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Combining oxytocin administration and positive emotion inductions: Examining social perception and analytical performance

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ABSTRACT

Intranasal administration of the hypothalamic neuropeptide oxytocin (OT) has, in some studies, been associated with positive effects on social perception and cognition. Similarly, positive emotion inductions can improve a range of perceptual and performance-based behaviors. In this exploratory study, we examined how OT administration and positive emotion inductions interact in their associations with social and analytical performance. Participants ($N = 124$) were randomly assigned to receive an intranasal spray of OT (40 IU) or placebo and then viewed one of three videos designed to engender one of the following emotion states: social warmth, pride, or an affectively neutral state. Following the emotion induction, participants completed social perception and analytical tasks. There were no significant main effects of OT condition on social perception tasks, failing to replicate prior research, or on analytical performance. Further, OT condition and positive emotion inductions did not interact with each other in their associations with social perception performance. However, OT condition and positive emotion manipulations did significantly interact in their associations with analytical performance. Specifically, combining positive emotion inductions with OT administration was associated with worse analytical performance, with the pride induction no longer benefiting performance and the warmth induction resulting in worse performance. In sum, we found little evidence for main or interactive effects of OT on social perception but preliminary evidence that OT administration may impair analytical performance when paired with positive emotion inductions.

1. Introduction

Biological and psychological manipulations can both influence a wide range of affective, social, and cognitive outcomes. For example, some neuroendocrine products, such as the neuropeptide oxytocin (OT), may have positive effects on social behavior (e.g., Taylor et al., 2000; Zak et al., 2007). Further, there is evidence that experiencing positive emotions can improve a range of perceptual and performance-based behaviors (Fredrickson, 2001; Isen, 2000). However, research is accumulating to suggest that OT administration can be less beneficial or even detrimental in some contexts (e.g., Campbell, 2008; Shamay-Tsoory et al., 2009; De Dreu et al., 2010) and when administered at higher concentrations (e.g., Cardoso et al., 2013). Similarly, it has been argued that high levels of positive emotions can be detrimental in some contexts (Gruber et al., 2011; Oishi et al., 2006). The current study examined whether combining acute increases in OT and positive emotions together would result in a similar, potentially detrimental, pattern. We addressed this question by experimentally manipulating OT levels via intranasal administration of OT (vs. placebo) and by inducing one of two positive emotions, social warmth or pride (vs. neutral affect), and then examining performance on social perception and cognitive tasks.

OT is a neurohypophyseal hormone that plays a role in social interactions and bonding (Taylor et al., 2000; Zak et al., 2007). Initial work on OT administration suggested that it may promote more positive social behavior, such as greater trust and generosity (Kosfeld et al., 2005; Zak et al., 2007), and more accurate social perception (Bartz et al., 2010a; Domes et al., 2007; Guastella et al., 2010). There has been less examination of the effects of OT on cognitive processes, but one study found that OT administration promoted greater holistic thinking and creative performance, but decreased analytical reasoning (De Dreu et al., 2013).

Of note, however, the positive social effects of OT administration have not been entirely reliable (see Conlisk, 2011; Nave et al., 2015, for critical reviews). This is likely in part because the statistical power of OT administration studies tends to be very low and there are likely publication and reporting biases within the field (Lane et al., 2016; Walum et al., 2016), but may also be in part because the effects of OT

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administration may be highly context-dependent (Bartz et al., 2011; Bakermans-Kranenburg and Van IJzendoorn, 2013; Guastella and MacLeod, 2012; Van IJzendoorn and Bakermans-Kranenburg, 2012). For example, OT administration has been shown to selectively improve the accuracy of social perception for men who are less socially proficient (Bartz et al., 2010a) and on more difficult social perception items (Domes et al., 2007). There is also evidence that OT administration is more beneficial for people with alexithymia (Luminet et al., 2011), autism and Asperger's disorders (Andari et al., 2010; Guastella et al., 2010; Hollander et al., 2007), and schizophrenia (Woolley et al., 2014). Further, OT administration has been found to have antisocial effects in negative social contexts, such as those that involve conflict (e.g., De Dreu et al., 2010). It remains unclear, however, whether and how OT administration would interact with experimentally induced positive social-emotional states to influence behavior and cognition, such as social perception and analytical thinking.

A large body of work has examined how emotion inductions influence a host of social and cognitive outcomes. In particular, positive emotion inductions can broaden mind-sets (Fredrickson, 2001), resulting in more flexible, creative solutions (Isen, 2000) and improve performance on social perception tasks, analytical problem solving tasks, and decision-making (see Isen, 2000 for review; Reed and Aspinwall, 1998). These effects appear to be due, in part, to increased motivation (Forgas and Vargas, 2000). In the current study, we compared two positive emotion inductions: social warmth, which may be more other-focused and socially engaging, and pride, which may be more self-focused and socially disengaging (Kitayama et al., 2006). Given that OT administration is argued to be particularly relevant to *social processes*, it is possible that potential interactive effects would be stronger for emotions such as social warmth than pride. Alternatively, if the broadening and motivating effects of positive emotions have similar effects on social and analytical outcomes, we may not see emotion-specific effects.

