OF LABORATORY-BASED STUDIES MANIPULATING SSA

Given the clinical importance of SSA, we sought to review ways in which SSA has been manipulated in a laboratory setting. A comprehensive search was conducted of the electronic databases of PubMed and PsycINFO for papers focusing specifically on laboratory-based experiments aimed at altering SSA in women. Combinations of the following terms were used to search the databases: "subjective," "mental," "cognitive," "psychological," "emotional," "sexual," and "arousal." No date range was specified to allow for the inclusion of as many studies as possible. Additional searches by hand were conducted. Results from the searches were compiled (N = 1,617) and duplicates were removed (remaining n = 1,235). The first 2 researchers reviewed the titles and abstracts of the remaining articles and removed articles that clearly did not pertain to laboratory-based SSA manipulation (eg, correlational studies, non-laboratory-based clinical trials, prevalence studies, psychometric evaluations). The full texts of the remaining articles (remaining n = 141) were reviewed and assessed for eligibility. Studies were eligible for inclusion if they: (i) were published in peer-reviewed journals; (ii) were published in English; (iii) presented original findings; (iv) included women; and (v) measured and explicitly manipulated SSA in a laboratory setting. While there were numerous studies that measured SSA, several used the term "subjective sexual arousal" to describe perceived genital arousal; therefore, they were excluded. Ultimately, 44 studies remained and were included in this review.

Manipulation studies were grouped into 3 primary categories: pharmacological, cognitive, and those based on changes to the autonomic nervous system (ANS). Pharmacological studies (n = 16) included studies examining the effects of drugs (eg, sildenafil citrate), alcohol, or hormones (eg, testosterone) on SSA. Cognitive studies (n = 22) examined the effects of mood induction, conditioning, cognitive engagement, and other psychological manipulations. Finally, ANS-based studies (n = 6) frequently attempted to manipulate SSA through hyperventilation or exercise.

Table 1. A summary of each study in which the primary manipulation was pharmacological in nature

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
2003	Basson and Brotto[39]	Post-menopausal, community	34 Women with FSAD	Sildenafil citrate (50 mg) or placebo 1 h prior to stimulus; counterbalanced	Film with clitoral stimulation	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of sildenafil citrate on SSA
2016	Brom et al[40]	Pre-menopausal, community	58 Women	Haloperidol (3 mg) or placebo pill, with or without genital vibrostimulation; counterbalanced	Images	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of haloperidol on SSA
2017	Dolder et al[41]	Pre-menopausal, college students	12 Women, 12 men	MDMA (12 5 mg), methylphenidate (60 mg), or placebo	None	Questionnaire	Pre- and post-manipulation	Unit comparison*	Significant, positive effect of MDMA on SSA compared to placebo
2009	George et al[42]	Pre-menopausal, community and college students	E1: 59 women, 56 men; E2: 165 men; E3: 173 women	E1: low alcohol dose (BAL = 0.04), moderate-high dose (BAL = 0.08), or control; E2 and E3: moderate dose (BAL = 0.06), moderate-high dose (BAL = 0.08), high dose (BAL = 0.10), or control	Film; vignette	Questionnaire	Post-stimulus; pre-vignette	Unit comparison*	E1: SSA significantly greater in the moderate-high dose condition compared to control; E2: SSA significantly greater in the high-dose group than in any other group; E3: significant effect of alcohol on SSA, regardless of condition
2011	George et al[43]	Pre-menopausal, community	E1: 78 women; E2: 74 women	E1: alcohol (BAL = 0.08) or control; E2: alcohol (BAL = 0.10) or control	Film	Questionnaire	Post-stimulus	Difference scores†	No effect of alcohol on SSA
2000	Graham et al[29]	Pre-menopausal, community	28 Women	Female, male, or no fragrance, tested during periovular and follicular phases; counterbalanced	Film; fantasy	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of fragrance on SSA
2002	Hackbert and Heiman[44]	Post-menopausal, community	16 Women	DHEA (300 mg) or placebo 60 min before watching film; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Unit comparison*	Significant, positive effect of DHEA on SSA
2008	Harte and Meston[45]	Pre-menopausal, community and college students	25 Women	Nicotine (6 mg) or placebo gum 40 min before watching film; counterbalanced	Film	Lever	Continuous	Unit comparison*	No effect of nicotine on SSA
2007	Heard-Davison et al[46]	Post-menopausal, community	10 Women	Methyltestosterone (5 mg) or placebo; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores†	No effect of methyltestosterone on SSA

