Journal Club

Editor's Note: These short, critical reviews of recent papers in the *Journal*, written exclusively by graduate students or postdoctoral fellows, are intended to summarize the important findings of the paper and provide additional insight and commentary. For more information on the format and purpose of the Journal Club, please see http://www.jneurosci.org/misc/ifa_features.shtml.

The Role of Flexibility in Personal Space Preferences

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Review of Holt et al.

Personal space is generally defined as the area individuals maintain around themselves into which others cannot intrude without arousing discomfort (Hayduk, 1983). It is a dynamic perception that plays an important role in social communication and behavior across species (Hayduk, 1983; Graziano and Cooke, 2006). Social crowding, or the presence of high population density, is related to personal space in that it reduces the area available for individuals to maintain without intrusion. There is evidence that social crowding produces both behavioral and physiological changes in rodents (Grippo et al., 2010) and nonhuman primates (Judge and De waal, 1997). In humans, personal space has been demonstrated to be important in pathogen avoidance (Peng et al., 2013), social dominance and hierarchies (Aono, 1981), and social attachment (Kaitz et al., 2004). Because awareness of personal space appears to play an integral role in a wide range of behaviors across species, a better understanding of its malleability across different contexts can expand our understanding of behavior in many realms.

The neural mechanisms underlying the dynamic regulation of personal space remain poorly understood. Research in nonhuman primates has provided evidence that attention to near space is represented in the ventral intraparietal area and a polysensory zone in the precentral gyrus (Graziano and Cooke, 2006). Similarly, evidence from humans suggests a representation of near space in parietal and frontal areas, including the intraparietal sulcus, inferior parietal lobe, and parts of the premotor cortex (for review, see Brozzoli et al., 2014). However, this literature primarily focuses on the presence of a stationary object within near surrounding space and does not address movement of objects within that space, or more importantly, the monitoring of an approaching object versus a withdrawing object. Additionally, previous studies have not answered the question of whether specific areas respond to personal space intrusion by conspecifics versus objects. Holt et al. (2014) extend this literature, finding that the dorsal intraparietal sulcus and ventral premotor cortex demonstrate greater responses to approaching faces than to withdrawing faces. However, when contrasting approaching cars to withdrawing cars and approaching spheres to withdrawing spheres, Holt et al. (2014) found no evidence for differential activity in these areas. Additionally, they found that participants' personal space size, measured behaviorally outside of the scanner environment, significantly negatively correlated with coupling between these two areas, suggesting a link between areas that respond to virtual approach in the scanner environment and individual differences in personal space preferences.

Holt et al., 2014 used both an out-of-scanner behavioral task (Stop Distance Paradigm) that measures individual differences in personal space preferences involving actual intrusion of space by a conspecific and a within-scanner virtual task designed to stimulate personal space intrusion through the apparent approach or withdrawal of a conspecific's face or inanimate objects. The Stop Distance Paradigm provides measures of personal space size, which refers to the moment the subject expresses that he/she feels "slightly uncomfortable," and personal space permeability, or the subject's ability to tolerate personal space intrusion, measured as the ratio of when the subject says he/she feels "slightly uncomfortable" and to when he/she feels "very uncomfortable" (Holt et al., 2014). Holt et al. (2014) compared the behavioral data from the Stop Distance Paradigm with the neural data during the virtual approach withdrawal task, finding a positive correlation between personal space size and connectivity between the dorsal intraparietal sulcus and ventral premotor cortex activity during virtual approach and a negative correlation between personal space permeability and connectivity. However, while the Stop Distance Paradigm involves active indication by the participant of when they feel uncomfortable with intrusions into their space, the virtual paradigm is a passive task where participants view approaching and withdrawing faces or objects. This makes it difficult to relate the data from the virtual task to the behavioral paradigm to determine whether the virtual task is indeed acting as a personal space intrusion rather than just approach or withdrawal. We suggest that future

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studies adapt Holt et al.'s (2014) methods by modifying the fMRI task such that participants are required to indicate the point at which they become uncomfortable during virtual approach and withdrawal to determine how this task corresponds to the results of the Stop Distance Paradigm. Comparing personal space preferences in this task with preferences in the Stop Distance Paradigm would allow one to substantiate that virtual and behavioral interpretations of personal space intrusion are indeed measuring similar constructs and to support the claim that the observed differences in neural activity are actually a result of monitoring personal space as opposed to just getting bigger and smaller or approaching and withdrawing. Previously, tasks designed to evaluate personal space through use of projective measures without interpersonal interaction have been criticized for limited construct validity and reliability (Hayduk, 1983). Repurposing Holt et al.'s (2014) fMRI task as a measure of personal space has the potential to provide researchers with a new tool to extend behavioral studies of personal space to a virtual environment.

The findings by Holt et al. (2014) advance knowledge of individual representations of personal space and provide a foundation for future studies examining the degree to which these representations are flexible and the factors influencing their fluctuations. There are several ways in which future work can build upon these insights. Integrating other physiological measures along with fMRI can bolster our understanding of how humans experience personal space intrusion. There is evidence of significant change in autonomic nervous system activity occurring in response to intrusions of personal space. Specifically, women approached by a male stranger have demonstrated significant changes in heart rate (Sawada, 2003) and individuals approached by an android robot have demonstrated significant increases in skin conductance responses (Tanaka et al., 2013). In the context of Holt et al.'s (2014) paradigm, these measures could be incorporated in both the behavioral measurement of individual personal space preferences during naturalistic responses to the approach of a conspecific and in the fMRI environment examining changes in response to virtual approach and withdrawal. These physiological responses likely relate to changes in neural activity during approach and withdrawal as well.

The dynamic nature of personal space preference is further emphasized in research highlighting individual differences that fluctuate based on social signaling factors such as race, group relatedness, gender, emotionality, disgust, experience with abuse, and attractiveness. For example, individuals approach their close friends to a nearer proximity than more distant friends or acquaintances, demonstrating variation in personal space preference based on closeness of the relationship (however, this is only true for females; males do not vary personal space based on the closeness of their relationships) (Sundstrom and Altman, 1976). In general, people have larger personal space preferences for space in front of them than behind them. However, veterans with posttraumatic stress disorder prefer overall larger interpersonal distances and have the greatest interpersonal distance when approached from behind (Bogovic et al., 2013). Additionally, early experiences can contribute to differences in personal space preference, as children who have experienced abuse have larger personal space preferences than their nonabused peers (Vranic, 2003). Differences in personal space have also been observed between children depending on attachment styles (Kaitz et al., 2004). This work suggests that personal space is not stable, but malleable and dynamic, affected by previous experiences and partially determined by context. As the intricacies of personal space flexibility have yet to be fully identified, future work will benefit from examining the many factors that influence personal space representations and extending these findings to the fMRI environment to better understand how neural networks involved in personal space representations allow for this flexibility.

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