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Oxytocin and the altruistic “Goldilocks Zone”

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Abstract

When choosing whether to act altruistically, people may compare the current option to an idiosyncratic ideal. Pro-social individuals seem to represent deviations from that ideal in the amygdala, but selfish individuals do not. Oxytocin administration makes selfish individuals look more like pro-socials, behaviorally and neurally.

Imagine that you and a friend receive a windfall inheritance from a rich acquaintance (lucky you!). The deceased was a bit peculiar, and made a very specific bequest. Of \$10,000, you get \$5,532, and your friend gets \$4,468. How would you feel? What if instead you received \$9,999, and your friend got only \$1? Or your friend got \$9,999 and you got \$1? \$5000 and \$5000? If you felt best about that first option, you wouldn't be alone. It's just a bit better for you, but not so much so that you feel too guilty to enjoy it. In other words, it's hit the “Goldilocks Zone” for balancing what you'd like for yourself and what you'd want for your friend. Of course, not everyone would feel the same way. Some would be much happier with \$9,999 for themselves. What explains such stark individual differences? New research from Liu et al.¹ suggests that the amygdala, a region of the brain important for emotion and arousal², might be key. In people who are relatively pro-social, but not in people who are relatively selfish, this area codes outcomes in reference to that “Goldilocks Zone” split. Moreover, administering oxytocin, a neuropeptide widely thought to be important for social bonding, moves the “Goldilocks Zone” for selfish individuals closer to prosocials, and amps up the amygdala response when proposed outcomes deviate from it. This research has important implications for a number of important outstanding questions about human sociality.

In the experiments, people rated how much they liked different proposed distributions of money to themselves and their assigned partner. To capture the pattern of preferences, the authors propose a model in which people calculate a ratio of their partner's outcomes to their own, and are sensitive to the difference between this ratio and an “ideal” or reference ratio. Importantly, Liu and colleagues also find that individuals vary widely in what that ideal ratio is. For someone generous, it might be close to 1:1, while for someone selfish, it might be skewed 5:1 or even 500:1 in favor of the self. They succinctly describe this ratio as the angle ϕ of a line drawn from the origin to the point representing the ideal combination of self and other. Deviations from ϕ reduced liking for an outcome. Remarkably, this “reference point” account provided a more parsimonious fit to the data than many other popular accounts of altruistic choice, including models based on inequality³.

The impact of reference points on choice has a long history of study⁴. In the social domain, researchers often assume that reference dependence is expressed as a concern for equality: outcomes for one party in reference to the other should be the same, and deviations from inequality are disliked. Importantly, inequality can be computed objectively as the difference in outcomes for self and other. Liu et al. give a new perspective by arguing that social preferences about resource distributions may also be processed in relation to *subjectively* defined reference points. The deviation from that reference point was represented neurally across multiple structures, including the posterior cingulate cortex (PCC) and the middle frontal gyrus, regions recently associated with context-sensitive representations of others⁵ and moral preferences⁶.

However, other brain regions encoding deviations from this reference point depended on whether people tend towards selfish or prosocial choices. In *individualists* (who favored distributions skewed to the self), deviations from the reference were more strongly represented in lateral orbitofrontal cortex (IOFC). In prosocials (who favored more equal ratios) these deviations appeared more strongly in the amygdala. The researchers also found that in prosocials, trial-by-trial fluctuations in amygdala response were associated with decreases in liking, even after controlling for model predictions. Moreover, the amygdala was functionally connected with an area of the ventromedial prefrontal cortex (vmPFC) thought to be important in constructing preferences. This suggests that the amygdala provides an important altruism-promoting input to the valuation process.

Liu and colleagues then went a step further. Some research suggests that individual differences in prosocial disposition result in part from differences in the action of the neuropeptide oxytocin (OT) and its receptor expression in the amygdala⁷. The authors thus hypothesized that administering OT might shift individualists' ideal reference point. Remarkably, this was exactly what they found. In the between-subjects fMRI study and then again in a larger, within-subjects replication study, OT shifted the reference points of *a priori* individualists towards more equitable monetary divisions, but had no effect on prosocials (Fig. 1). The same pattern was observed in a modified version of the task that evoked competitive motives. Moreover, OT increased individualists' amygdala representations of reference point deviance and functional connectivity with the vmPFC.

