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DOI

[10.1016/j.heliyon.2020.e03540](https://doi.org/10.1016/j.heliyon.2020.e03540)

Publication date

2020

Document Version

Final published version

Published in

Heliyon

License

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[Link to publication](#)

Citation for published version (APA):

Sun, R., Vuillier, L., Deakin, J., & Kogan, A. (2020). Oxytocin Increases Emotional Theory of Mind, But Only for Low Socioeconomic Status Individuals. *Heliyon*, 6(3), [e03540]. <https://doi.org/10.1016/j.heliyon.2020.e03540>

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Research article

Oxytocin increases emotional theory of mind, but only for low socioeconomic status individuals

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ARTICLE INFO

Keywords:

Neuroscience

Psychology

Oxytocin

Emotional theory of mind (eToM)

Socioeconomic Status (SES)

Individual differences

Read the mind in the eyes test (RMET)

ABSTRACT

Studies have linked oxytocin to emotional theory of mind (eToM) — the ability to recognise and understand others' emotions. However, multiple replications have so far failed to reach a consistent result. Growing evidence suggests that oxytocin's positive effects on social-emotional tasks such as eToM are highly dependent on trait-level individual differences. In the present study, we theorised that socioeconomic status (SES) could influence oxytocin's impact on emotional mentalising processes. We tested our hypothesis in a double-blind between-subjects oxytocin nasal spray study on 147 Caucasian white male participants in the United Kingdom. In accordance with our hypothesis, we found that oxytocin (as compared to placebo) did boost emotional theory of mind, but only in people from low subjective SES backgrounds. Our results expand existing theory on how individual differences moderate oxytocin's role on social behaviours.

1. Introduction

Oxytocin, a neuropeptide synthesized in the hypothalamus, has generated substantial interest in psychology as well as within the popular press as a potential biological substrate of social processes (see Bartz et al., 2011, for review). It has been suggested to guide social approach and avoidance by modulating the perceived salience of socially meaningful cues (Averbeck, 2010; Groppe et al., 2013; Shamay-Tsoory and Abu-Akel, 2016). This has made oxytocin a prime candidate for playing a key role in the underlying mechanisms behind many socio-emotional behaviours, such as being able to recognize and understand other people's emotions, also known as emotional theory of mind (eToM, Baron-Cohen and Belmonte, 2005).

A few studies have investigated the link between oxytocin and eToM, but the results have been mixed—with some studies finding a positive relationship, while many more failing to find a main effect (see review, Leppanen et al., 2017). Although the inconsistencies in results could be partly explained by the fact that studies have used small sample sizes, a variety of tasks, and looked at a set of diverse populations (males, females, healthy, clinical, etc), Bartz et al. (2011) proposed that the main reason for non-replicable effects in the oxytocin literature might be because trait-level individual differences (Bartz et al., 2011). For example, participants with low empathy score have been shown to

benefit the most in being able to identify other people's mental states with the Read the Mind in the Eye task (RMET) (Baron-Cohen et al., 2001) under oxytocin condition compared to placebo condition (Feeser et al., 2015; Radke and de Bruijn, 2015).

However, besides trait-level individual differences, little is known about whether societal-shaped individual differences could also help explain how oxytocin influences social-emotional processes. In the current study, we propose such a moderator that has not been evaluated before: socio-economic status (SES). Defined by how individuals identify themselves within a certain economic group and within a certain social class (Cantril, 1943), SES can be measured both objectively and subjectively. Objective SES, measured by one's income, occupation and education level, and subjective SES, measured by perceptions of others' respect and admiration as well as individuals' judgements about their social standing in a given society or community, usually correlate with each other (Adler et al., 2000; Demakakos et al., 2008; Keltner et al., 2003).