How might OT administration and positive emotion inductions interact with each other? On the one hand, it is plausible that combining OT administration with positive emotion states would accrue additive benefits. Indeed, there is some evidence that OT administration can be beneficial in more positive contexts. For example, individuals with more supportive family backgrounds have more positive social responses to OT administration (e.g., Bartz et al., 2010b; Van IJzendoorn et al., 2011). Further, individuals in a more supportive social context experience greater stress-reducing effects after OT administration (Heinrichs et al., 2003) and those lower in loneliness demonstrate better cardiac control after receiving OT administration (Norman et al., 2011). There is also evidence that OT administration can have adverse consequences for those who tend to experience more negative emotional states, such as those with elevated levels of depression (Ellenbogen et al., 2013) and major depressive disorder (MacDonald et al., 2013). Thus, it is possible that OT administration and positive emotion inductions combined could be more beneficial for social and cognitive outcomes than either OT administration or positive emotion inductions alone.

On the other hand, it is possible that positive emotion inductions combined with OT administration could be detrimental. Indeed, there are studies that underscore the limits of beneficial effects of very high levels of positive emotion (see Gruber et al., 2011; Oishi et al., 2006). For example, while moderate levels of positive emotion can promote creativity, very high levels do not (Davis, 2008). Further, moderate levels of happiness are associated with more successful achievement outcomes than very high levels of happiness (Oishi et al., 2006). Similarly, recent dose response work has found that at with higher dosages of intranasal OT there is less attenuation of cortisol reactivity to physical stress (Cardoso et al., 2013) and less effective enhancement of the positive valence engendered by social memories (Cardoso et al., 2014). Further, women, who tend to be higher in endogenous levels of OT (Altemus et al., 1999), sometimes show more negative responses to OT administration. For example, OT administration (vs. placebo) in women has been shown to decrease neural activity in regions associated with social bonding and reward (Rilling et al., 2014) and enhance anger following social evaluation (Kubzansky et al., 2012).

Overall, then, both positive emotions and OT may be less beneficial or even detrimental at high levels. In turn, it is possible that combining OT administration with positive emotion inductions would have similarly detrimental effects on social and cognitive outcomes. In the first study that we are aware of to do so, we test this possibility by experimentally manipulating both OT administration and positive emotions, to examine their independent and interactive effects on both social perception and analytical performance.

2. Method

2.1. Overview

In the current study, participants received a single intranasal dose of either OT (40 IU) or placebo in a double-blind, randomized design. Orthogonal to the OT/placebo manipulation, participants were randomly assigned to one of three emotion inductions: social warmth, pride, or a neutral affect (control) condition. Participants reported their positive affect prior to and after the positive emotion inductions and then completed two social perception tasks and an analytical performance measure.

2.2. Participants and design

Participants between the ages of 18 and 35 who spoke English as their first language were recruited from the San Francisco community through flyers and advertisements on Craigslist. Prior to scheduling a lab appointment, participants were pre-screened and excluded if they were pregnant, lactating, or in poor mental or physical health.[1] A total of 126 participants arrived for their lab appointment, of which 2 chose to discontinue their participation due to discomfort from the nasal spray. The final dataset included 124 participants (60 female, 64 male; $M_{age} = 24.99$, $SD_{age} = 4.11$), although there were additional missing data on individual items due to lack of participant response, technical difficulties, or experimenter error. Upon arrival, participants were randomly assigned to a 2 (intranasal spray: oxytocin administration vs. placebo, double-blind) × 3 (emotion induction: social warmth vs. pride vs. neutral) between subjects design. The gender distribution was similar across conditions (see Table 1 for a full breakdown by condition). FDA approval (IND #111906) was obtained for the use of oxytocin and all study procedures were approved by the University of California San Francisco Committee for Human Research.

