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Abstract

Despite acknowledging that musicality evolved to serve multiple adaptive functions in human evolution, Savage et al. promote social bonding to an overarching super-function. Yet, no unifying neurobiological framework is offered. We propose that oxytocin constitutes a socio-allostatic agent whose modulation of sensing, learning, prediction, and behavioral responses with reference to the physical and social environment facilitates music's social bonding effects.

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Oxytocin as an allostatic agent in the social bonding effects of music

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Despite acknowledging that musicality evolved to serve multiple adaptive functions in human evolution, Savage et al. promote social bonding to an overarching super-function. Yet, no unifying neurobiological framework is offered. We propose that oxytocin constitutes a socio-allostatic agent whose modulation of sensing, learning, prediction, and behavioral responses with reference to the physical and social environment facilitates music's social bonding effects.

Both target articles acknowledge that human musicality evolved to serve more than one adaptive function. Although Mehr et al. (2020) exalt credible signaling to a unitary mechanism, they eventually promote two ultimate-level explanations in terms of credible signaling of coalition strength and parental attention, manifesting in divergent forms of music (i.e., loud drumming/chanting vs. lullabies). In this way, one of their arguments opposing Savage et al.'s (2020) *Music and Social Bonding* (MSB) hypothesis—namely that (some types of) musics are poorly designed to coordinate groups—can be turned against themselves in that lullabies are poorly designed to signal coalition strength and war chants are poorly designed to signal parental attention. This functional multiplicity leads Savage and colleagues to search for an overarching super-function through synthesis and extension of previous proposals.

Savage et al.'s MSB account is convincing in many aspects. Yet, their overview of candidate neurobiological mechanisms exposes the somewhat rudimentary state of research in this area. For example, their Figure 3 treats the oxytocinergic and endogenous opioid systems under the same

umbrella despite comprising distinct—albeit interconnected (Kovatsi & Nikolaou, 2019)—systems. In light of oxytocin's well-established role in social learning and memory (Chini et al., 2014), direct links of oxytocin to learning/knowledge (e.g., through laryngeal motor cortex, ventral tegmental area, or Broca's area; Theofanopoulou et al., 2017) could also be considered in addition to indirect links via the dopaminergic system (Baskerville & Douglas, 2010; Love, 2014). While the detailed interactions of these three systems lies beyond the scope of a brief commentary, it suffices to say that the overarching super-function envisioned by the target authors indeed requires a unifying neurobiological framework.

Given its manifold roles in a multitude of peripheral and central nervous processes with direct relevance for the proposed adaptive functions of music (as depicted in Fig. 1), we suggest that the nonapeptide oxytocin may contribute crucially to such a unifying neurobiological framework. Specifically, oxytocin-mediated increases in generosity (Zak et al., 2007), emotional face recognition (Shahrestani et al., 2013), and (potentially) trust (Kosfeld et al., 2005; but see Declerck et al., 2020) may increase music's effects on group cohesion resulting in social coping benefits. Changes in eye gaze (Eckstein et al., 2019), selective sociality (Carter, 2017), and sexual arousal and orgasm (Alley & Diamond, 2020) mediated by oxytocin may enhance musical effects on courtship behavior and exclusionary pair formation. Oxytocin-mediated empathy (Wu et al., 2012), playful behavior (Szymanska et al., 2017), and peripheral effects on parturition and lactation (Carter, 2014) could underlie musical infant-caregiver bonding. Moreover, oxytocin-related increases in synchrony (Gebauer et al., 2016; Josef et al., 2019) along with

out-group gloating (Shamay-Tsoory et al., 2009), derogation (De Dreu et al., 2011), and threat perception (Egito et al., 2020) may promote competitive musical coalition signaling. Oxytocin’s analgesic (González-Hernández et al., 2014) and anxiolytic (Lancaster et al., 2018) effects may, in turn, enhance music’s facilitation of coordinated

physical labor. Finally, oxytocin-enhanced social learning and memory (Graustella & MacLeod, 2012) could increase music’s capacity for preserving civilizational knowledge and forming shared cultural identities.

Figure 1. Overview of how the socio-allostatic effects of oxytocin may contribute to a unifying neurobiological framework for music’s adaptive functions. Specifically, music making—which often occurs in social contexts—may lead to oxytocin release that promotes internal adjustment of sensing and response set-points as well as assists learning and prediction processes with reference to the external physical and social environment. These allostatic optimizations may, in turn, increase the efficacy of music’s adaptive functions as a facilitator of social cohesion, pair formation, parental bonding, coalition signaling, group coordination, and preservation of communal knowledge and identity. These adaptive functions of music are each associated with specific musical forms employing distinct acoustic features. Such function-to-form associations are, however, statistical (rather than deterministic) as well as highly interconnected in that dance, for example, can contribute to multiple adaptive functions such as cohesion, courtship, coalition, and coordination, depending on the context in which it appears.