Individuals from different SES differ in their needs and motivations in understanding others' thoughts and behaviours. Lower SES individuals, compared to their higher SES counterparts, live in areas which are more chaotic and potentially have more dangers (Kraus et al., 2010), and therefore have greater needs and motivations to accurately interpret the intentions of others (Kraus et al., 2012). Higher mentalising ability,

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indeed, seems to be especially adaptive for lower SES individuals because their welfare may depend on discerning others' emotions, intentions, desires, and attitudes (Hall et al., 2015).

However, lower SES individuals' ability of reading others' emotions may not be higher than their higher SES counterparts. For example, family income is positively associated with children's perception and emotion understanding because higher income gives parents more time to spend with their children and thus more opportunities to talk with them about feelings and other matters relevant to perspective taking (Pears and Moses, 2003). The literature suggests that individuals low in SES find themselves rife to benefit more from oxytocin than their high SES counterparts: Low SES individuals have greater needs and motivation for paying attention to socially salient cues, yet on average show lower ability to do so than higher SES people. Since oxytocin makes the social cues more salient, we hypothesised that intranasal oxytocin treatment may benefit lower SES individuals more on a social-emotional task compared to their higher SES peers.

The present study had two aims. First, we aimed to recruit a large sample to add to the literature on the relationship between oxytocin administration and emotional ToM. Given that only three out of nine previous studies had found a main effect, we did not expect to find a main effect. Second and more critically, we aimed to test whether SES moderated the relationship between oxytocin and emotional TOM. Specifically, we aimed to test whether lower SES individuals benefited more from oxytocin compared to their higher SES counterparts. Even though there is currently no research evaluating how SES may moderate the effect of oxytocin on social cognition, one study has explored the moderating role of SES on the relationship between the oxytocin receptor gene rs53576 and coping strategies (Sun et al., 2019). The researchers found that individuals with GG phenotype (similar to getting a dose of oxytocin in the current study) use better coping strategies, and that the relationship was specifically found among lower SES individuals.

Testing the moderating effect of SES on oxytocin's influence on socio-emotional tasks has great importance: Unlike well-established personal-trait individual difference such as empathy, SES is a complex social concept representing one's social role and obtained social capital (Bradley and Corwyn, 2002). If this societal-shaped concept moderated oxytocin's influence on socio-emotional tasks, it would expand existing understanding on how oxytocin functions on social tasks and may help explain inconsistent results in the literature.

To test our hypotheses, we conducted a double-blind, between-subjects nasal spray experiment where we followed the most widely used methods in the literature to ensure uniformity with previous work. In particular, hoping to resolve some of the inconsistencies reported in the literature, we recruited a large number of participants ($n = 147$) to reach 80% power, which most studies in the literature have not (Faul et al., 2007).

2. Method

2.1. Participants

One hundred and forty-seven Caucasian males ($M_{\text{age}} = 24.54$; $SD_{\text{age}} = 5.75$) living in the UK took part in the study¹. All participants gave written consent before participating in the study. Our inclusion criteria

¹ We did not include female participants in the current study for two main reasons: First, most human studies that manipulate OT experimentally have tested males only (e.g. Baumgartner et al., 2008; Gregor Domes et al., 2007; Kirsch, 2005; Kosfeld et al., 2005; Petrovic et al., 2008) and we wanted to be able to compare our results to the rest of the literature. Second, females' menstrual cycle and oral contraception use have been shown to affect intra-nasal oxytocin's influence on socio-emotional tasks (Theodoridou et al., 2009) as well as the perception of emotional stimuli (Conway et al., 2007; Pearson and Lewis, 2005).

included being Caucasian², male, 18–55 years old, not diagnosed with any psychological problems in the past 5 years, and not taking any medication regularly.

2.2. Procedure

This study received ethical approval from Cambridge Psychology Research Ethics Committee.

In the randomized, double-blind, between-subject experiment, participants received either oxytocin ($N = 73$) or placebo ($N = 74$). Before the experimental session, participants reported their objective and subjective SES.

