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COMMENTARY

Conceptualizing Neural Responses to Sexual Stimuli

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In their Target Article, Ziogas et al. (2020) provided a comprehensive review of decades of studies on neuroelectric correlates related to human sexuality. As they highlighted, this literature is diverse with no systematic attempts to summarize the range of findings. The lack of integration of results to this point has limited the strength of conclusions that can be drawn and has left various research areas developing in silos. Ziogas et al. offered many insights and discussion points regarding limitations and directions for future inquiry. One limitation they noted throughout was the heterogeneity of stimuli used in past research. In this Commentary, I discuss the implications of this limitation on a conceptual level. In particular, I focus on the Cognition and Sexual Arousal section of the Ziogas et al. Target Article, which comprised the largest body of work reviewed on neuroelectric responses elicited by erotic stimulation (primary visual or auditory stimulation). Building on Ziogas et al.'s Target Article, I hope this discussion will motivate researchers to move forward in directions that will further elucidate fundamental processes involved in sexual response.

Ziogas et al. (2020) stated that their primary goal in reviewing literature on Cognition and Sexual Arousal was "to investigate how any form of erotic stimulation influenced electrical signals on the scalp and cognitive functions in healthy participants" (p. 15). Their meta-analysis showed robust effects where event-related potentials (ERPs) involved in attention ("P3" or "P300") and motivation ("late positive potential" [LPP]) were heightened to sexual stimuli. Yet, the choice to include a broad range of studies with respect to stimuli has significant implications for what can be concluded. I propose that, to have a greater impact on future directions in the field, the Target Article warranted further discussion of the conceptual implications of the diversity of stimuli in past studies. For example, based on the data reviewed, can we conclude that neural responses differentiating sexual and nonsexual stimuli are specific to processing sexual stimuli? And if not, how should we interpret heightened neural responses to sexual stimuli? This discussion would help clarify what can be concluded about the processing of sexual cues, per se, and in turn identify directions for future work.

Choice of Sexual Stimuli and Comparison Stimuli

The sexual stimuli of studies reviewed in Ziogas et al.'s (2020) Cognition and Sexual Arousal section were varied, as were the types of stimuli that responses were compared against. These included (but were not limited to): (1) erotic images of couples versus non-sexual emotional or neutral images; (2) images of faces (e.g., attractive versus unattractive, male versus female); and (3) images of bodies (e.g., nude versus clothed, male versus female). An initial question arises regarding what makes a sexual/erotic stimulus? For the purposes of this Commentary, a sexual cue is defined as the element/s of a stimulus that have the capacity to evoke sexual arousal or interest, as distinct from other cues that may also be conveyed in the stimulus.

As Ziogas et al. (2020) discussed, they treated images of faces and bodies as sexual because these can be used to infer physical attractiveness. At the same time, Ziogas et al. reviewed evidence that faces are associated with unique (non-sexual) processing, conveying social and interpersonal information—including information on gender, age, race—and are a cue that humans are experts at perceiving. Indeed, there is a large body of work suggesting that "faces are special" in terms of their place in the human brain (McKone & Robbins, 2011, p. 169), with some ERPs sensitive to processing faces and particularly eyes (e.g., Bentin et al., 1996; Itier et al., 2007; Itier & Taylor, 2004; Rossion et al., 1999). There is also evidence of unique processing of the human body,

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with dissociable regions of the extrastriate cortex involved in processing bodies, faces, or objects (Pitcher et al., 2009). Distinct ERPs have also been identified as sensitive to images of bodies versus faces (Thierry et al., 2006).