Importantly, the two target theories propose opposite causal relationships between oxytocin and musical synchronization. Whereas MSB predicts that joint music making would increase oxytocin levels, the credible signaling theory predicts that higher oxytocin levels achieved through pre-existing social cohesion would increase musical synchronization. Burgeoning evidence for both of these effects (*former*: Grape et al., 2002; Keeler et al., 2015; *latter*: Gebauer et al., 2016; Josef et al., 2019) suggests that both hypotheses may ultimately be viable. Yet, findings are sometimes contradictory (e.g., Schladt et al., 2017), sample sizes are typically low (Walum et al., 2016), and intranasal administration and salivary assays of oxytocin have faced methodological criticisms (Leng & Ludwig, 2016; McCullough et al., 2013). Theorizing, therefore, converges on oxytocin effects being highly individualistic/context-dependent (Bartz et al., 2011) and modulatory/interactive rather than primary (Marsh et al., 2020).

Consistent with this view, an allostatic theory of oxytocin has recently gained traction (Quintana & Guastella, 2020). This theory posits that oxytocin facilitates the adjustment of sensing and response set-points and assists learning and prediction in ways that proactively optimize systemic adaptation with reference to a constantly changing environment. The resulting criticality in brain states and behavioral flexibility are beneficial under many circumstances—but perhaps especially so in complex social interactions like music and dance where ongoing anticipation of environmental consequences is essential (D’Ausilio et al., 2015). Beyond the individual level, oxytocin’s allostatic effects may further extend to social allostasis in that behavioral flexibility can resolve vicious circles of rigid interaction patterns and inflexible group dynamics (Saxbe et al., 2020; Schulkin, 2011). A socio-allostatic view of oxytocin, moreover, connects well with intellectual currents such as enactive cognition and biocultural evolution where biological and cultural dimensions constitute factors

in the same evolving system of living agents embedded in an environment (van der Schyff & Schiavio, 2017).

Savage et al. (2020) propose that music and musicality coevolved through an iterated Baldwin process whereby musical behaviors were culturally invented to tackle the environmental challenges of social living which gradually manifested as adaptive musicality traits (Podlipniak, 2017). The neurochemical feedback loop depicted in Fig. 1 is consistent with such a process of gene-culture coevolution in that genetic mutations leading to tighter connections between music making and oxytocin release would accelerate the extent to which the adaptive functions of music can capitalize upon oxytocin-mediated sensing, learning, prediction, and response processes. The proposed feedback mechanism whereby oxytocin in itself stimulates more oxytocin release (Grippio et al., 2012) may further accelerate this process.

When oxytocin-mediated sensing, learning, prediction, and response capacities are sharpened in the encounter with the in-group, phenomena like social cohesion arise, which in turn promote coordinated labor as well as civilizational mnemonics and identity formation (Fig. 1). When faced with an out-group, heightened social allostasis may manifest in coalition signaling. Finally, when presented with offspring or potential mates, infant-caregiver bonding and dyadic courtship result, respectively. These effects could be mediated by the manifold empirically substantiated effects of oxytocin on human behavior summarized above.

Conflicts of interest

None.

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References

Alley, J. C., & Diamond, L. M. (2020). Oxytocin and human sexuality: recent developments. *Current Sexual Health Reports*, 12, 182–185. doi:10.1007/s11930-020-00274-4

Bartz, J. A., Zaki, J., Bolger, N., & Ochsner, K. N. (2011). Social effects of oxytocin in humans: context and person

matter. *Trends in Cognitive Sciences*, 15(7), 301–309. doi:10.1016/j.tics.2011.05.002

Baskerville, T. A., & Douglas, A. J. (2010). Dopamine and oxytocin interactions underlying behaviors: potential contributions to behavioral disorders. *CNS Neuroscience & Therapeutics*, 16(3), e92–e123. doi: 10.1111/j.1755-5949.2010.00154.x

Carter, C. S. (2014). Oxytocin pathways and the evolution of human behavior. *Annual Review of Psychology*, 65, 17–39. doi:10.1146/annurev-psych-010213-115110

Carter, C. S. (2017). The role of oxytocin and vasopressin in attachment. *Psychodynamic Psychiatry*, 45(4), 499–517. doi:10.1521/pdps.2017.45.4.499

