

10.1 Blood flow: vaginal photoplethysmography

Nicole Prause, Erick Janssen

The most widely used method for assessing vaginal blood flow (see Chapters 4.1–4.3 and 5.4–5.6 of this book) is vaginal photoplethysmography. The vaginal photoplethysmograph, introduced by Palti and Bercovici¹ and refined by Sintchak and Geer,² is made of clear, acrylic plastic and is shaped like a menstrual tampon. Embedded in the device is an incandescent light that projects toward the vaginal wall. Some of the light is reflected back to a photosensitive cell within the body of the probe, while the rest of the light, presumably, is dispersed through the vaginal tissue (for tissue absorption estimates, see Niklas et al.³). Researchers generally assume that more light will return to the photosensitive cell as the amount of blood in the vaginal blood vessels increases. The change is represented as a change in mV from a basal value. In later years, an infrared light-emitting diode was introduced as an alternative to incandescent light,⁴ a phototransistor replaced the photocell,⁴ and a stabilizing, acrylic plate was developed that can be attached to the external cord of the device.⁵ These innovations are thought to reduce potential signal drift (possibly produced by warming of the incandescent light), minimize probe movement, and allow for standardization of probe position. The vaginal photoplethysmograph can be easily placed by the participant herself and usually is cleaned with glutaraldehyde-based antiseptics (e.g., Cidex Plus, Cidex PA, or Metricide).

The photometer output typically is filtered to yield two signals. One signal is the direct current signal, also referred to as the vaginal blood volume, which is thought to provide an index of the total blood volume change in the vaginal wall.⁶ The other signal is the alternating current signal, or vaginal pulse amplitude, which is thought to reflect pressure changes within the blood vessels of the vagina's vascular walls.⁷ Signal cleaning usually includes filtering high-frequency noise and manually deleting artifacts. Next, response levels are computed for the time periods of interest. The length of the time period can vary from five or ten second intervals over a condition to the entire condition. Within the selected period(s), signal values (in mV) are either averaged or the maximum value is taken. Response for the vaginal blood volume is represented by the actual value

of the signal, whereas response for the vaginal pulse amplitude is represented by the amplitude of each complete cycle in the signal. Typically, researchers use a baseline period to calculate difference scores for use in analysis.

The sensitivity and specificity of the vaginal photoplethysmograph for assessing sexual arousal, as opposed to general arousal, has been supported by several studies (e.g., Henson et al.⁸ or Zingheim and Sandman⁹). Available data strongly suggest that vaginal blood volume is the less sensitive measure,^{5,10,11} so vaginal blood volume will not be discussed further. The influence of anxiety-inducing, sexually threatening, or neutral stimuli on vaginal pulse amplitude responses is specific, increasing only to subsequent stimuli with sexual content.^{5,12} Mirroring participants' self-reported sexual arousal, genital response increased significantly from baseline during the presentation of a sexually threatening film, but increased further during a non-threatening sexual film.^{5,12} In general, these findings demonstrate response specificity of vaginal pulse amplitude to sexual stimuli.

Alternative measures of genital response

Over the years, several instruments have been developed to assess physiologic sexual arousal in women (see Chapters 10.2–10.4). For example, thermography is a method for detecting and measuring heat from various regions of the body, including the genital area, which can be recorded photographically.¹³ This approach, however, lacks convincing validity data, having been tested in only one male and one female. Devices also have been designed to measure vaginal pH.^{14,15} On average, vaginal pH increases with increasing sexual arousal. Measurement of pH, however, requires potentially disruptive experimenter involvement, and pH seems to vary nonsystematically across different areas of the vagina.¹⁶ A heated electrode to measure oxygen pressure and heat dissipation also has informed

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researchers about vaginal changes that accompany sexual arousal, and is minimally affected by artifacts.^{17,18} On the other hand, this instrument must be placed directly by an experimenter, and the heating element and suction cup to attach it could cause tissue damage if left in place too long. Finally, some researchers have used Doppler ultrasonography to record clitoral vascular changes by quantifying changes in blood velocity.¹⁹ However, this method currently requires a technician to hold the probe in place over the clitoris.²⁰