While Ziogas et al. (2020) discussed unique processing of faces and bodies as a limitation of their work, this point requires further attention. On a conceptual level, neural responses to faces or bodies—including erotic images of couples or individuals that contain these elements—involve processing of the sexual features of these stimuli (e.g., cues of physical attractiveness), as well as non-sexual processing inherent to these stimuli, as described above. Thus, ERPs that are heightened in response to sexual stimuli including faces and/or bodies could reflect a range of theoretically distinct cognitive processes, including but not limited to, sexual processing (i.e., processing of sexual information). On this point, some may note that in real-world settings, sexual stimuli typically do include faces and bodies, thus their processing may well be part of decoding and responding to sexual cues. I would agree with this, however, the sexual stimuli used thus far have not enabled distinguishing of neural processing related to detecting faces or bodies, versus detecting sexual features of those faces or bodies. I propose that there would be value of future work aimed at identifying ERPs that may be uniquely sensitive to processing sexual cues (i.e., cues with capacity to evoke sexual arousal or interest, as distinct from other cues conveyed in a stimulus). In so doing, future studies on neural responses to sexual stimuli—including those sexual stimuli that include faces and bodies—might assess ERPs with more sensitivity to sexuality. Within the scope of Ziogas et al.'s Target Article, a closer discussion of how the nature of sexual stimuli impacts interpretations of ERP responses could reveal novel research directions such as these.

In addition to considering the types of sexual stimuli used in past ERP studies, the stimuli that responses were compared against have implications for what can be concluded from heightened ERPs to sexual stimuli. In the studies Ziogas et al. (2020) reviewed, the sexual stimuli differed from comparison stimuli in ways beyond their inclusion of sexual cues. For example, neural responses to erotic images of couples were commonly compared with responses to non-sexual images conveying other emotional or neutral states. As Ziogas et al. acknowledged, "Instead of the sexual content, the observed effects on the P3 and the LPP could alternatively be explained with stimulus salience, as erotic stimuli could also be seen as more salient compared to other emotional and neutral stimuli" (p. 66). Beyond potentially differing in their salience, the sexual stimuli have differed from comparison stimuli in a range of cues such as novelty, taboo content, social interaction, activity level, or processing of faces and bodies. From a cognitive neuroscience perspective, it is recommended to compare conditions that are subtly different, in order to ideally isolate a single ERP component (or few components) involved in the processing of interest (Luck, 2014). Although a range of processes would be expected to be elicited in response to sexual stimuli, the complexity of sexual stimuli presented and their level of distinction from comparison stimuli in past ERP studies has limited knowledge of neural processes that may be uniquely sensitive to detecting sexual cues.

Responses to Sexual Stimuli vs. Sexual Processing

A central point to this discussion is that responses to sexual stimuli encompass a range of cognitive processes, some being specific to the processing of sexual information, and some being related to non-sexual information that is processed together with sexual cues. Ziogas et al. (2020) allude to this point in noting that results are limited by the heterogeneity of stimuli; however, the conceptual implications of this limitation are not clearly articulated. With their broad approach in examining neural responses to "any form of erotic stimulation" (p. 15), Ziogas et al. found robust effects for P3 and LPP being heightened to sexual stimuli. Large bodies of work have shown these ERPs to be sensitive to emotional stimuli and to involve processes of attention (P3; Luck & Kappenman, 2012; Polich, 2007) and motivation (LPP; Luck & Kappenman, 2012; Olofsson et al., 2008; Schupp et al., 2004). These findings fit with models of sexual response, which outline essential roles of attention and motivation in sexual processing and response (e.g., Janssen et al., 2000; Toates, 2009). However, these reflect fairly global cognitive processes, and future work may be able to use electroencephalography (EEG) to provide even more novel insights into the processes involved in decoding sexual cues.

One of EEG's greatest strengths is its high temporal resolution, which allows for the identification of components of brain electrical activity linked with distinct aspects of stimulus processing. By simplifying the choice of sexual stimuli in future work and presenting comparison stimuli that differ more specifically in the presence or absence of a sexual cue, it may be possible to isolate ERP component/s involved in processing sexual cues in particular. This could mean isolating brain activation associated with detecting "sexualness", as separate from attentional and motivational processes. I do not suggest that processes of attention and motivation are not important aspects of sexual response. Rather, I note that there may be other, distinct neural processes associated with decoding sexual cues that have yet to be identified, and which the EEG methodology is uniquely positioned to explore.