2.3. Procedure

2.3.1. Arrival and nasal spray administration

Upon arrival at the lab, participants were given a brief overview of the procedure and informed consent was obtained (see Fig. 1 for an overview of the study procedures timeline). The experimenter then confirmed a negative test for pregnancy for all female participants via a urine sample. Next, participants were taught how to self-administer

[1] These data come from a larger project that also assessed individual differences and other outcome measures in the lab. Analyses with these individual difference measures and other outcome variables can be found elsewhere (Human et al., 2016) and do not overlap with or influence the results presented in the current manuscript. Specifically, Human et al., examined the interactive effects between OT administration and extraversion on social connection and prosocial tendencies – extraversion did not significantly interact with OT administration or positive emotion inductions in its associations with the dependent variables examined in the current manuscript and controlling for extraversion does not alter the results of the current manuscript. In addition, the positive emotion inductions did not significantly relate to or interact with extraversion or OT administration in their associations with the dependent variables in Human et al., 2016. Additional details can be found in the online supplemental materials corresponding to Human et al., 2016: http://spp.sagepub.com/content/7/7/735/suppl/DC1.

Table 1
Sample sizes and descriptive statistics for all outcome variables by condition and gender.

	Social warmth						Pride						Neutral					
	Male			Female			Male			Female			Male			Female		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Placebo																		
PA	9	4.52	1.61	11	4.65	1.26	10	4.71	0.79	8	4.51	1.50	12	3.84	1.19	10	4.01	1.40
RMET	9	68.83	17.00	9	74.07	6.94	10	72.50	12.86	8	70.14	12.58	10	73.06	12.43	10	68.06	10.58
IPT	8	66.25	13.02	8	65.00	7.56	10	63.00	21.11	8	60.00	9.26	11	53.64	10.27	10	62.22	9.72
LSAT	9	38.22	20.38	10	48.90	28.93	10	59.30	30.89	6	49.50	24.85	12	39.67	18.29	9	40.40	20.22
OT																		
PA	10	4.32	1.59	10	4.76	1.32	11	4.39	0.99	9	4.18	1.01	11	4.77	0.80	12	4.42	1.06
RMET	10	63.06	14.29	10	75.56	8.57	11	71.72	11.77	8	71.53	9.59	9	71.60	8.31	12	71.53	9.78
IPT	11	63.64	15.02	9	54.44	8.82	11	61.82	18.34	8	55.00	11.95	11	48.18	19.40	11	66.36	19.12
LSAT	9	35.22	17.06	8	26.00	15.19	10	41.70	26.87	9	48.89	20.77	10	42.80	28.27	12	60.33	26.95

Note. *N* = sample size per cell; *M* = mean; *SD* = standard deviation. PA = positive affect; RMET = Reading the Mind in the Eyes task; IPT = Interpersonal Perception Task; LSAT = Law School Admission Test; OT = oxytocin.

a nasal spray, which contained either 40 International Units (IU) of OT (Syntocinon spray, Novartis) or placebo (same compounds as Syntocinon minus OT).

In line with recommendations by Guastella et al. (2013), the nasal spray was administered via a metered multi-dose pump spray bottle, with each spray containing no > 100 μL. Participants were given the opportunity to blow their nose prior to administration in order to clear the nasal passage if needed. The MD-trained experimenter then primed the bottle and demonstrated a test spray. Participants were instructed to keep their head upright and to cover the opposite nostril and inhale while spraying. Participants were instructed to pause and take another slow inhale prior to alternating nostrils, and to sniff in any excess fluid as needed. This procedure was continued until the bottle was empty, which generally took under 5 min; the experimenter remained in the room with the participant for the entire process to monitor and encourage compliance.

Intranasal administration has been proposed to deliver OT to the brain via uptake by the olfactory or trigeminal nerves and by passive diffusion into the cerebrospinal fluid through the nasal epithelium (for detailed reviews see Churchland and Winkielman, 2012; Guastella et al., 2013; Veening and Oliver, 2013). Intranasal OT has been demonstrated to lead to significant increases in CSF OT levels in humans as measured by lumbar puncture (Striepens et al., 2013), although it was only detectable 75 min after administration and there is controversy surrounding the nature and the mechanisms of the effects of OT administration on the brain (Leng and Ludwig, 2015). Studies with other peptides (e.g., vasopressin) administered intranasally have found that they are absorbed within 30 min, as assessed by peptide levels in the cerebrospinal fluid (Born et al., 2002). Other experimental work with intranasal oxytocin in humans has consistently utilized an absorption period ranging between 40 and 50 min (Heinrichs et al., 2003; Kosfeld et al., 2005; Shamay-Tsoory et al., 2009). In our study, behavioral testing did not