Chini, B., Leonzino, M., Braidà, D., & Sala, M. (2014). Learning about oxytocin: pharmacologic and behavioral issues. *Biological Psychiatry*, 76(5), 360–366. doi:10.1016/j.biopsych.2013.08.029

D'Ausilio, A., Novembre, G., Fadiga, L., & Keller, P. E. (2015). What can music tell us about social interaction? *Trends in Cognitive Sciences*, 19(3), 111–114. doi:10.1016/j.tics.2015.01.005

Declerck, C. H., Boone, C., Pauwels, L., Vogt, B., & Fehr, E. (2020). A registered replication study on oxytocin and trust. *Nature Human Behaviour*, 4, 646–655. doi:10.1038/s41562-020-0878-x

De Dreu, C. K., Greer, L. L., Van Kleef, G. A., Shalvi, S., & Handgraaf, M. J. (2011). Oxytocin promotes human ethnocentrism. *Proceedings of the National Academy of Sciences*, 108(4), 1262–1266. doi:10.1073/pnas.1015316108

Eckstein, M., Bamert, V., Stephens, S., Wallen, K., Young, L. J., Ehlert, U., & Ditzen, B. (2019). Oxytocin increases eye-gaze towards novel social and non-social stimuli. *Social Neuroscience*, 14(5), 594–607. doi:10.1080/17470919.2018.1542341

Egito, J. H., Nevat, M., Shamay-Tsoory, S. G., & Osório, A. A. C. (2020). Oxytocin increases the social salience of the outgroup in potential threat contexts. *Hormones and Behavior*, 122, 104733. doi:10.1016/j.yhbeh.2020.104733

Gebauer, L., Witek, M. A., Hansen, N. C., Thomas, J., Konvalinka, I., & Vuust, P. (2016). Oxytocin improves synchronisation in leader-follower interaction. *Scientific Reports*, 6, 38416. doi:10.1038/srep38416

González-Hernández, A., Rojas-Piloni, G., & Condés-Lara, M. (2014). Oxytocin and analgesia: future trends. *Trends in Pharmacological Sciences*, 35(11), 549–551. doi:10.1016/j.tips.2014.09.004

Grape, C., Sandgren, M., Hansson, L. O., Ericson, M., & Theorell, T. (2002). Does singing promote well-being? An empirical study of professional and amateur singers during a singing lesson. *Integrative Physiological & Behavioral Science*, 38(1), 65–74. doi:10.1007/BF02734261

Graustella, A. J., & MacLeod, C. (2012). A critical review of the influence of oxytocin nasal spray on social cognition in humans: evidence and future directions. *Hormones and Behavior*, 61(3), 410–418. doi:10.1016/j.yhbeh.2012.01.002

Grippio, A. J., Pournajafi-Nazarloo, H., Sanzenbacher, L., Trahanas, D. M., McNeal, N., Clarke, D. A., ... & Sue Carter, C. (2012). Peripheral oxytocin administration buffers autonomic but not behavioral responses to