Upon arrival, participants self-administered a single dose of 24 IU oxytocin or placebo intra nasally, as per Domes et al. (2007) and Feeser et al. (2015) studies. A battery of cognitive tasks³ started 40-minutes after oxytocin/placebo administration, in accordance with other studies (Radke and de Bruijn, 2012, 2015). The RMET was administered around 60-minutes after the spray had been administered.

2.3. Reading the Mind in the Eyes Test (RMET)

We measured participants' theory of mind using the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001). In 36 trials, participants inferred the emotional mental state of another individual based on photographs of the eye region. For each set of eyes, participants chose which word out of 4 choices best described what the person in the picture is thinking or feeling. Performance was determined by calculating the number of correct answers, with a total RMET score ranging between 0 and 36. The RMET validity has been proven in healthy subjects (Hysek et al., 2012).

2.4. Socioeconomic status

We followed previous literature to measure objective and subjective SES (Kraus et al., 2009). For objective SES, participants reported their occupation, annual household income, own education level, and their father's and mother's education.

Participants reported their subjective SES using the MacArthur Scale of Subjective Social Status (Adler et al., 2000; Kraus et al., 2009). Participants were shown a picture of a ladder and imagined this ladder as representing where people stand in the UK, with people who have the most money, the most education, and the most respected jobs at the top of the ladder, and people with the least money, least education, and the least respected jobs or no job at the bottom of the ladder. Participants selected one of the 10 options (1 being the worse off and 10 being the best off), therefore, their subjective SES could range between 1 and 10.

2.5. Statistical analysis procedure

We used R studio 3.1 for our data analysis.

To achieve the first aim of replicating previous research results on oxytocin and RMET, we ran a linear regression where we dummy coded oxytocin condition (1 = oxytocin and 0 = placebo). Second, we ran a linear regression, with total RMET score as the dependent variable, and

² We only recruited Caucasian participants because literature has suggested that oxytocin motivates in-group favoritism (e.g. De Dreu, Greer, Van Kleef, Shalvi and Handgraaf, 2011; Luo et al., 2015) Pictures in the RMET task come from Caucasian models. If our participants had mixed race background, certain participants may have had an advantage recognizing the emotions in the task over others. To avoid this situation, we only recruited Caucasians in our study.

³ Apart from the RMET, participants completed a series of tasks related to social cognition and behaviours. A full list of tasks tested in the study is listed in the Supplementary Materials (S3). We did not find Oxytocin \times SES interaction on those tasks.

Table 1. Participants' RMET score and demographic information, with mean score and standard deviation.

	Overall	Oxytocin Group	Control Group	t	p
RMET	28.48 (2.87)	28.47 (3.03)	28.50 (2.71)	-.07	.94
Annual household income	£50,000 (£31,700)	£52,900 (£33,200)	£47,200 (£30,100)	1.09	.28
Education ⁴	3.9 (1.58)	3.85 (1.57)	3.97 (1.59)	-.48	.63
Parents' education ⁵	4.52 (1.70)	4.44 (1.73)	4.60 (1.68)	-.62	.53
Objective SES	4.46 (1.42)	4.57 (1.45)	4.34 (1.40)	.95	.34
Subjective SES	6.83 (1.56)	6.92 (1.62)	6.74 (1.52)	.68	.50

drug condition, SES (z-scored), as well as the interaction term of SES and drug condition as the independent variables.

3. Results

3.1. Participant characteristics

Participants' RMET score and demographic information are listed in Table 1.

In total, we had the following measures of SES: subjective SES, income, own education, parents' education; we also created a composite objective SES score by averaging participants' income and own education (Please see Supplementary Materials S2 for more details).

3.2. Oxytocin and RMET

We did not find a main effect of oxytocin nasal spray on RMET score, $b = -.034$, 95%CI [-.97, .90], $SE = .474$, $t(145) = -.072$, $p = .94$. This is in line with our hypothesis and previous literature (please see Supplementary Materials S1 for findings from previous research).