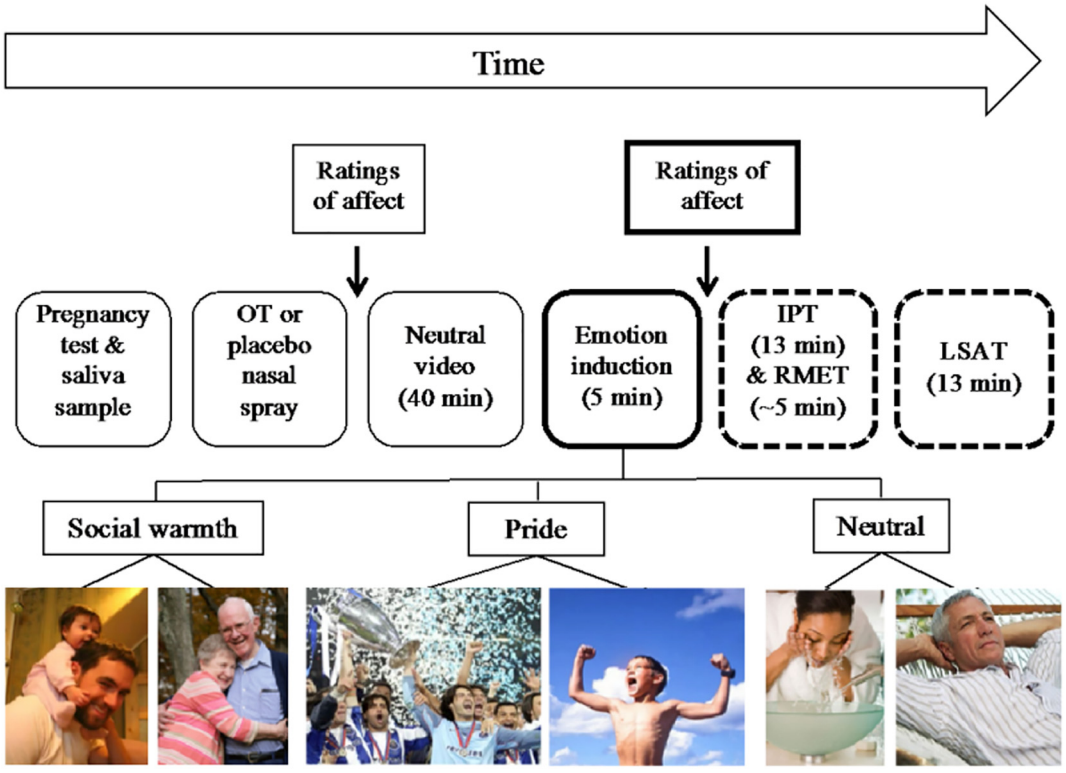

Fig. 1. Overview of the procedure. Oxytocin (OT) delivered via nasal spray was absorbed by the time of the tasks outlined in bold. Dashed outlines indicate the two portions of the procedure that were counterbalanced. RMET = Reading the Mind in the Eyes task; IPT = Interpersonal Perception Task; LSAT = Law School Admission Test.

begin until at least 45 min post-administration and continued for approximately 45 additional minutes. During the initial wait time, participants first completed baseline affect measures (see Outcome measures section below) and then watched an emotionally neutral video about hiking the Appalachian Trail.

2.3.2. Emotion inductions

45 min after the OT/placebo administration, we presented one of three five-minute slideshows that served as the emotion induction. Each slideshow consisted of photos and brief statements while music played. In the social warmth condition, pictures meant to induce feelings of social warmth and social connection, such as family and friends enjoying time together, photos of weddings, parents holding their infants, and people hugging in a warm and affectionate way were shown while the medley "Somewhere Over the Rainbow/What a Wonderful World" by Israel Kamakawiwo-ole played. Messages such as "The best times in life are spent with other people" and "The way to happiness is through love, friendship, and kindness with others" were embedded in the slideshow. In the pride condition, pictures meant to induce feelings of pride and success, such as athletes celebrating victory, school graduations, and winners receiving awards, were shown while the theme song from the movie *Chariots of Fire* played. The pictures were interspersed with statements such as "You can succeed at anything you put your mind to" and "The way to happiness is to fulfill your extraordinary potential." In the neutral condition, people saw images of a typical day. The slideshow described people waking up in the morning, eating breakfast, going to work or school, and falling asleep at night, with pictures of those events throughout the slideshow. The pictures were interspersed with statements such as "During the day, people have different tasks to do" and "At night, they get ready to go to sleep again." A song used for meditation played in the background.[2]