Several studies have been reported on the relationship between labial temperature and the vaginal photoplethysmograph. D.E. Henson et al.²¹ examined the reliability of the two instruments across two sessions. Although both the general response pattern and response amplitude proved fairly reliable for both instruments, labial temperature was the most consistent on both parameters. In a second study, C. Henson et al.⁸ found high correlations between subjective sexual arousal and both vaginal pulse amplitude and labial temperature changes. Although the labial temperature clip currently is used in few laboratories, it offers several advantages over vaginal photoplethysmograph. The labial temperature clip offers an absolute scale of measurement, is less sensitive to movement artifacts than the vaginal photoplethysmograph (as discussed in a later section), and may be more easily be used during menses. Some have criticized the labial clip because it requires the control of ambient temperature and does not consistently return to baseline levels.^{22,23} However, the vaginal photoplethysmograph also does not consistently return to baseline levels (e.g., Graham et al.²⁴). The slow return to baseline genital response levels may not be a problem with the vaginal photoplethysmograph per se, especially considering that the labial thermistor also rarely returns to baseline levels, and it may reflect an actual, slow physiologic process in females.

Another new approach, the labial photoplethysmograph, relies on measurements of genital responses that are similar to the vaginal photoplethysmograph. The labial photoplethysmograph is a small plastic clip, originally designed to measure blood flow in the ear lobe (BIOPAC Systems, Model TSD100). It can be attached to the labium minorum. In a small study ($n=10$), the labial photoplethysmograph was compared simultaneously with the vaginal photoplethysmograph while participants viewed neutral, sexual, sexually threatening, and threatening film clips.¹² Both instruments were specific to sexual content and correlated strongly with participants' own ratings of their sexual arousal. Although participants reported that the labial photoplethysmograph was somewhat more difficult to place and less comfortable, the labial device exhibited fewer movement artifacts than the vaginal photoplethysmograph. Given the potentially large impact that movement artifacts may be having on the analysis of vaginal photoplethysmograph data,²⁵ the labial photoplethysmograph warrants further development.

In summary, several promising alternatives to the vaginal photoplethysmograph exist. In particular, it is unclear why the labial thermistor is not more widely used. The thermistor has

particularly strong advantages over the vaginal photoplethysmograph, including an absolute scale of measurement and resistance to movement artifacts.

Interpreting vaginal pulse amplitude

Despite the title of this chapter, the vaginal photoplethysmograph does not necessarily measure vaginal blood flow. The vagina consists of a layered, scaly cell epithelium with numerous folds (but without sweat or hair glands), surrounded by sheaths of smooth muscle.^{26,27} Although the vascular vaginal walls are supplied by an extensive anastomotic network of blood vessels, the vagina itself is almost anaerobic. The amount of blood in the vaginal walls increases with sexual arousal, although the mechanism causing the increase has recently become a topic of debate. Historically, researchers described the increased blood flow as a process of vasocongestion, a gradual increase in capillary blood flow. Levin and Goddard²⁸ have suggested that vasomotion, the oscillation of vascular tone in capillaries,²⁹ may better characterize changes in vaginal pulse amplitude. As support for this idea, they cite a pattern of large and small amplitude peaks in vaginal pulse amplitude that change in proportion with increasing sexual arousal. Vasomotion refers to the phenomenon that capillaries are, essentially, open or closed, and different capillaries are recruited at different levels of sexual arousal (cf. motor unit recruitment). Increased blood volume in the vaginal walls increases the force in the vaginal walls, which drives transudation of NaCl⁺-rich plasma through the vaginal epithelium, coalescing into the slippery film of vaginal lubrication and neutralizing the vagina's usually acidic state (see Chapters 4.1–4.3 and 5.4–5.6).^{16,30} Given the many and complex changes that occur in vaginal physiology during sexual arousal, it is too early to assume that vaginal pulse amplitude indexes changes in blood flow alone, if at all. More comprehensive models of vaginal physiology and its relationship to other (central and peripheral) systems are yet to be developed.