3.3. Moderating effect of SES

We ran our regression models with the dependent variable RMET, the independent variables drug condition, SES (z-scored), and the interaction term of SES and drug condition as predictors. Results are reported in Table 2.

Of all the SES measures, only subjective SES moderated how intranasal oxytocin influenced RMET. To correct for multiple-comparison, we ran the "Bonferroni-Holm" statistical correction. The corrected p value for the subjective SES \times oxytocin interaction was .05.

To further analyse the direction of the moderating effect, we ran two more variants of the interaction model described above, once by centering 1SD below the mean subjective SES and once by centering 1SD above the mean. This allowed us to evaluate how oxytocin influenced RMET for individuals with relatively lower SES and relatively higher SES. We found that oxytocin marginally decreased RMET performance for participants 1SD above the mean ($\beta = -1.23$, 95%CI [-2.54, .08], $SE = .66$, $t(143) = -1.86$, $p = .07$), and trended towards increasing RMET performance of people 1SD below the mean ($\beta = 1.08$, 95%CI [-.22, 2.39], $SE = .66$, $t(143) = 1.65$, $p = .10$). Because it is possible that our interaction effect was driven by individuals with much higher and much lower subjective SES individuals (rather than only 1SD above and below

⁴ When we recruited participants, we used all possible recruiting channels to include a sample with a wide range of background. However, since the study took place in a university town, most participants who signed up for the study were students (including undergraduate students, master students, PhD/MD, etc). Participants' education level had a right-tailed distribution, driven by a large number of undergraduate students. Undergraduate students also registered their "finished degree" as "high-school", although it does not fully represent their educational level.

⁵ Parents' education was calculated by averaging father's and mother's achieved degree.

the mean), we ran another two regression models with subjective SES centered around 2SD below the mean and 2SD above the mean. Indeed, this analysis showed that oxytocin decreased RMET performance for individuals 2SD above the mean ($\beta = -2.39$, 95%CI [-4.45, -.32], $SE = 1.05$, $t(143) = -2.28$, $p = .02$) and increased RMET performance for individuals 2SD below the mean ($\beta = 2.25$, 95%CI [.18, 4.31], $SE = 1.04$, $t(143) = 2.15$, $p = .03$). It therefore suggests that oxytocin helped individuals with very low subjective SES (ranking themselves on the SES ladder at less than 3.7) and impaired individuals with very high subjective SES (ranking themselves at the top of the ladder) in identifying emotions in others. Figure 1 shows oxytocin's influence on RMET for +/-1SD and +/-2SD SES individuals.

However, it is worth mentioning that the fact there was an effect at -2/+2 SD does not mean there was ONLY an effect at -2/+2SD. To further demonstrate this point, we visually display how oxytocin influenced RMET for individuals with different subjective SES in Figure 2. This shows that for individuals with relatively low subjective SES (labeling themselves on the SES ladder at less than 5, which is -1.17 SD and below), there was a positive relationship between Drug Condition and RMET; there was no relationship when subjective SES was between 5 and 9; and there was a negative relationship for people with the highest subjective SES (labeling themselves on the SES ladder at above 9, however, there were only 4 out of 145 participants labeling themselves at 10).

Past literature suggests that individuals with low social-proficiency benefit the most from oxytocin administration on social and emotional tasks. Therefore, we also tested whether lower SES individuals benefited the most from oxytocin administration because they were less good at the task compared to higher SES individuals. We ran a linear regression model between subjective SES and RMET in our placebo group and found a positive relationship between SES (z-scored) and RMET, ($b = .90$, 95% CI [.28, 1.52], $SE = .31$, $t(72) = 2.91$, $p < .01$). This suggests that in our sample, oxytocin improved lower SES individuals who were not as good at the RMET task as their higher SES counterparts. This relationship is presented in Supplementary Figure S1.