2.3.3. Pretesting emotion inductions

We recruited a different sample ($N = 114$; 60% female) to pretest the emotion inductions ($n = 40$ viewed the pride video; $n = 42$ viewed the social warmth video; $n = 32$ viewed the neutral video). Before and after viewing the videos, participants rated the extent to which they felt *warm*, *sociable*, *proud*, *successful*, *happy*, and *excited* on a 1 to 7 scale (anchored at "no feeling" to "intense feeling") (pre-video $\alpha = 0.88$; post-video $\alpha = 0.93$). We first examined increases in a composite of positive affect as a function of the emotion induction, controlling for baseline positive affect and gender and then followed up significant omnibus tests with post-hoc (Tukey) tests. Overall we observed a significant effect for the emotion induction for changes in positive affect, $F(2, 109) = 7.94$, $p = 0.0006$. The pride and social warmth videos engendered significantly larger positive affect ratings (*Ms* (*SDs*) = 4.3 (1.3), 4.55 (1.25), respectively) than the neutral video ($M = 3.8$ (1.6)). We then calculated a *social warmth* subscale by combining warm and sociable ($r = 0.61$) and a *pride* subscale by combining proud and successful ($r = 0.77$). Confirming the intended emotion induction, feelings of *social warmth* were significantly higher among those who watched the social warmth video ($M = 4.9$, $SD = 1.2$) than those assigned to the pride video ($M = 3.9$, $SD = 1.4$) or the neutral video ($M = 4.2$, $SD = 1.7$), $F(2, 109) = 11.61$, $p < 0.0001$. In contrast, ratings of *pride* were higher among those who watched the pride-induction video ($M = 4.24$, $SD = 1.5$) than the social warmth ($M = 3.7$, $SD = 1.5$) or neutral video ($M = 3.8$, $SD = 1.8$), $F(2, 109) = 3.16$, $p = 0.046$.

2.4. Outcome measures

2.4.1. Self-reported affect

Participants rated the degree to which they felt each of 13 emotions at the beginning of the experiment (this was taken immediately after the OT manipulation and prior to the emotion manipulation so it is considered a baseline measure of affect) and after the emotion induction. The items were completed on a scale of 1 (*no feeling*) to 7 (*intense feeling*) and were designed to assess social warmth: warm, loved, sociable, friendly, and close to loved ones; pride: dominant, proud, and successful; and general positive affect: happy, interested, inspired, excited, sad (reversed). Although these items are quite diverse, the composite measures of pre- and post-emotion induction positive affect (PA) had high internal consistency ($\alpha s > 0.87$), and the pride and social warmth subscales were highly correlated (baseline: $r = 0.64$, $p < 0.0001$; post-induction: $r = 0.77$, $p < 0.0001$). Thus, we focus on the PA composites (sad reverse coded; $M_{pre} = 4.38$; $SD = 1.06$; $M_{post} = 4.42$; $SD = 1.20$) rather than subscales (see Table 1 for a full breakdown of means and standard deviations by condition and gender). After rating their post-emotion induction affect, participants completed tasks assessing social and analytical performance.

2.4.2. Social perception tasks

To assess social perception, participants completed the Reading the Eyes in the Mind Task (RMET; Baron-Cohen et al., 2001) and the Interpersonal Perception Task (IPT; Costanzo and Archer, 1989). For the RMET, participants viewed 36 images of other individuals' eye regions and attempted to infer their affective state from the photo (*M* percent correct = 70.98; $SD = 11.41$). For the IPT, participants watched videos of ten 30- to 60-second scenarios and then answered a question about each of the scenes. For example, one of the scenes shows two people talking about a basketball game they just played, and participants are asked who won the game. The questions have objectively correct answers, and the task is meant to measure how well participants can interpret verbal and nonverbal behaviors (*M* proportion correct = 59.83; $SD = 15.22$). See Table 1 for a full breakdown of means and standard deviations for each task by condition and gender.

2.4.3. Analytical task

To assess analytical ability, participants completed up to sixteen logical reasoning questions from the Law School Admission Test (LSAT). Participants were given 13-min to answer as many of the questions as they could. Therefore not all participants completed all questions (*M* attempted = 8.27; Range = 1–16) and the percent correct was calculated based on only those attempted (*M* percent correct = 44.67; $SD = 24.62$). To match time spent on the LSAT and IPT, participants only completed the first ten scenarios of the IPT, which lasted 13 min. The order of the social perception and analytical tasks was counterbalanced in case one task influenced the other, but we did not observe any order effects. See Table 1 for a full breakdown of means and standard deviations of LSAT performance by condition and gender.

2.4.4. Additional measures

We also assessed time (in minutes) since nasal spray administration before the LSAT ($M = 64.03$; $SD = 14.83$) and IPT ($M = 69.45$; $SD = 10.52$), and verbal intelligence, measured with the vocabulary subtest of the Wechsler Adult Intelligence Scale and administered prior to the emotion induction (WAIS; $M = 25.19$, $SD = 8.87$). All results presented below were highly consistent when these variables were included in the analyses and they did not moderate any of the results presented below; therefore we present the results without these variables in the models. We also examined if there were any main effects of gender or if it interacted with our primary independent variables but found no significant associations, $ps > 0.07$, and all results held controlling for gender. As such, we present results without gender in the models.

