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The effect of oxytocin on group formation and strategic thinking in men

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A B S T R A C T

Decision-making in groups is a remarkable and decisive element of human societies. Humans are able to organize themselves in groups, engage in collaborative decision-making processes and arrive at a binding agreement, even in the absence of unanimous consent. However, the transfer of decision-making autonomy requires a willingness to deliberately expose oneself to the decisions of others. A lack of trust in the abilities of others or of the underlying decision-making process, i.e. public trust, can lead to a breakdown of organizations in political or economic domains. Recent studies indicate that the biological basis of trust on an individual level is related to Oxytocin, an endogenous neuropeptide and hormone, which is also associated with pro-social behavior and positive conflict resolution. However, little is known about the effects of Oxytocin on the inclination of individuals to form or join groups and to deliberately engage in collaborative decision-making processes. Here, we show that intranasal administration of Oxytocin (n = 60) compared to placebo (n = 60) in males causes an adverse effect on the choice for forming groups in the presence of a competitive environment. In particular, Oxytocin negatively affects the willingness to work collaboratively in a *p*-Beauty contest game, whereas the effect is most pronounced for participants with relatively high strategic sophistication. Since our data provide initial evidence that Oxytocin has a positive effect on strategic thinking and performance in the *p*-Beauty contest game, we argue that the adverse effect on group formation might be rooted in an enhanced strategic sophistication of participants treated with Oxytocin.

1. Introduction

Decision-making in groups is a remarkable and decisive element of human societies. Humans are able to organize themselves in groups, engage in collaborative decision-making processes and are able to arrive at a binding agreement, even in the absence of unanimous consent (Kerr and Tindale, 2004). Accordingly, numerous important decisions in the realm of economics or politics are made by small groups (Charness and Sutter, 2012; Kugler et al., 2012). For instance, boards of directors determine the corporate strategy of a company, councils set the monetary policy of economies, and elected representatives decide on the fate of a nation. Besides the importance of participation rights and its positive effects on cooperation within societies (Frey, 1994; Sutter et al., 2010), small groups have a striking advantage compared to individual decision-making and typically outperform individuals in intellectual tasks due to a better computation of information (Laughlin and Ellis, 1986; Laughlin et al., 2006). Moreover, a growing number of empirical evidence suggests that groups exhibit a superior strategic sophistication compared to individuals (Charness and Sutter, 2012; Cooper and Kagel, 2005; Kocher and Sutter, 2005; Kugler et al., 2012). Despite the various advantages of group decision-making, the willingness to decide in groups requires a certain transfer of decision-making autonomy and a preference to be deliberately exposed to decisions of others. That is, a person has to trust in the ability of the group to arrive at a mutual beneficial agreement, and most importantly, to achieve a superior outcome.[1] Thus, the ability to form (or join) a group crucially depends on the inclination to deliberately expose oneself to the decisions of others.

Despite the importance of group decision-making, little or nothing is known about the neurobiological roots of the inclination to engage in collaborative decision-making. Since Oxytocin, an endogenous neuropeptide and hormone, is known for its positive effects on attachment

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[1] Conversely, it is important to point out that a lack of trust in the abilities of others or the underlying decision-making process can have a detrimental effect on cooperation and collaboration in political or economic domains (Knack and Keefer, 1997; Zak and Knack, 2001).

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(Donaldson and Young, 2008), trust (Kosfeld et al., 2005) and group-cohesion (De Dreu et al., 2010; De Dreu et al., 2011), we hypothesized that Oxytocin would enhance the inclination of individuals to form groups. Moreover, Oxytocin has been shown to play a key role in many basic elements of social interactions among group members like trust (Kosfeld et al., 2005), cognitive empathy (Domes et al., 2007; Shamay-Tsoory et al., 2013), positive conflict resolution (Ditzen et al., 2009) and additionally, recent findings even suggest that Oxytocin enhances the quality of group decision-making due to better information sharing among group members (De Wilde et al., 2017). Thus, in light of these results, we hypothesized that an exogenous alteration of brain Oxytocin levels would have a positive effect on the willingness to transfer decision-making autonomy to a group. Moreover, in an explorative manner, we examined Oxytocin's effects on task performance and the success of teams in collaborative decision-making (De Wilde et al., 2017).

2. Methods

To test our hypothesis, we used a double-blind study design to compare group formation behavior in male subjects who received either a single dose of intranasal Oxytocin (24 IU) or a placebo containing all ingredients except for the neuropeptide. First, subjects received neutrally written instructions, which we read aloud (see Supplementary information A5 for details). All parts of the experiment were fully computerized and independent of one another. To proceed to the next part of the experiment, the previous portion had to be accomplished by all participants. Thirty minutes after substance administration we started with the behavioral experiment, which consisted of two main parts.

In part one of the behavioral experiment, participants were asked to play a cognitive and interactive task, the *p*-Beauty contest game (Nagel, 1995), for one round as individuals. Subjects played independently in groups of four by choosing a real number from the interval $I \equiv [0, 100]$. The participant whose number was closest to 2/3 of the mean of all chosen numbers in the respective unit would win a real monetary prize (12 € per Round) or an equal split in the case of a tie. Accordingly, all participants had to form beliefs about their opponents' guesses, and the most accurate estimation of 2/3 times the mean would win. Participants received feedback about their success in this part at the end of the experiment – not immediately afterward – to avoid affecting decisions in Part Two.