4. Discussion

The present study aimed to 1) use a large sample to add to the literature on oxytocin's effect on eToM, and 2) explore the societal-shaped individual difference – SES – as a moderator in this effect. Whilst our study had the largest sample among all 9 studies investigating the effect of oxytocin on eTOM, and the power to find such an effect, we did not find that a single dose of intranasally administered oxytocin enhanced emotional ToM. However, confirming our second hypothesis, we found a moderating effect of subjective SES on the oxytocin-eToM relationship. More specifically, we found that oxytocin only enhanced the performance of individuals who considered themselves being worse off compared to the general population, and surprisingly, decreased the performance of those who considered themselves at the very top on the social ladder (however, since only 4 out of 145 individuals rated themselves at the highest SES, we should treat this finding with caution). We also found that in our study, people with lower subjective SES also had lower eToM, suggesting that oxytocin enhanced emotional mentalising for those who were not good at the RMET in the first place. This is in line

Table 2. Results of the regression analyses with different SES tested.

	Drug Condition (Dummy coded)		SES		Drug × SES interaction	
	β	t	β	t	β	t
Subjective SES	-0.07	-0.15	0.9	2.67**	-1.16	-2.47*
Income	-0.1	-0.22	0.4	1.13	-0.04	-0.07
Own education	-0.06	-0.13	-0.32	-0.96	-0.04	-0.08
Parents' Education	0.04	0.08	0.52	1.57	0.35	0.75
Objective SES	-0.07	-0.15	0.23	.67	0.01	0.01

* $p < .05$, ** $p < .01$.

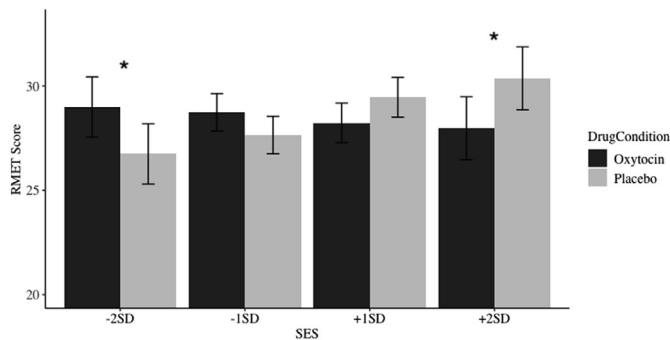


Figure 1. Oxytocin's influence on RMET for +/-2SD and +/-1SD SES individuals.

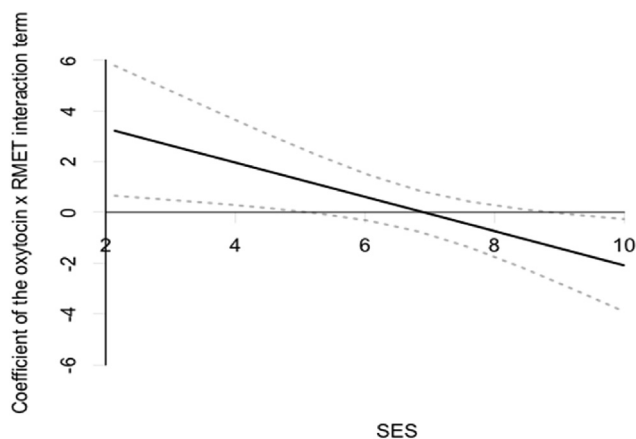


Figure 2. Oxytocin's influence on RMET for different SES individuals. (Solid line shows the influence of oxytocin on RMET, dotted lines represent 95% upper and lower confidence interval).

with existing literature that shows that individuals who finds the social-cognitive task challenging actually benefit more from oxytocin (e.g Bartz et al., 2010; Feeser et al., 2015; Pavarini et al., 2019; Quirin et al., 2011; Radke and de Bruijn, 2015). What distinguished our finding from existing research is that while current literature documents trait-level deficits (such as by looking at people on the ASD spectrum or people who have low empathy) we suggest that a complex societal-shaped concept, SES, also seems to moderate how oxytocin influences social cognition.