- environmental stressors in isolated prairie voles. *Stress*, 15(2), 149–161. doi:10.3109/10253890.2011.605486
- Josef, L., Goldstein, P., Mayseless, N., Ayalon, L., & Shamay-Tsoory, S. G. (2019). The oxytocinergic system mediates synchronized interpersonal movement during dance. *Scientific Reports*, 9(1), 1–8. doi:10.1038/s41598-018-37141-1
- Keeler, J. R., Roth, E. A., Neuser, B. L., Spitsbergen, J. M., Waters, D. J. M., & Vianney, J. M. (2015). The neurochemistry and social flow of singing: bonding and oxytocin. *Frontiers in Human Neuroscience*, 9, 518. doi:10.3389/fnhum.2015.00518
- Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, 435(7042), 673–676. doi:10.1038/nature03701
- Kovatsi, L., & Nikolaou, K. (2019). Opioids and the hormone oxytocin. *Vitamins and Hormones*, 111, 195–225. doi:10.1016/bs.vh.2019.05.003
- Lancaster, K., Goldbeck, L., Pournajafi-Nazarloo, H., Connelly, J. J., Carter, C. S., & Morris, J. P. (2018). The role of endogenous oxytocin in anxiolysis: structural and functional correlates. *Biological Psychiatry*, 3(7), 618–625. doi:10.1016/j.bpsc.2017.10.003
- Leng, G., & Ludwig, M. (2016). Intranasal oxytocin: myths and delusions. *Biological Psychiatry*, 79(3), 243–250. doi:10.1016/j.biopsych.2015.05.003
- Love, T. M. (2014). Oxytocin, motivation and the role of dopamine. *Pharmacology Biochemistry and Behavior*, 119, 49–60. doi:10.1016/j.pbb.2013.06.011
- Marsh, N., Marsh, A. A., Lee, M. R., & Hurlemann, R. (2020). Oxytocin and the neurobiology of prosocial behavior. *The Neuroscientist*, 15(2), 469–482. doi:10.1177/1745691619876528
- McCullough, M. E., Churchland, P. S., & Mendez, A. J. (2013). Problems with measuring peripheral oxytocin: can the data on oxytocin and human behavior be trusted? *Neuroscience & Biobehavioral Reviews*, 37(8), 1485–1492. doi:10.1016/j.neubiorev.2013.04.018
- Mehr, S., Krasnow, M., Bryant, G., & Hagen, E. (2020). Origins of music in credible signaling. *Behavioral and Brain Sciences*, 1–41. doi:10.1017/S0140525X20000345
- Podlipniak, P. (2017). The role of the Baldwin effect in the evolution of human musicality. *Frontiers in Neuroscience*, 11, 542. doi:10.3389/fnins.2017.00542
- Quintana, D. S., & Guastella, A. J. (2020). An allostatic theory of oxytocin. *Trends in Cognitive Sciences*, 24(7), 515–528. doi:10.1016/j.tics.2020.03.008
- Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., & Fitch, W. T. (2020). Music as a coevolved system for social bonding. *Behavioral and Brain Sciences*, 1–36. doi:10.1017/S0140525X20000333
- Saxbe, D. E., Beckes, L., Stoycos, S. A., & Coan, J. A. (2020). Social allostasis and social allostatic load: a new model for research in social dynamics, stress, and health. *Perspectives on Psychological Science*, 15(2), 469–482. doi:10.1177/1745691619876528
- Schladt, T. M., Nordmann, G. C., Emilius, R., Kudielka, B. M., de Jong, T. R., & Neumann, I. D. (2017). Choir versus solo singing: effects on mood, and salivary oxytocin and cortisol concentrations. *Frontiers in Human Neuroscience*, 11, 430. doi:10.3389/fnhum.2017.00430
- Schulkin, J. (2011). Social allostasis: anticipatory regulation of the internal milieu. *Frontiers in Evolutionary Neuroscience*, 2, 111. doi:10.3389/fnevo.2010.00111
- van der Schyff, D., & Schiavio, A. (2017). Evolutionary musicology meets embodied cognition: biocultural coevolution and the enactive origins of human musicality. *Frontiers in Neuroscience*, 11, 519. doi:10.3389/fnins.2017.00519
- Shahrestani, S., Kemp, A. H., & Guastella, A. J. (2013). The impact of a single administration of intranasal oxytocin on the recognition of basic emotions in humans: a meta-analysis. *Neuropsychopharmacology*, 38(10), 1929–1936. doi:10.1038/npp.2013.86
- Shamay-Tsoory, S. G., Fischer, M., Dvash, J., Harari, H., Perach-Bloom, N., & Levkovitz, Y. (2009). Intranasal administration of oxytocin increases envy and Schadenfreude (gloating). *Biological Psychiatry*, 66(9), 864–870. doi:10.1016/j.biopsych.2009.06.009
- Szymanska, M., Schneider, M., Chateau-Smith, C., Nezelof, S., & Vulliez-Coady, L. (2017). Psychophysiological effects of oxytocin on parent-child interactions: A literature review on oxytocin and parent-child interactions. *Psychiatry and Clinical Neurosciences*, 71(10), 690–705. doi:10.1111/pcn.12544
- Theofanopoulou, C., Boeckx, C., & Jarvis, E. D. (2017). A hypothesis on a role of oxytocin in the social mechanisms of speech and vocal learning. *Proceedings of the Royal Society B: Biological Sciences*, 284(1861), 20170988. doi:10.1098/rspb.2017.0988
- Walum, H., Waldman, I. D., & Young, L. J. (2016). Statistical and methodological considerations for the interpretation of intranasal oxytocin studies. *Biological Psychiatry*, 79(3), 251–257. doi:10.1016/j.biopsych.2015.06.016
- Wu, N., Li, Z., & Su, Y. (2012). The association between oxytocin receptor gene polymorphism (OXTR) and trait empathy. *Journal of Affective Disorders*, 138(3), 468–472. doi:10.1016/j.jad.2012.01.009
- Zak, P. J., Stanton, A. A., & Ahmadi, S. (2007). Oxytocin increases generosity in humans. *PLOS ONE*, 2(11), e1128. doi:10.1371/journal.pone.0001128