(continued)

Table 1. Continued

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
2002	Laan et al[47]	Pre-menopausal, college students	12 Women	Sildenafil citrate (50 mg) or placebo; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	No effect of sildenafil citrate on SSA
1998	Meston and Heiman[48]	Pre-menopausal, community and college students	20 Women	Ephedrine (50 mg) or placebo 40 min before watching film; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	No effect of ephedrine on SSA
2002	Meston and Worcel[49]	Post-menopausal, community	23 Women with FSAD	L-arginine glutamate (6 g) plus yohimbine HCl (6 mg), L-arginine glutamate placebo (6 g) plus yohimbine HCl (6 mg), or placebo; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of any drug on SSA
2015	Schmid et al[50]	Pre-menopausal, college students	15 Women, 15 men	MDMA (75 mg), methylphenidate (40 mg), or placebo	Images	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of methylphenidate on SSA compared to MDMA or placebo
2000	Sipski et al[51]	Pre-menopausal	19 Women with SCI	Sildenafil (50 mg) or placebo 1 h before stimulus, with or without clitoral stimulation; counterbalanced	Film	Verbally on a scale from 0–10	Continuous	Unit comparison*	Significant, positive effect of sildenafil on SSA, regardless of clitoral stimulation
2000	Tuiten et al[53]	Pre-menopausal, college students	8 Women	Testosterone (0.5 mg) or placebo; counterbalanced	Film	Visual analog scale	Post-stimulus	Unit comparison*	No effect of testosterone on SSA
2002	Tuiten et al[52]	Pre-menopausal, college students	10 Women	Testosterone (0.5 mg) or placebo; counterbalanced	Film	Visual analog scale	Post-stimulus	Unit comparison*	No effect of testosterone on SSA

BAL = blood alcohol level; DHEA = dehydroepiandrosterone; E = experiment; FSAD = female sexual arousal disorder; HCl = hydrochloride; MDMA = 3,4-methylenedioxymethamphetamine; SCI = spinal cord injury; SSA = subjective sexual arousal.
All women were sexually functional unless otherwise specified.
*Compared 2 time points of SSA.
†Post-stimulus SSA minus pre-stimulus SSA.

Table 2. A summary of each study that employed a primarily cognitive manipulation

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
2011	Both et al[56]	Pre-menopausal, community and college students	32 Women	Classical conditioning in response to neutral images (CS) paired with genital vibrostimulation (+) or nothing (−)	Images	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of CS+ on SSA; no extinction of differential response to CS+ and CS−
2011	Both et al[57]	Pre-menopausal, community and college students	47 Women, 37 men	Instructional set: imagine yourself as one of the actors ("hot"), focus on the setting ("cold"), or no instructions	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of the "hot" condition on SSA, regardless of gender
2014	Brom et al[58]	Pre-menopausal, community and college	62 Women, 40 men	Classical conditioning in response to neutral images (CS) paired with genital vibrostimulation (+) or nothing (−)	Images	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of CS+ on SSA, regardless of gender; significant revival
2015	Brom et al[59]	Pre-menopausal, community and college students	34 Women, 38 men	Classical conditioning in response to images (CS) followed by shock (+) or no shock (−)	Images	Questionnaire	Post-stimulus	Unit comparison*	Compared to men, women reported significantly less SSA following CS+ than CS−
2013	Carvalho et al[60]	Community	28 Women, 29 men	Instructional set: fantasize about your partner or fantasize about someone who isn't your partner; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of fantasizing about one's partner on SSA, regardless of gender
1997	Elliott and O'Donohue[61]	Pre-menopausal	48 Women	Induced anxiety or control, random assignment; no, low, or high distraction, counterbalanced	Audio	Questionnaire	Post-stimulus	Unit comparison*	SSA was significantly higher in the no distraction condition compared to low or high, regardless of whether anxiety was induced
2007	Gillath et al[62]	Pre-menopausal, college students	23 Women, 17 men	Subliminal sexual images followed by neutral images	Images	Questionnaire	Post-stimulus	Unit comparison*	Significant, negative effect of subliminal sexual stimuli on SSA for women only
2006	Kuffel and Heiman[63]	Pre-menopausal, community and college students	56 Women	Positive or negative sexual schema induction; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of positive compared to negative schema on SSA