Levin³¹ stated that one of the basic assumptions underlying the use of the vaginal photoplethysmograph is that changes in vaginal pulse amplitude reflect vascular events only in the genitalia. He further suggests that vaginal pulse amplitude reflects rather complex interactions between sympathetic and parasympathetic regulatory processes and between circulatory and vaginal blood pressure. Vaginal blood flow changes could partly reflect increases in general circulatory blood pressure that occur with sexual, as well as general, arousal.³² However, some preliminary data argue against that idea.¹²

Part of the difficulty in deciphering what vaginal pulse amplitude represents lies in its lack of an absolute scale. Since the scale is relative and no published calibration method exists, the use of vaginal pulse amplitude in between-subjects designs requires caution when drawing conclusions. Vaginal pulse amplitude has not been shown to represent any specific physiologic process or event, and may in fact reflect multiple physiologic processes or events. Disentangling which components of

vaginal pulse amplitude indicate which physiologic phenomena would allow researchers to select filters more accurately, according to the specific phenomenon they wish to investigate.

Artifacts

Artifacts in vaginal pulse amplitude are common and variable in appearance. The detection of artifacts is not standardized, and the procedures used often are not described in research publications. Movement artifacts are inferred when the signal has sudden, strong fluctuations in amplitude. Not only distinct body movements (such as sitting back in a chair), though, but also less conspicuous behaviors (such as tensing one's abdominal or pelvic muscles, or crossing one's ankles) can affect the vaginal photoplethysmograph's output,^{33,34} and these artifacts are not always as easy to detect. They may increase or decrease the amplitude, cause a basal shift, or obliterate the signal for a period of time. Moreover, some circumvaginal muscular contractions during sexual arousal are normal.³⁵⁻³⁷ As a result, artifacts threaten the validity of vaginal pulse amplitude data, and ignoring their presence or editing them in inconsistent or ill-defined ways could render vaginal pulse amplitude findings unreliable.

Two potential strategies exist for managing artifacts. The most apparent strategy is to prevent them. For instance, providing a reclining chair or an examination table and instructing participants to try not to move or tense their muscles, especially during stimulus presentations, may help considerably to reduce the number of movement artifacts. More realistically, researchers may manage artifacts after data collection is complete. Usually, each individual artifact is edited out of a signal after visual inspection by a researcher. The potentially low reliability of single raters begs for better standardization. Standardization is achieved in other fields by signal processing algorithms,³⁸⁻⁴⁰ which could benefit sexual psychophysicists who use the vaginal photoplethysmograph as well. Due to high intra- and interparticipant artifact variability, however, developing algorithms for the editing of vaginal pulse amplitude signals is a challenge. Standardization would minimize processing time, and encourage the operationalization of artifacts. If laboratories cannot develop artifact processing algorithms, they should, at a minimum, articulate what methods were used to identify and edit signal artifacts in publications.

Menstruation

Several psychophysic studies in women have found that levels of subjective sexual arousal in response to sexual stimuli tend to remain stable across phases of the menstrual cycle. However, a more complex picture emerges for genital sexual response. Some studies have found stable response patterns across menstrual phases.^{41,42} Others have found higher response levels during the premenstrual than the periovulatory phase.^{43,44}

Still others have reported complex interactions between menstrual phases and the order in which the phases were tested.^{24,45} Among the factors that may have contributed to this lack of consistency are differences in the method used for determining cycle phase, experimental design, and participant characteristics.⁴⁶ Although there is no consensus about the possible effects of menstrual cycle phase on sexual arousal, it is important to control for, or, at the very least, assess participants' menstrual phase.

Relationship of physiologic and subjective sexual arousal

As in other psychophysic research areas, physiologic and subjective indices of sexual arousal do not correlate perfectly (cf. Lang and Cuthbert⁴⁷). Correlations between vaginal pulse amplitude and subjective sexual arousal vary widely, whether subjective arousal is measured discretely⁴⁸ or continuously.⁴⁹ Women typically are reported to exhibit lower concordance between physiologic and subjective sexual arousal than men,⁵⁰⁻⁵³ although men with and without sexual dysfunction also frequently exhibit discordance between their erection level and subjective reports of sexual arousal.^{10,54-56} Since sexual arousal is a construct that may not be captured best by vaginal pulse amplitude,^{22,57} it is inappropriate to characterize correlations in women as "poor". Variations in concordance may occur for many different reasons which, upon further investigation, might contribute to our understanding of vaginal pulse amplitude.