[2] All stimuli, data and syntax are available upon request and online at: www.laurenhuman.com/publications

3. Results

3.1. Preliminary analyses – positive affect

We first examined whether the emotion inductions and OT administration were associated with changes in positive affect by examining a between subjects 2 (intranasal spray: oxytocin administration vs. placebo, double-blind) × 3 (emotion induction: social warmth vs. pride vs. neutral) ANOVA with change in PA from baseline to post-emotion induction as the dependent variable. Note that for these and all analyses that follow, we did not correct for multiple comparisons and therefore the results should be taken as preliminary. There was a significant main effect of emotion condition on change in PA (Neutral: $M = -0.21$, $SD = 0.82$; Warmth: $M = 0.30$, $SD = 0.63$; Pride: $M = -0.004$; $SD = 0.56$), $F(2, 113) = 5.42$, $p = 0.006$, but no significant main effects of OT condition, $F(1, 113) = 0.23$, $p = 0.63$ (Placebo: $M = -0.03$; $SD = 0.64$; OT: $M = 0.04$; $SD = 0.79$), or a significant interaction, $F(2, 113) = 24$, $p = 0.79$.

Examining the simple main effects of emotion induction revealed that the social warmth induction was associated with significant increases in PA relative to the neutral condition, $F(1, 113) = 9.10$, $p = 0.003$, $d = 0.58$, 0.95CI[0.20, 0.96], whereas change in PA from the pride induction did not significantly differ from either the warmth condition, $F(1, 113) = 3.41$, $p = 0.07$, $d = 0.36$, 0.95CI[−0.03, 0.74], or the neutral condition, $F(1, 113) = 1.74$, $p = 0.19$, $d = 0.26$, 0.95CI[−0.13, 0.64]. Overall, these effects suggest that the positive emotion inductions, and particularly the social warmth induction, did successfully enhance overall PA.[3] The lack of effect of OT administration on self-reported affect is in line with previous studies that have found little effect of OT administration on self-reported affect (Alvares et al., 2010; Buchheim et al., 2009; Kirsch et al., 2005; Kosfeld et al., 2005; Linnen et al., 2012).

3.2. Task performance

3.2.1. Social perception

On the RMET, there were no significant main effects of OT condition (Placebo: $M = 71.13$; $SD = 12.04$; OT: $M = 70.83$; $SD = 10.88$), $F(1, 110) = 0.02$, $p = 0.89$, $d = 0.03$, 0.95%CI[−0.34, 0.39], or the positive emotion inductions (Neutral: $M = 71.07$, $SD = 10.17$; Warmth: $M = 70.32$; $SD = 12.89$; Pride: $M = 71.55$; $SD = 11.37$), $F(2, 110) = 0.11$, $p = 0.90$, $ds = 0.04$–0.09 (Range of 0.95%CIs[−0.36, 0.49]), nor was there a significant interaction between OT condition and emotion induction condition, $F(2, 110) = 0.19$, $p = 0.83$ (see Fig. 2a). Similarly, on the IPT, there were no significant main effects of OT condition (Placebo: $M = 61.30$; $SD = 13.04$; OT: $M = 58.52$; $SD = 16.91$), $F(1, 109) = 0.94$, $p = 0.34$, $d = 0.18$, 0.95%CI[−0.19, 0.55], or the positive emotion inductions, (Neutral: $M = 57.38$, $SD = 16.68$; Warmth: $M = 62.22$; $SD = 12.22$; Pride: $M = 60.27$; $SD = 16.07$), $F(2, 109) = 1.02$, $p = 0.36$, $ds = 0.12$–0.23 (Range of 0.95CIs[−0.28, 0.63]), nor was there a significant interaction, $F(2, 109) = 0.35$, $p = 0.70$ (see Fig. 2b). Thus, in contrast to prior work, we did not observe that OT administration was associated with more accurate social perception, nor did we find any interactive effects as a function of the positive emotion inductions.[4]