(continued)

Table 2. Continued

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
1993	Laan et al[64]	College students	49 Women	Instructional set: become as aroused as possible or focus on your pleasure; counterbalanced	Film; fantasy	Questionnaire; lever	Pre- and post-stimulus; continuous	Unit comparison*	Significant, positive effect of being told to become aroused on SSA
1995	Laan and Everaerd[65]	Pre-menopausal, college students	E1: 32 women; E2: 42 women	E1: 10 trials of the same image followed by 1 novel image or 11 varied images; E2: 21 uniform films or 21 varied films	S1: images; S2: film	Lever	Continuous	Unit comparison*	E1: significant, positive effect of varied images on SSA; E2: marginal, positive effect of varied films on SSA
1995	Laan et al[28]	Pre-menopausal	51 Women	Induced "positive mood for sex" or control; random assignment	Film, fantasy	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of mood induction on SSA
1997	Letourneau and O'Donohue[66]	Pre-menopausal, college students	25 Women	Classical conditioning in response to amber incandescent light paired with or without erotic film clips	Film	Questionnaire	Pre- and post-stimulus	Unit comparison*	No effect of conditioning on SSA
2007	McCall and Meston[67]	Community	15 FSAD, 16 control	False-positive or false-negative feedback; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores†	SSA was significantly greater following false-positive and lower following false-negative feedback, regardless of sexual functioning
1985	Messé and Geer[68]	Community and college students	30 Women	Kegel exercises or control	Fantasy	Questionnaire	Post-stimulus	Unit comparison*	Fantasy plus tensing elicited significantly greater SSA than tensing alone
2008	Middleton et al[69]	Pre-menopausal, community	17 FSAD, 17 control	Positive or negative sexual schema induction; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of positive compared to negative schema on SSA, regardless of sexual function
1990	Palace and Gorzalka[70]	Community and college students	16 with Sexual dysfunction, 16 control	Anxiety-provoking or neutral film; counterbalanced	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, negative effect of the anxiety-erotic film on SSA, regardless of sexual function
2006	Salemink and Van Lankveld[71]	Pre-menopausal, community and college students	20 Women with sexual dysfunction, 21 control	Low, medium, high distraction or control; counterbalanced	Film	Lever	Continuous	Difference scores†	SSA was significantly lower in high distraction compared to control; no effect for moderate distractions, regardless of sexual function

(continued)

Table 2. Continued

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
2007	Seal and Meston[76]	Community	21 Women with FSAD	Body awareness or control; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores†	Significant, positive effect of body awareness on SSA
2009	Sheen and Koukounas[72]	Community and college students	62 Women	Instructional set: picture yourself with a partner in the film or evaluate the film; random assignment	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, positive effect of picturing one's self with a partner in the film on SSA
1996	Sipski et al[73]	Community	10 Women with SCI, 10 control	Distraction via the Stroop test or control	Clitoral stimulation	Verbal scale	Continuous	Unit comparison*	Significant, negative effect of the Stroop test on SSA
2007	ter Kuile et al[74]	Pre-menopausal	59 Women	Acute psychological distress or control; random assignment	Film	Questionnaire	Post-stimulus	Unit comparison*	Significant, negative effect of acute distress on SSA
2010	ter Kuile et al[75]	Pre-menopausal, community	32 Women	Happy or sad mood induction; counterbalanced	Film	Questionnaire	Pre- and post-manipulation; post-stimulus	Unit comparison*	Significant, negative effect of sad compared to happy mood on SSA

CS = conditioned stimulus; E = experiment; FSAD = female sexual arousal disorder; SCI = spinal cord injury; S1 = session 1; S2 = session 2; SSA = subjective sexual arousal.
All women sexually functional unless otherwise specified.
*Compared 2 time points of SSA.
†Post-stimulus SSA minus pre-stimulus SSA.