The current study tested SES as a representative societal-shaped concept to function as a moderator in the oxytocin – eToM relationship. SES decides one's solipsistic or contextualist social cognitive tendencies: while higher SES individuals are less dependent on others, lower SES individuals are more dependent on the environment and are more motivated to pay attention to other individuals' intentions (Kraus et al., 2012). SES therefore influences social cognition such as sense of control,

emotion experience, self-concept, and moral judgment (Côté et al., 2010; Horberg et al., 2009; Piff and Moskowitz, 2017; Stephens et al., 2011). Our study is the first to document that lower SES individuals selectively benefited from the oxytocin administration, and we hypothesise that it may be because oxytocin made the social cues more salient to those who are more motivated to mentalise. However, we did not directly test whether lower SES individuals in the oxytocin vs placebo condition indeed paid more attention to these social cues. We recommend future research should use tools such as eye-tracking, and extend our findings to other social cognitive tasks such as self-concept, threat perception, and moral judgement.

We found that only subjective SES, rather than objective SES, moderated how oxytocin influenced RMET. It is however not surprising because there is a substantial body of literature that suggests the subjective SES measure is valid, appropriate, and in fact superior to objective metrics of SES – even amongst student populations; subjective SES is also better than objective SES in predicting psychological functions (Adler et al., 2000; Link et al., 1993; Operario et al., 2004; Singh-Manoux et al., 2005). Subjective SES individual difference, therefore, may be more sensitive as a moderator to oxytocin administration than objective SES on social emotional tasks. Indeed, because subjective SES allows the respondent to weigh income, education and occupation in proportion to the importance of each marker in the respondent's own social context, it may be more accurate than objective values that do not take this context into account (Cohen et al., 2008). Furthermore, since we are likely in a restricted range of objective SES values (58% undergraduate students, a relatively homogenous education level), our effects on objective SES are likely underestimating the true population effect where there is a broader range of SES values. Moreover, household income might also be an issue in our largely student sample as some reported their parents incomes, which may have led to inaccuracy. We did try to advertise our study as widely as possible to recruit a diverse population but because the study took place in a university town it was difficult to avoid. Therefore, we cannot rule out the possibility that objective SES could also function as a moderator and we suggest that future research should investigate this further.

It is worth mentioning that, besides RMET, we also tested other tasks after the oxytocin nasal administration. While for practical reasons, it is common practice to test multiple tasks after the oxytocin nasal spray (e.g. Di Simplicio, Massey-Chase, Cowen and Harmer, 2009; Radke and de Bruijn, 2015), it poses the risk that those measures could have interacted with the targeted measures to produce the effect we found. It may also have increased the chance for a false positive effect in our finding, although some statistical research suggests that adjustments for multiple comparisons are not needed when data under evaluation are not random numbers (Rothman, 1990; Saville, 1990). Even though our study has one of the largest samples in oxytocin nasal spray research, more research is needed to replicate the oxytocin × SES interaction effect on social cognition.

To conclude, our study showed that oxytocin selectively enhanced eToM among the relatively lower subjective SES individuals. Our study expands the understanding of moderating factors in the oxytocin administration literature to societal-level individual differences. Future

research may consider the moderating effect of subjective SES of oxytocin on other social cognitive tasks.

Declarations

Author contribution statement

R. Sun: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

L. Vuillier: Conceived and designed the experiments; Wrote the paper.

J. Deakin: Performed the experiments; Contributed reagents, materials, analysis tools or data.

A. Kogan: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the grant ESRC Future Research Leaders awarded to Dr. Aleksandr Kogan, UK. ES/K008331/1.

Competing interest statement

The authors declare no conflict of interest.

Additional information

Data associated with this study has been deposited at https://osf.io/4cavb/?view_only=36ceba499d66431ca769c8b86c7da4f4

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2020.e03540>.

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