One reason for the variability in concordance could be that components of sexual arousal are under the control of multiple mechanisms.⁵⁸ Janssen et al.⁵⁹ presented a model that highlights the interaction between automatic (unconscious) and controlled (conscious) cognitive processes, and proposed that different levels of processing may differentially affect subjective and physiologic sexual arousal. The model states that unconscious processes help explain the automaticity of the genital response, whereas subjective feelings of sexual arousal are under the control of higher-level, conscious, cognitive processing. Several studies suggest that preconscious, automatic activation of sexual cognitive networks are possible in both men and women, and that subsequent conscious evaluations of sexual stimuli do not always match subjectively reported sexual arousal or sexual attraction.⁶⁰⁻⁶³

The variability in concordance could also be due to different women attending to different cues, or even different cues at different points of their sexual response. Laan et al.⁶⁴ found that women's subjective and physiologic indices of sexual arousal were more strongly correlated at later moments of sexual stimulation (presumably at greater levels of sexual arousal). Physical cues may become more salient at higher levels of sexual arousal when, for instance, vaginal lubrication increases and is more easily detected.

Finally, the variability in women's concordance may appear

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low because of the way that they are asked to report their level of sexual arousal. Research suggests that if women are asked to report on their genital changes, rather than on their sexual arousal, the agreement between their genital and subjective measures will be stronger.^{65,66} This supports the contention of researchers who have suggested that women attend to many factors in addition to their genital response when reporting their level of sexual desire or arousal (e.g., Basson⁶⁷). If the latter is true, and if men tend to focus more on physiologic cues in estimating their sexual arousal, then a lower correlation between genital blood flow and reported sexual arousal in women than men is to be expected. Low correlations are not, *de facto*, problematic. Discerning what factors alter the relationship between subjective and physiologic components of sexual arousal in women could inform better models of female sexual function. In view of the variability in physiologic and subjective response patterns, it is arbitrary to promote either response as the reference standard. Sexual arousal is, at this time, best approached as a construct with multiple (affective, physiologic, and behavioral) indicators.⁶⁸

Clinical application

Clinical diagnoses, in general, are based on the presence of stable tendencies that are designated as dysfunctional and present in some individuals, but not in others. Since the vaginal photoplethysmograph cannot reliably be used in between-subject designs, vaginal pulse amplitude response alone is an inadequate basis for diagnosing sexual dysfunction. On the other hand, psychophysiologic measures are used to compare diagnostic groups in other research areas even though they also lack an absolute scale and are not associated with a single physiologic process (e.g., electroencephalography⁶⁹). Certainly, less is understood about vaginal pulse amplitude than many of these other measures, and vaginal pulse amplitude appears more variable between individuals. In sum, researchers should use a within-participants design whenever possible with vaginal pulse amplitude. Should they use a between-participants design, attempts should be made to recruit large samples, and between-participant differences in vaginal pulse amplitude should be interpreted with caution.

One way that vaginal pulse amplitude may be useful for diagnostic purposes is through the identification of patterns of dysfunctional sexual response. For instance, Wouda⁷⁰ found that the vaginal response of women with dyspareunia decreased during the portion of an erotic video portraying penetrative sex, as compared to portions portraying oral sex or petting, although genital response to the penetrative sex portion increased further in women without dyspareunia. Moreover, Tuiten et al.⁷¹ demonstrated that women with hypothalamic amenorrhea exhibited a smaller vaginal pulse amplitude increase from baseline to fantasy than controls, but that they exhibited increases to sexual films similar to nonamenorrheic women; the decreased response to fantasy in the patient group was eliminated with

testosterone administration. While not diagnostic *ipso facto*, this may prove a useful addition to diagnostic approaches if future research confirms its incremental validity.⁷²

Vaginal pulse amplitude has also been used to assess treatment effects. For example, Morokoff and Heiman⁷³ compared a group of women entering sex therapy for treatment of low arousal with a control group of sexually functional women across two sessions. In addition to the problems associated with the use of between-subject designs when measuring vaginal pulse amplitude, the comparison of women's responses over two sessions introduces new complications. This approach requires that women reinsert the vaginal photoplethysmograph, which is not likely to result in exactly the same positioning. As a result, the vaginal photoplethysmograph may record from different tissue(s) leading to potentially substantial differences in observed baseline and response levels.