In Part Two, subjects were asked to choose between playing the same *p*-Beauty contest game alone or as a member of a team with three (randomly chosen) subjects. Subjects were also told that they would remain in this role until the end of the experiment. That is, 3 solo individuals and one 3-person team played the game with the same players for four rounds. Teams had to come to a single unanimous number. The decision-maker (whether an individual or team) whose number was closest to 2/3 the mean of all chosen numbers in the respective round would again win a monetary prize (12 € per Round), or an equal split in the case of a tie. To keep the per capita payoff constant, each member of a winning team would receive the same amount as an individual (i.e. 12 €). Unlike in part 1, decision-makers received feedback about the winning number and their success immediately after each round.

After indicating their preferred role (team or individual) but before beginning Part Two, participants were asked to answer a short questionnaire regarding their motivation and their beliefs regarding the success of teams in the task (see Supplementary information A1 for details).[2] Subjects who correctly guessed the winning frequency of teams received a bonus of 2 €. To ensure anonymity in this experiment, we employed a fully computerized setting in which teams were able to use an interactive chat interface to discuss and agree on a particular number. They were told that in the event that a team was unable to agree upon a number within 4 min, the computer would randomly draw a number for them.[3] That is, all team members would have to agree on one particular guess, which also required the willingness to compromise or even resign oneself to the decisions of others. Accordingly, when a participant chose to play this game in a team of three, he had to be willing to expose himself to the decisions of his team members and therefore risk making an inferior decision (Kocher et al., 2006). Conversely, when a participant chose to play this game as an individual and preserve his decision-making autonomy, he would sacrifice the potentially superior knowledge of teammates and, thus, potentially miss out on making superior guesses (Kocher et al., 2006; Kocher and Sutter, 2005; Sutter, 2005). In this way, a rational decision maker would only opt for team decision-making if he predicts that his teammates are likely to possess knowledge superior to his own.

It is important to note that if players are perfectly rational (and if it is common knowledge that all players are rational), there is no benefit in collaborating within a team to play the *p*-Beauty contest game, because all players would play the unique Nash equilibrium of the game and choose 0 (Nagel, 1995).[4] However, empirical evidence provided by Kocher and Sutter (2005), Kocher et al. (2006) and Sutter (2005) suggests that players are far from optimal play, and additionally, that on average teams outperform individual players in this game. Accordingly, the authors argue that in line with information load theory (Chalos and Pickard, 1985) teams are better than individuals in retaining and processing the information in this intellectual task. Consequently, in contrast to most other economic games, it might be beneficial for participants to partially give up their decision-making autonomy in the *p*-Beauty contest game and opt for collaborative decision-making in a team, depending on their strategic aptitude (Kocher et al., 2006).

Moreover, we also explored the effects of Oxytocin on task performance, since the actual performance on the task might influence a participant's decision to opt for the team. In particular, the *p*-Beauty contest game constitutes an ideal tool for studying the performance of teams and individuals under the influence of Oxytocin as it is possible to measure the steps of reasoning that a decision maker actually applies to solve the game (Camerer et al., 2004; Coricelli and Nagel, 2009; Nagel, 1995; Weber, 2003). For instance, a player who forms no beliefs about the guesses of other players will pick any random number between 0 and 100 (that is, their selections are assumed to fall across a uniform distribution), and be labeled a 'step 0' thinker. At the next level of reasoning, 'step 1' players will anticipate that others are 'step 0' players and respond by selecting 33 (which represents 2/3 of 50 – the mean of 0 and 100).[5] Similarly, a 'step 2' thinker assumes that other players are a combination of 'step 0' and 'step 1' thinkers and anticipates an average number between 33 and 50. Accordingly, we can pursue this method with any number of iterations and estimate the number of steps a decision-maker applies to solve this task. Because players may estimate different frequencies of players engaging in each step, we employed the cognitive hierarchy model, which incorporates participants' estimations of the frequencies of players engaging in each level of reasoning.[6] That is, this model accounts for estimations of the

[2] Since there were 12 participants in each session, and each unit consisted of 6 participants (three team members and three individuals), it was difficult to assign each participant to his preferred role. However, we were able to respect the preferences of 91.6% of all participants.

[3] This was never the case, as all subjects were able to agree on a specific number.

[4] Standard game theory suggests (for $p = ⅔$) that everyone chooses 0, the unique (Nash) equilibrium of this game (Nagel, 1995). Through the iterated elimination of weakly dominated strategies (IEwDS), all numbers greater than $p^k \cdot 100$, with $k \to \infty$, should be excluded from a player's choice set. The only remaining strategy is 0, the unique equilibrium of this game.

[5] Note that by assumption subjects are prone to overconfidently mispredict the sophistication of others and believe that others will use a lower level of reasoning as they do (Nagel, 1995).

[6] For instance, a step-2 player might assume that two of his opponents are step-0 thinkers and one is a step-1 thinker. Instead of playing 22, he takes into account the distribution of each thinker and therefore plays 28.