Pharmacological Studies

Overall, there does not appear to be robust support for laboratory-based pharmacological manipulation of SSA. Of the 16 studies that assessed pharmacological approaches,[29,39–53] only 5 studies yielded significant effects. One study investigating the effects of 30 mg of dehydroepiandrosterone found a significant enhancing effect of the drug on SSA.[44] Additional research not included in this review indicates that dehydroepiandrosterone is positively correlated with SSA,[54] thus supporting this result. Methylphenidate was also found to significantly increase SSA.[50] In this study, 30 college students (15 women) were administered 40 mg of methylphenidate, 75 mg of 3,4-methylenedioxymethamphetamine (MDMA), or placebo prior to watching a sexually explicit film. It was found that methylphenidate had a significant, positive effect on SSA compared to MDMA or placebo. However in a later study, MDMA, not methylphenidate, was linked with increased SSA.[41] A significant, facilitating effect was also found for alcohol on SSA,[42] though this was not replicated in a later study conducted within the same laboratory.[43]

Three studies assessed the impact of sildenafil on SSA with mixed results; a significant effect of sildenafil was found in only 1 study. In this counterbalanced study, participants (19 pre-menopausal women with spinal cord injury) received either 50 mg of sildenafil or placebo prior to watching a sexually explicit film. During the film, half of the women received clitoral stimulation. It was found that sildenafil significantly increased SSA regardless of whether clitoral stimulation was employed.[51] However, a longitudinal, randomized clinical trial failed to find a significant effect of sildenafil on SSA in women with spinal cord injury.[55] This suggests that, while sildenafil may produce gains in SSA in a laboratory setting for women with spinal cord injury, these effects may not be maintained at home when women are in a more natural setting.

Taken together, the findings from these studies suggest that, within a laboratory setting, drug-induced physiological changes (eg, hormone level[46,52,53]) may not be strongly related to women's SSA. One potential explanation for this conclusion is that the samples included in this review were heterogeneous in nature. Participants were of a variety of ages and had varying levels of sexual function and overall physical health. It is possible that the heterogeneity of the studies included in this review, and the lack of replication studies (only 3 drugs were assessed in more than 1 study), could have masked potential effects of drugs on SSA. It is also conceivable that psychological variables such as mood, attention, or relationship satisfaction, may have a stronger influence on a woman's experience of SSA, in which case non-pharmacological interventions may be better suited for women with SSA-related concerns. See Table 1 for sample characteristics, form of manipulation, SSA measurement, analysis, and relevant results of each study that employed a pharmacological manipulation.

COGNITIVE STUDIES

Half of the studies included in this review employed some form of cognitive manipulation.[28,56–76] The most common

Table 3. A summary of each study in which the primary manipulation involved changes to the autonomic nervous system