In line with these ideas, a group of neuroimaging researchers presented images of sexually aroused genitals, noting benefits of simplified sexual stimuli to minimize factors

that could confound brain activation related to processing of non-sexual information (e.g., faces, gestures, social information; Ponseti et al., 2006). Although images of genitals do not reflect the full extent of a sexual stimulus in the real world, there is evidence that men and women have heightened genital and subjective sexual responses to images of sexually aroused/exposed genitals compared to genitals in a non-sexually prepared state, suggesting these stimuli do elicit sexual processes and responses (Spape et al., 2014; Timmers et al., 2021). My colleagues and I have begun examining ERP responses to these types of stimuli, finding that P3 and LPP were heightened to images of sexually aroused genitals, but not particularly heightened to those in line with the viewer's sexual attractions (e.g., heterosexual men's P3 and LPP amplitudes were not greater to exposed vulvas than erect penises; Huberman, 2020; Huberman et al., 2020). We also identified some novel ERPs and seemingly distinct cognitive processes that were heightened to sexually aroused genitals, such as the N270-400, which may reflect decoding others' mental states (Huberman, 2020; Huberman et al., 2020; Sabbagh et al., 2004). Thus, by focusing more closely in future research on neural responses associated with processing sexual cues, new insights may be made regarding cognitive processes involved in sexual response.

As another example of a simplified sexual stimulus, a recent series of studies found that variation of a woman's facial expression affected whether the face was processed as a sexual cue (i.e., a cue to sexual interest; Haj-Mohamadi et al., 2021). Investigating ERP responses to faces varying in the presence of such a sexual cue, or other specific sexual cues (e.g., faces registering orgasm; courtship cues such as raised eyebrows/lowered heads), could reveal neural responses associated with processing specifically sexual information. These examples are provided to highlight how further discussion by Ziogas et al. (2020) on implications of stimuli could help generate exciting new directions for research on neural correlates of sexuality.

The identification of neural responses uniquely associated with processing sexual cues could have widespread impacts on the field of sexuality. At a basic level, this would refine models of sexual response by elucidating early stages of processing sexual cues. As a researcher deeply interested in the sexual response process myself, I see this work as fundamental to our understanding of human sexuality and potentially sexual response. In terms of clinical implications, a greater understanding of ERPs involved in sexual processing could allow greater sensitivity for research aimed at studying group-level differences in sexuality. Ziogas et al. (2020) described inconsistent results with respect to neuroelectric responses differentiating individuals with, and without, paraphilic sexual interests, or individuals who have or have not committed sexual offences. With more specific knowledge of ERPs involved in detection of sexual cues, it is possible that more consistent effects could be observed. Similarly, this work could enhance research aimed at understanding sexual orientation or sexual dysfunction by identifying neural responses that may be specific to the processing of sexual information. In sum, rather than testing between-group differences at ERPs involved in global processes such as attention and motivation, it may be possible to examine differences focused on processing of sexual cues, which could have greater sensitivity in meaningfully distinguishing groups.

Conclusions

Ziogas et al. (2020) presented a comprehensive review of neuroelectric correlates of sexuality, summarizing a wide range of findings that have accrued over many years. Their review is timely and essential for consolidating what is known and paving the way for future research aimed at advancing knowledge of foundational processes in human sexuality. As discussed in this Commentary, the heterogenous sexual stimuli and comparison stimuli in the studies reviewed have implications for what can be concluded on a conceptual level, regarding heightened ERPs to sexual stimuli. I propose that by further discussing these implications, Ziogas et al.'s Target Article would have a greater impact in shaping developing research in this field. This would distinguish neural responses to sexual stimuli from neural responses that may be specific to processing sexual cues, thus stimulating novel directions for research on fundamental sexual processes.

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Declarations

Conflict of interest The author declares that she has no conflict of interest.

References

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8*, 551–565. https://doi.org/10.1162/jocn.1996.8.6.551.

Haj-Mohamadi, P., Gillath, O., & Rosenberg, E. L. (2021). Identifying a facial expression of flirtation and its effect on men. *Journal of Sex Research, 58*, 137–145. https://doi.org/10.1080/00224499.2020.1805583.

Huberman, J. S. (2020). *Neural correlates of sexual response: An ERP investigation of responses to de-contextualized sexual cues*. Doctoral thesis, Queen's University. QSpace.

Huberman, J. S., Mangardich, H., Sabbagh, M. A., & Chivers, M. L. (2020). *Ready for action: An ERP signal for detecting sexual readiness*. Canadian Sex Research Forum.