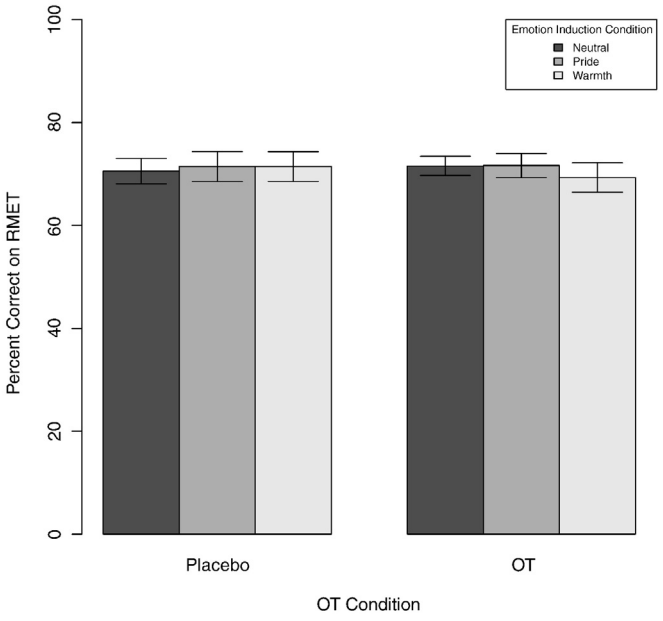

Fig. 2a. Reading the Mind in the Eyes Task (RMET) performance (percent correct on full task) in the social warmth, pride, and neutral emotion inductions, as a function oxytocin (OT) condition. Error bars represent standard errors. b. Interpersonal Perception Task (IPT) performance (percent correct on full task) in the social warmth, pride, and neutral emotion inductions, as a function oxytocin (OT) condition. Error bars represent standard errors.

3.2.2. Analytical performance

We next examined analytical task performance in a 2 × 3 ANOVA. We did not observe significant main effects of emotion induction condition, $F(2,109) = 2.52$, $p = 0.09$, nor OT condition, $F(1,109) = 0.20$, $p = 0.66$, on the percentage of correct answers on the LSAT (out of those attempted). However, there was a significant interaction between OT condition and emotion induction condition, $F(2, 109) = 3.48$, $p = 0.03$. To determine the nature of this interaction, we first conducted two orthogonal planned contrasts (Contrast 1: comparing the neutral emotion condition to the combined positive emotion conditions; Contrast 2: comparing the two positive emotion conditions to one another) before examining the simple main effects (which are presented in Fig. 3 and reported below).

3.2.2.1. Planned contrast 1: positive emotion vs. neutral inductions. First, on average across OT administration and placebo, the comparison between the neutral induction condition ($M = 46.18$; $SD = 24.54$) and the two positive emotion conditions combined together ($M = 43.73$; $SD = 24.80$) was not significant, $F(1109) = 0.28$, $p = 0.60$, $d = 0.10$, 0.95%CI[−0.28, 0.48]. That is, on average across OT condition, LSAT performance did not significantly differ for those in the neutral emotion

[3] We also examined the effects of the emotion inductions on change on the PA subscales separately. We observed a significant main effect of the emotion inductions on change in social warmth (Neutral: $M = -0.26$, $SD = 0.89$; Warmth: $M = 0.37$, $SD = 0.76$; Pride: $M = -0.09$; $SD = 0.56$), $F(2, 113) = 7.29$, $p = 0.001$. Simple main effects analyses revealed that the increase in warmth in the social warmth condition was significantly different from both the neutral condition, $F(1, 113) = 13.51$, $p = 0.0004$, $d = 0.71$, 0.95CI[0.32, 1.09], and the pride condition, $F(1, 113) = 6.53$, $p = 0.01$, $d = 0.50$, 0.95CI[0.11, 0.89], whereas the neutral and pride conditions did not significantly differ from each other, $F(1, 113) = 1.06$, $p = 0.30$, $d = 0.20$, 0.95CI[−0.18, 0.58]. There were no significant main or simple main effects on change on the pride subscale, all $ps > 0.14$.

[4] We also examined two orthogonal planned contrasts comparing the neutral vs. positive emotions combined and pride vs. social warmth and again did not find significant main effects or interactions, all $ps > 0.64$. Further, in line with previous work that has examined the effects of OT administration on difficult vs. easy items (Domes et al., 2007), we also differentiated the RMET items into easy vs. difficult items by taking a median split. In our sample, items that 72.46% or less of our participants got correct were deemed "difficult", which included the following items: 1, 2, 7, 10, 11, 13, 15, 16, 17, 18, 19, 23, 26, 27, 31, 33, 34, 35. The remaining 18 items were deemed "easy". However, we did not observe significant main effects or interactions when examining scores on difficult items only, all $ps > 0.33$.