Year	Authors	Population	Sample size	Manipulation	Erotic stimulus	Form of SSA measurement	Time of SSA measurement	SSA analysis	Results
2002	Brotto and Gorzalka[77]	Community	25 Young pre-menopausal, 21 old pre-menopausal, 25 post-menopausal women	Hyperventilation (2-min rapid breathing) or control; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores*	No effect of hyperventilation on SSA, regardless of age
2009	Brotto et al[78]	Community	16 Women with genital SAD, 16 with subjective SAD, 28 with combined SAD, 42 control	Hyperventilation (2-min rapid breathing) or control; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores*	No effect of hyperventilation on SSA, regardless of sexual function
2008	Hamilton et al[80]	Pre-menopausal, community	16 Women	20 min of Exercise or 20 min of questionnaires; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores*	No effect of exercise on SSA
2012	Lorenz and Meston[79]	Pre-menopausal, community	32 Women taking SSRIs, 15 taking SNRIs	20-min Exercise, wait 5 min; 20-min exercise, wait 15 min; 20 min of questionnaires; counterbalanced	Film	Questionnaire	Pre- and post-stimulus	Difference scores*	No effect of exercise or time until stimulus exposure on SSA, regardless of antidepressant use
2017	Stanton and Meston[82]	Pre-menopausal, college students	33 Women	14 min of Autogenic training	Film	Questionnaire; lever	Post-stimulus; continuous	Unit comparison†; HLM	Significant, positive effect of autogenic training on SSA
2018	Stanton et al[87]	Pre-menopausal, community	25 Women	22 min of Autogenic training	Film	Questionnaire; lever	Post-stimulus; continuous	Unit comparison†; HLM	Significant, positive effect of autogenic training on SSA

HLM = hierarchical linear modeling; SAD = sexual arousal disorder; SNRI = serotonin-norepinephrine reuptake inhibitor; SSA = subjective sexual arousal; SSRI = selective serotonin reuptake inhibitor. All women were sexually functional unless otherwise specified.
*Post-stimulus SSA minus pre-stimulus SSA.
†Compared 2 time points of SSA.

forms of these manipulations were attempts to vary the degree of participant engagement in the sexually explicit stimulus ($n = 6$). In these studies, researchers typically provided participants with instructional sets on how to engage with the sexually explicit film. For example, in a study conducted by Both and colleagues,[57] participants were randomly assigned to 1 of 3 counterbalanced conditions: high absorption (ie, highly engaged), low absorption (ie, minimally engaged), and control. In the high-absorption condition, participants were instructed to imagine themselves as one of the actors in the film, whereas in the low-absorption condition participants were instructed to focus on the film's setting. No instructions were provided to participants in the control condition. After watching the film, participants completed a questionnaire measuring SSA. Both and colleagues[57] found that the high-absorption condition yielded significantly higher levels of SSA than the low-absorption or control conditions. Conversely, the low-absorption condition did not differ significantly from control. Similar results have been reported elsewhere.[72] Consistent with the IPM, which stresses the importance of both attending to the erotic stimulus and appraising it as sexual, these studies suggest that, in the treatment of women's sexual concerns, it is important to address one's focus of attention during sexual activity. As no differences emerged between the low-absorption and control conditions, it appears as though low levels of absorption in a sexually explicit stimulus may be more typical of women's experience than high levels of absorption. However, interventions designed to teach women to pay attention to the sexual aspects of the stimulus (eg, a partner) may be a promising avenue for treatment development.

The second most common form of cognitive manipulation that we noted in the literature was classical conditioning ($n = 5$). In a recent study by Brom et al,[59] participants (34 women) were shown 2 explicit images (conditioned stimulus [CS]) followed either by an electric shock or no shock. It was found that, compared to men, women reported significantly lower levels of SSA in response to CS followed by electric shock than to the CS with no shock. Separate studies have reported similar findings.[56,58,65,66] These studies indicate that subjective responses to sexual stimuli appear to be modifiable through repeated exposure to specific stimuli (eg, electric shock); stimuli can be given sexually activating characteristics through basic learning processes. However, differences in SSA tended to diminish during the extinction phases (ie, when the CS and un-CS were unpaired), suggesting that long-term changes in SSA may not be readily obtained through single, laboratory-based sessions of conditioning. Refer to Table 2 for sample characteristics, form of manipulation, SSA measurement, analysis, and relevant results of each study that implemented a cognitive manipulation.