These striking results expand our understanding of how contextual and dispositional factors can modulate the behavioral effects of OT administration⁸. Previous findings regarding OT's effect on social behavior have been decidedly mixed, and the literature has been the target of deeply-worrying statistical⁹ and physiological¹⁰ criticisms. Liu and colleagues' work features larger-than-typical sample sizes and includes a separate well-powered replication experiment. This adds considerably to the strength of their conclusions. Thus, the work by Liu and colleagues exemplifies how concerns over the replicability of OT results should be met. Of course, questions of *how* exactly intranasal OT influences choice remain, and the results pose several interesting questions for how social preferences are expressed during decision-making.

For example, this new "social referencing" model suggests that choices arise from a comparison process that evaluates potential outcomes relative to a *ratio* of self and other

outcomes rather than their absolute magnitude. This suggests that the size of outcomes may be less consequential than their relative distribution. Individuals may similarly like receiving \$3 while their partner receives \$2 and receiving \$6 when their partner receives \$4. This also makes the counterintuitive prediction that people may sometimes prefer that both parties receive less money, as long as the ratio is more even. Future work will need to more directly test the idea that social preferences are scale-independent.

These results also raise important questions about how to conceptualize the amygdala's computational role in prosocial decision making. This area is strongly implicated in the production of emotional, autonomic and visceral responses, and prior work also points to its importance in prosocial choice¹¹. The current findings conceptualize it as a type of comparator that, in conjunction with the vmPFC, integrates multiple factors relative to a holistic social reference point. Such a role is consistent with research suggesting that the amygdala influences attentional deployment after unexpected events¹², which here might be represented by deviations from a social reference.

Considering the influence of OT raises more intriguing possibilities. Some theories¹³ argue that OT attenuates the precision or salience of interoceptive signals, permitting attention to turn outward, away from the self. This outward deployment of attention then enables incoming social signals to be incorporated into predictions about desired outcomes. In the studies presented here, OT may have attenuated interoceptive signals in individualists that otherwise lead to an overly self-focused reference point. Shifting reference point "predictions" from egocentric to more egalitarian appears to also alter brain regions that encode deviations--from IOFC to amygdala, respectively. This raises the intriguing possibility that a more prosocial reference might be a default¹⁴ that is released when interoceptive inputs to the IOFC are attenuated. While obviously speculative, future studies measuring physiological arousal and linking those responses to choice could test such hypotheses and provide support for the social predictive coding interpretation suggested by Liu and colleagues.

Future work should also be targeted at integrating these findings with previous results. For example, whereas OT increased the prosociality of individualists in the current study, it has decreased trusting behavior in people with borderline personality disorder¹⁵. This suggests that a fruitful avenue for exploration might be to compare social references points and effects of oxytocin in individualists and people with borderline personality disorder, as well as other disorders that have sometimes been tied to oxytocin, such as autism¹³.

A final key set of questions concerns *how* the amygdala computes social reference signals, which require considerations of self and other to construct. Previous work suggests that computations related to these quantities may be partially dissociable, with others' outcomes represented in the temporoparietal junction and PCC/precuneus⁵. Is there a functional connection between these regions and the amygdala? Does this connection depend on OT? Future research answering these questions would provide a clearer map of the different computations carried out by different components of a distributed brain network during prosocial choice.

How people make social decisions, and what produces changes in prosocial behavior, has occupied philosophers, economists and psychologists for decades. More recently, interest has also grown in understanding how the brain is implicated in these complex social decisions. Liu and colleagues' work points to the important idea that people's social behavior depends on their reference point, which can be manipulated by oxytocin. In making this case, we suspect their work will itself serve as a reference point in the field of social neuroscience.

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Fig. 1.

Participants rated various possible monetary divisions between themselves and a partner. Liu and colleagues calculated each participant's reference point based on these ratings. On placebo, prosocials exhibited a reference point that was closer to equality while individualists had a more selfish reference point. The degree to which each proposal deviated from a given person's reference point was encoded in amygdala, among prosocials, or lateral OFC, among individualists. On OT, the reference points of individualists became more like those of the prosocials and the amygdala encoded deviations from this shifted reference point.