Even measuring vaginal pulse amplitude within participants during a single session (for example, to assess the effects of a drug) can be problematic. One problem is that vaginal pulse amplitude baselines within a single, brief session often cannot be re-established (e.g., Graham et al.²⁴). If physiologic arousal truly dissipates so slowly, studies testing drugs with long time-to-efficacy or a slow clearance rate, as is typical of many selective phosphodiesterase type-5 inhibitors, require careful interpretation of vaginal pulse amplitude when using a single-session, within-participants design. In those cases, unless extensive return-to-baseline periods are used, counterbalancing conditions will more likely than not reveal order effects. Moreover, whether or not this failure of vaginal pulse amplitude to return to baseline levels reflects a true physiologic process (possibly representing the presence of a sustained genital response), the relative scaling means that an increase of 10 mV over baseline in one condition is not necessarily equivalent to an increase of 10 mV over a second baseline in a later condition.

Signal acquisition and processing

Hardware and software

Laboratory equipment for the measurement of vaginal pulse amplitude is available from various manufacturers. No hardware brand is necessarily better than another for recording vaginal pulse amplitude, although selecting hardware that is already made to work with the vaginal photoplethysmograph may simplify laboratory setup. The more significant components to consider during hardware selection are amplifiers and any external filters. Many hardware components offer the option to adjust manually amplification and filter settings. In fact, some vaginal photoplethysmograph users adjust amplification for individual participants to equate better (visually, at least) the highly variable vaginal photoplethysmograph output between participants. Modern signal-processing software and greater data storage capacity make this practice outdated. The vaginal pulse amplitude signal is fairly easy to detect and requires little

amplification. In the past, experimenters amplified the vaginal pulse amplitude signal as much as 100 mV/cm,⁸ but amplification settings of 1 mV/cm are now common.⁷⁴ Researchers now also often oversample vaginal pulse amplitude purposefully and make filtering decisions post-acquisition.

Many laboratories currently use Biopac Systems' MP100 hardware and its accompanying software package, AcqKnowledge. AcqKnowledge has the advantage of a point-and-click environment and requires relatively little startup knowledge. The trade-off is that its analytic capabilities are limited, and the description of its existing functions sometimes lacks an appropriate level of detail. In contrast, a software program such as MatLab⁷⁵ has different strengths and weaknesses. Compared to AcqKnowledge, MatLab requires extensive startup knowledge and is more often used for data analysis than for data collection. Conversely, MatLab has a highly accessible, freely available, flexible code, offers extensive help, and can perform more advanced data manipulation and statistical analyses than AcqKnowledge.

Sampling

Sampling rates for the vaginal photoplethysmograph vary widely. Researchers often fail to report sampling rates, but published reports vary from 511 to 200 Hz.⁶⁵ Two factors determine the acceptable range of sampling rates for signal collection. First, the Nyquist frequency indicates the lowest sampling rate that will still capture the signal of interest. Second, available data storage capacity may suggest a reasonable upper sampling range.

The Nyquist theorem states that only the frequencies in the waveform below half of the sampling frequency are recorded in a digitized signal. The Nyquist frequency is therefore the highest frequency that can be represented in a digital signal of a specified sampling frequency, and it will determine the lowest reasonable sampling rate. Vaginal pulse amplitude is unlikely to exceed 3 Hz (180 bpm); thus, sampling at 6 Hz should capture the signal of interest. However, the inter-beat-interval of vaginal pulse amplitude does vary, and artifacts can also make the signal irregular, so recording at only 6 Hz, where artifacts may be less identifiable, is not recommended. The highest recommended sampling rate is truly limited only by the size of files for which storage is available. Often researchers will sample beyond the Nyquist frequency of their signal, which conservatively avoids aliasing and seems reasonable given the increased capacity of modern computers and storage devices.