ANS-BASED STUDIES

Six studies attempted to manipulate SSA through changes to the ANS; 4 studies[77-80] used physical activation to manipulate SSA while 2 studies[82,87] used relaxation. Of the studies attempting to manipulate SSA through physical activation, 2 studies employed laboratory-induced hyperventilation[77,78] and 2 studies employed exercise.[79,80] No effect of physical activation was found on SSA regardless of age,[77] sexual functioning,[78] and timing of exercise relative to sexually explicit stimulus exposure,[79] in any study. The results of these studies suggest that feelings of general physical activation may not influence SSA, even when that physical activation does facilitate increases in objective measures of genital arousal (eg, VPA). Rather, as women with arousal concerns are more likely to become distracted during sexual activity and subsequently disengage from physical sensations,[81] it may be necessary to improve attention to physical sensations before enhancing the sensations themselves. As noted earlier, the IPM highlights the importance of the recognition and appraisal of sexual cues in the experience of SSA.

A recent study by Stanton and Meston[82] examined the effects of autogenic training on SSA in sexually functional college-aged women. In this study, participants watched a sexually explicit film, during which they moved a lever to indicate increases or decreases in SSA. They then listened to a brief autogenic training recording before watching a second sexually explicit film. Autogenic training is a psychophysiological relaxation technique that aims to induce bodily sensations, such as heaviness and warmth in the limbs, via verbal self-suggestions.[83] This practice has been shown to significantly increase heart rate variability (HRV),[84,85] which is depressed in women with clinically low levels of sexual arousal.[86] After the autogenic training manipulation, significant increases in SSA, when measured both discretely and continuously, were observed. Moreover, greater increases in HRV from pre- to post-manipulation were associated with greater changes in SSA when it was measured continuously. A similar protocol was tested among women with self-reported sexual arousal problems.[87] Significant increases in acute SSA were again observed during the second sexually explicit film, presented after the autogenic training manipulation, and the degree of change in HRV moderated this increase. These results suggest that autogenic training, and perhaps other interventions that specifically aim to increase HRV, may be useful additions to treatment protocols for sexual arousal dysfunction. See Table 3 for sample characteristics, form of manipulation, SSA measurement, analysis, and relevant results of the 6 studies that attempted to manipulate SSA through changes to the ANS.[77-80,82,87]

CONCLUSION

This review examined laboratory-based measurement, analysis, and manipulation of SSA in women. SSA is commonly measured with a Likert-type questionnaire, which participants complete immediately after they are exposed to a sexually explicit stimulus. However, there are a number of concerns with this form of measurement. Self-report questionnaires may be capturing one's post-stimulus SSA rather than SSA experienced during stimulus exposure. Discrete (opposed to continuous) measurement is also negatively impacted by extraneous factors, such as impression

management.[26] To address these issues, some researchers measure SSA continuously throughout the presentation of the sexually explicit stimulus. An additional concern regarding discrete measurement of SSA is that it cannot be compared contemporaneously with VPA, which was thought to possibly explain the low, variables rates of agreement between those 2 constructs. However, the degree of agreement between SSA and VPA is only slightly higher when SSA is measured continuously.[2]

Cognitive interventions are more effective than pharmacological or ANS-based manipulations at increasing SSA. In fact, 91% of studies that implemented a cognitive manipulation reported significant changes in SSA, whereas only 31% of pharmacological and 33% of ANS-based studies reported significant effects of the manipulation on SSA in women. There are 2 possible explanations for the non-significant effect of laboratory-based pharmacological manipulations on SSA. First, psychological variables (eg, mood, attention, relationship satisfaction) may have a stronger influence on a woman's experience of SSA than pharmacologic agents. If this is the case, non-pharmacological interventions may be better suited for women with psychological, as opposed to physiological (eg, difficulties with lubrication), arousal concerns. This conclusion is supported by the IMM, which highlights the necessary integration of psychological variables in the conceptualization of sexual arousal, which has been historically dominated by biological or physiological perspectives.

Second, it is possible that a single, in-laboratory dose of a given drug may not be enough to influence SSA. Indeed, a number of non-laboratory-based randomized clinical trials assessing pharmacological interventions for women's sexual concerns have had promising effects on a number of sexual variables (for a review, see Belkin et al[88]). For example, Davis and colleagues[89] conducted a large, 65-site study examining the effects of daily testosterone on sexual function in pre-menopausal women. Over the course of the 52-week study, significant improvements in desire, SSA, orgasm, pleasure, sexual responsiveness, and sexual self-image were made (see also a study by Fernandes and colleagues[90]). Thus, it is possible that, for pharmacological manipulations, repeated administration may be necessary to see gains in SSA.