Itier, R. J., Alain, C., Sedore, K., & McIntosh, A. R. (2007). Early face processing specificity: It's in the eyes! *Journal of Cognitive Neuroscience, 19*, 1815–1826. https://doi.org/10.1162/jocn.2007.19.11.1815.

Itier, R. J., & Taylor, M. J. (2004). N170 or N1? Spatiotemporal differences between object and face processing using ERPs. *Cerebral Cortex, 14*, 132–142. https://doi.org/10.1093/cercor/bhg111.

Janssen, E., Everaerd, W., Spiering, M., & Janssen, J. (2000). Automatic processes and the appraisal of sexual stimuli: Toward an information processing model of sexual arousal. *Journal of Sex Research, 37*, 8–23. https://doi.org/10.1080/00224490009552016.

Luck, S. J. (2014). *An introduction to the event-related potential technique*. Massachusetts Institute of Technology.

Luck, S. J., & Kappenman, E. S. (Eds.). (2012). *The Oxford handbook of event-related potential components*. Oxford University Press.

McKone, E., & Robbins, R. (2011). Are faces special? In A. J. Calder, G. Rhodes, J. V. Haxby, & M. H. Johnson (Eds.), *Oxford handbook of face perception* (pp. 149–176). Oxford University Press.

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77*, 247–265. https://doi.org/10.1016/j.biopsycho.2007.11.006.

Pitcher, D., Charles, L., Devlin, J. T., Walsh, V., & Duchaine, B. (2009). Triple dissociation of faces, bodies, and objects in extrastriate cortex. *Current Biology, 19*, 319–324. https://doi.org/10.1016/j.cub.2009.01.007.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*, 2128–2148. https://doi.org/10.1016/j.clinph.2007.04.019.

Ponseti, J., Bosinski, H. A., Wolff, S., Peller, M., Jansen, O., Mehdorn, H. M., Büchel, C., & Siebner, H. R. (2006). A functional endophenotype for sexual orientation in humans. *NeuroImage, 33*, 825–833. https://doi.org/10.1016/j.neuroimage.2006.08.002.

Rossion, B., Delvenne, J. F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., & Guérit, J. M. (1999). Spatio-temporal localization of the face inversion effect: An event-related potentials study. *Biological Psychology, 50*, 173–189. https://doi.org/10.1016/S0301-0511(99)00013-7.

Sabbagh, M. A., Moulson, M. C., & Harkness, K. L. (2004). Neural correlates of mental state decoding in human adults: An event-related potential study. *Journal of Cognitive Neuroscience, 16*, 415–426. https://doi.org/10.1162/089892904322926755.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Hillman, C. H., Hamm, A. O., & Lang, P. J. (2004). Brain processes in emotional perception: Motivated attention. *Cognition and Emotion, 18*, 593–611. https://doi.org/10.1080/02699930341000239.

Spape, J., Timmers, A. D., Yoon, S., Ponseti, J., & Chivers, M. L. (2014). Gender-specific genital and subjective sexual arousal to prepotent sexual features in heterosexual women and men. *Biological Psychology, 102*, 1–9. https://doi.org/10.1016/j.biopsycho.2014.07.008.

Thierry, G., Pegna, A. J., Dodds, C., Roberts, M., Basan, S., & Downing, P. (2006). An event-related potential component sensitive to images of the human body. *NeuroImage, 32*, 871–879. https://doi.org/10.1016/j.neuroimage.2006.03.060.

Timmers, A. D., Micanovic, N., & Chivers, M. L. (2021). *Specificity of sexual response among nonheterosexual women and men to prepotent sexual cues*. Manuscript under review.

Toates, F. (2009). An integrative theoretical framework for understanding sexual motivation, arousal, and behavior. *Journal of Sex Research, 46*, 168–193. https://doi.org/10.1080/00224490902747768.

Ziogas, A., Habermeyer, E., Santtila, P., Poeppl, T. B., & Mokros, A. (2020). Neuroelectric correlates of human sexuality: A review and meta-analysis. *Archives of Sexual Behavior*. https://doi.org/10.1007/s10508-019-01547-3.