Filtering and smoothing

The alternating current signal is usually band-pass filtered (0.5–30 Hz). The basis for the selection of these specific settings is unclear, aside from convention and avoiding 60-Hz light cycles. The sawtooth-shaped vaginal pulse amplitude signal generally peaks once for each heart beat. Heart rate variability during sexual arousal, then, could inform researchers which

frequency spectrum of the vaginal pulse amplitude signal would be most appropriate for analysis.

Resting heart rate is approximately 60 beats per minute (bpm) or about 1 cycle per second (Hz). Masters and Johnson¹⁴ reported increases in heart rate up to 175 bpm (during the "plateau" phase) and a slightly greater heart rate with orgasm. Laboratory studies typically record much lower heart rate levels, even to erotic films (e.g., maximum = 80 bpm⁴⁸), with often only a small increase in bpm to erotic films over resting heart rate.⁵ This suggests that the frequencies of the vaginal pulse amplitude that are of greatest interest to researchers might fall between 1 (60 bpm) and 2 (120 bpm) Hz. Indeed, using Fast Fourier Transform to extract the 1–2-Hz spectrum of interest from vaginal pulse amplitude yields very similar results to peak amplitude analyses.²⁵ Polan et al.⁷⁶ found similar results with a 0.7–1.2-Hz spectrum, which varied slightly between participants. Since the 0.7–1.2 Hz band varied by individuals based on a visual judgment of the Fast Fourier Transform power peak, this data-driven spectral band selection will require better standardization and replication before its value is understood.

Signals rarely contain only the frequency of interest. In addition to previously discussed movement artifacts, the vaginal pulse amplitude signal may also contain high- and low-frequency noise. High-frequency noise includes waves that occur above the frequency of interest. Visually, these are seen as small "jitter" on top of the 1–2-Hz vaginal pulse amplitude signal. High-frequency noise can be minimized during data acquisition by altering the alternating current band pass filter and selecting a lower high-band limit (e.g., 20 instead of 30 Hz). Alternatively, the signal can be smoothed or low-pass filtered after data collection. Smoothing and low-pass filtering can have the same effect, but are usually differentiated in software programs. The extensive literature on filters cannot be thoroughly reviewed (for an introduction, see Cunningham⁷⁷). The main consideration is that selecting filter parameters always involves a tradeoff between cutting undesired noise and biasing the signal of interest (e.g., vaginal pulse amplitude peaks decrease as one increases the filter window).

Low-frequency noise may also be decreased by increasing the low end of the band pass filter (e.g., from 0.05 to 0.08 Hz). High-pass filters also are useful. Researchers have speculated that low-frequency noise is related to breathing.¹ This proposition, however, lacks empirical support, and the slow waves' unpredictable appearance in parts of some signals suggests a different physiologic process. A gradual, steady rise in the signal suggests that the vaginal blood volume frequency band was not sufficiently filtered out, and detrending could be used to remove linear drift and improve the quality of the data.

Amplitude calculation

In the past, researchers calculated vaginal pulse amplitude peak amplitude by hand with a ruler (e.g., Wincze et al.⁷⁸). While this method encourages thorough screening of raw data, the reliability of this procedure is unknown. Computerized algorithms to

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remove artifacts and detect peaks standardize measurement and significantly reduce processing time. However, computerization is hampered by the high between-subject signal variability of the vaginal pulse amplitude, particularly with regard to artifacts and low-frequency noise. Wavelets may overcome this variability (for a relevant example of this method, see Browne and Cutmore⁷⁹). Researchers are encouraged to develop an algorithm to promote standardization across laboratories, but at the same time to evaluate critically the assumptions underlying the peak-detection algorithms used in their software packages (e.g., Prause and Janssen⁸⁰).