It is notable that activating the sympathetic (sympathetic nervous system [SNS]) branch of the ANS did not facilitate increases in SSA, whereas autogenic training, which increases HRV, was associated with improved SSA in women with and without arousal concerns. In line with the IMM, it seems that increasing SNS actively acutely via exercise does lead to increases in VPA, but not in SSA.[79,91–94] In general, HRV level provides important information about the state of the ANS. The SNS and parasympathetic branches of the ANS act antagonistically to preserve a dynamic equilibrium of vital functions; this balance results in the fluctuation of the lengths of time between successive heart beats, also known as HRV.[95] Higher HRV is reflective of organized variability, rather than static SNS or parasympathetic nervous system input, which enables the body to respond adaptively to environmental demands.[96] Given the association between HRV level and the inhibitory pathways that are regulated by the parasympathetic branch of the ANS, HRV is considered an index of emotional regulation.[97] Adaptive emotional regulation is likely relevant to SSA. If a woman is about to engage in sexual activity alone or with a partner, her ability to effectively regulate her emotional responses in the moment will, according to the IMM, at least partially contribute to the success of the overall experience. Indeed, feeling mentally turned on during sexual activity is an adaptive response to a sexual situation.

There are a few limitations of this review that should be mentioned. First, the studies included in this review were heterogeneous in nature. Participants were of a variety of ages and had varying levels of sexual function and overall physical health and only a limited number of studies examined the effect of the manipulation in multiple populations. This is problematic as a manipulation that failed to increase SSA in one population could have produced important results in a different population. Second, nearly all studies recruited cisgender women who identified as heterosexual or were in an opposite-sex relationship. Given that the lesbian, gay, bisexual, and transgender community is relatively understudied, particularly with regards to sexual arousal outside of category specificity, this is not unusual. However, this limits the generalizability of this review. Future research should aim to incorporate individuals who identify as lesbian, gay, bisexual, and transgender to broaden our understanding of sexual arousal. Third, due to language constraints, the authors of this review only assessed papers that had been written in English and that had been subjected to peer review. Therefore, language selection may be a possible source of bias, as studies may be more likely to be published in English when results are significant.

Despite these limitations, the findings of this review offer insight on potential avenues for future research and treatment development. The majority of the studies included here used non-clinical samples; therefore, to build on these findings, future work should test the interventions that did effectively increase SSA in women with sexual difficulties. If these interventions do effectively increase SSA in clinical populations, then researchers can begin to develop treatment protocols that specifically target SSA.

Even though many of these interventions have yet to be examined among women with sexual problems, this review has some important clinical implications. First, though it is unlikely that classical conditioning paradigms will be used as effective treatments for sexual difficulties in women, the mechanisms of conditioning can still be applied to treatment. For women struggling with low SSA, it is recommended that clinicians advise patients to refrain from engaging in any sexual activity that is not pleasurable. Within the classical conditioning framework, repeatedly engaging in painful or uncomfortable sexual activity leads to expectations that all future sexual activity will not be pleasurable. Such a relationship is also suggested by the IPM. Clinicians should therefore assist patients in rediscovering sexual

pleasure (eg, through sensate focus or directed masturbation) and encourage them to only engage in sexual acts when they are pleasurable, thus strengthening the association between sex and pleasure. The principles of classical conditioning indicate that this repeated pairing should then lead patients to expect that their next sexual experience will be pleasurable, which could feasibly increase levels of SSA.

The results of studies included in this review, as well as the IMM and IPM, suggest that treatments designed to increase attention to sexual cues may be beneficial for women struggling with low SSA. Several studies found that directing attention to certain elements of the sexual stimuli, via instructions to focus only on the sexual aspects of the sexually explicit film,[57,72] increases SSA. This supports the growing area of research indicating that mindfulness,[98] which focuses on building non-judgmental awareness of bodily sensations,[99] is a promising treatment for women's sexual difficulties.

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