Binning

Most researchers report using relatively large (e.g., 30-s) intervals, or bins.²³ Averaging across (or using the maximum of) entire conditions is problematic because it prohibits the exploration of changes over time. In presenting participants with a composite stimulus, such as a video clip containing different sexual behaviors (e.g., 1 min of petting, 1 min of oral sex, and 1 min of sexual intercourse), stimulus intensity could be used as a within-participants factor when conducting statistical analyses. For the assessment of concordance between physiologic and subjective sexual arousal at a within-participants level, even smaller windows would be preferable (e.g., 10-s intervals). Smaller bins also permit examination of time-lagged correlations (cross-correlations). Large bins may obscure patterns over time. They also can make the identification of outliers more difficult and, even when they are identified, could cause additional data loss.

Analysis of vaginal pulse amplitude

While a few researchers use raw vaginal pulse amplitude data, the data are usually transformed before analysis. Transformations could include z-scores, percentage of "full" response, or difference scores. Z-score transformations may decrease between-subject variability, possibly by correcting for anatomic differences or variations in probe placement, but, currently, little empirical support exists for its assumed increased validity. Percentage scores are quite problematic because participants have to reach their maximum sexual response in the laboratory. Not only may this procedure increase volunteer bias and session time, but the likely variability in participants' subjective identification of a "maximum" response is problematic.

In repeated-measures designs, difference scores are most commonly used, but calculating these scores becomes problematic because participants' vaginal pulse amplitude often does not return to initial baseline levels. Using distraction tasks (e.g., counting backward from 1000) and lengthening the time between testing conditions may increase the likelihood of vaginal pulse amplitude returning to initial baseline levels; alas, our limited knowledge of vaginal physiology makes it difficult to say whether it is reasonable to expect a return even to initial

baseline level. At the very least, few criteria exist for deciding when return-to-baseline levels are "close enough" to the initial baseline. Usually, the initial baseline is used for calculation of difference scores unless the vaginal pulse amplitude does not decrease to initial baseline levels between subsequent testing conditions. In that case, researchers could calculate difference scores, using the baseline immediately preceding each testing condition, or use those baselines as covariates for the test condition following each.⁷

A repeated-measures analysis of (co)variance (AN(C)OVA) or multivariate analysis of (co)variance (MAN(C)OVA) is often used to test hypotheses statistically. Within-participants designs are standard given the relative nature of the vaginal pulse amplitude. An additional within-participants factor of bin (or interval) is sometimes added to examine patterns of change over time and also to increase statistical power.

Conclusion

The vaginal photoplethysmograph has proven to be a useful instrument in psychophysiological sex research, but its considerable limitations are not always taken into account. Perhaps the most pressing problem is that researchers know relatively little about precisely what physiologic processes the vaginal photoplethysmograph detects. This lack of knowledge means that vaginal pulse amplitude provides only a relative scale, which limits the conclusions that researchers can draw when comparing participants. Without a better theoretic understanding of vaginal physiology, the clinical utility of the vaginal photoplethysmograph will remain limited.

In addition to our limited understanding of what the vaginal photoplethysmograph measures, large differences in signal-processing procedures across laboratories are problematic as well. High interlaboratory variability in data processing hardly is unique to sexual psychophysiology (cf. Jennings et al.⁸¹), but methods for vaginal pulse amplitude processing are far less standardized than for signals in many other research areas. In particular, managing movement artifacts is potentially a significant source of variability in vaginal pulse amplitude processing. Publishing detailed descriptions of signal-processing procedures (e.g., the proportion of data deleted for artifacts) could increase standardization, and thereby comparability, of study findings.

The construct of sexual arousal is also still poorly understood and defined. This leaves researchers with limited understanding of the causes or determinants of concordance between physiologic and psychologic response components, as well as with problems in selecting the most appropriate measures of sexual arousal in both basic and clinical research.

Finally, potentially useful signal-processing and analysis advances (e.g., time series) are not well utilized. Fourier decomposition, lagged correlations, and wavelet-based signal-cleaning algorithms are all promising candidate techniques and warrant exploration in the analysis of vaginal pulse amplitude. New

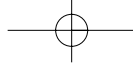
techniques may increase not only its reliability but also our understanding of what the signal represents.

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