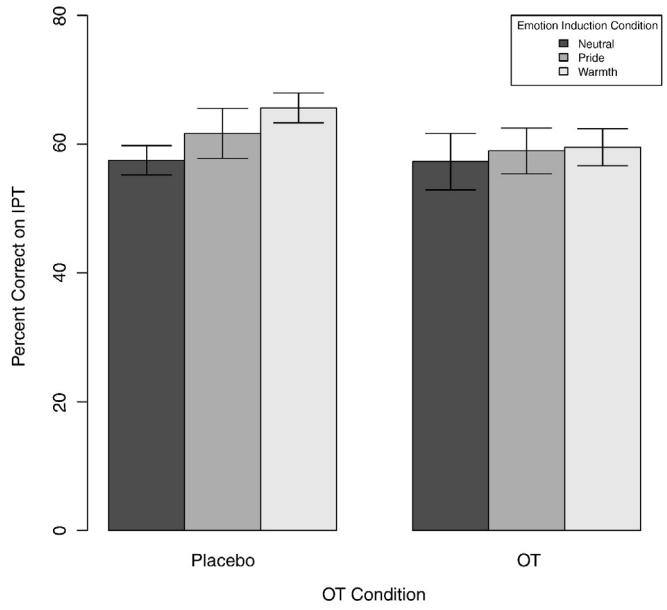

Fig. 2b. Interpersonal Perception Task (IPT) performance (percent correct on full task) in the social warmth, pride, and neutral emotion inductions, as a function oxytocin (OT) condition. Error bars represent standard errors.

induction vs. those in the two positive emotion induction conditions. However, there was a significant interaction between this planned contrast and OT condition, $F(1109) = 6.92$, $p = 0.0098$, indicating that how OT condition interacted with the emotion conditions was different in the neutral vs. the two positive emotion conditions. That is, if the presence of OT administration is linked to either increased or decreased benefits of positive emotion manipulations for LSAT performance, we should not necessarily expect a similar pattern to emerge for the neutral manipulation.

3.2.2.2. Planned contrast 2: pride vs. warmth inductions. The comparison between the two positive emotion inductions (pride vs. social warmth) was significant, such that, on average across OT conditions, participants in the pride condition performed significantly better on the LSAT ($M = 49.91$; $SD = 26.12$) than participants in the social warmth condition ($M = 37.72$; $SD = 22.17$), $F(1109) = 4.75$, $p = 0.03$, $d = 0.44$, 0.95%CI[0.04, 0.84]. However, we did not observe a significant interaction with OT condition, $F(1109) = 0.05$, $p = 0.83$, indicating the nature of the relationship with OT condition was similar for the pride and warmth conditions. That is, if the presence of OT administration is linked to either increased or decreased benefits of pride for LSAT performance, a similar pattern should emerge for the social warmth manipulation.

3.2.2.3. Simple main effects of emotion induction condition: within placebo condition. Even though the results above indicate that the pride and warmth manipulations interacted with the OT condition in a similar way (planned contrast 1), given the mean level differences in the associations between pride vs. social warmth on LSAT performance (planned contrast 2), we examined the simple main effects of each positive emotion induction condition vs. neutral on LSAT performance separately within the placebo vs. OT administration conditions, as illustrated in Fig. 3. Starting with pride, within the placebo condition, the pride induction was associated with significantly better performance on the LSAT ($M = 55.63$; $SD = 28.33$) compared with the neutral condition ($M = 40.00$; $SD = 18.72$), $F(1, 109) = 3.97$, $p = 0.049$, $d = 0.40$, 0.95%CI[0.002, 81]. In contrast, looking at social warmth, within the placebo condition, the social warmth induction was not associated with significantly better LSAT performance ($M = 43.84$; $SD = 25.16$) relative to the neutral condition ($M = 40.00$; $SD = 18.72$), $F(1, 109) = 0.26$, $p = 0.61$, $d = 0.10$, 0.95%CI[−0.29, 0.50]. Thus, in the absence of OT administration (i.e., in the placebo condition), the pride induction was associated with better analytical performance compared with the neutral condition and the warmth induction was associated with similar analytical performance relative to the neutral condition.

3.2.2.4. Simple main effects of emotion induction condition: within OT administration condition. In the OT administration condition, however, the pride induction was no longer associated with better performance on the LSAT ($M = 45.11$; $SD = 23.80$) relative to the neutral condition ($M = 52.36$; $SD = 28.33$), $F(1, 109) = 0.94$, $p = 0.33$, $d = 0.20$, 0.95%CI[−0.20, 0.60]. Further, in the OT administration condition, participants in the social warmth condition performed significantly worse ($M = 30.88$; $SD = 16.40$) than those in the neutral condition ($M = 52.36$; $SD = 28.33$), $F(1, 109) = 7.76$, $p = 0.006$, $d = 0.56$, 0.95%CI[0.16, 0.96]. Thus, when pride and warmth inductions occurred alongside OT administration, analytical performance was hindered, with the pride induction no longer associated with better performance and the warmth induction becoming associated with worse performance.

3.2.2.5. Simple main effects of OT condition. None of the simple effects of OT condition on LSAT performance within emotion induction conditions were statistically significant. Specifically, performance in the placebo vs. OT administration conditions did not significantly differ in the neutral condition, $F(1, 109) = 2.95$, $p = 0.09$, $d = 0.32$, 0.95%CI[−0.05, 0.69], pride condition, $F(1, 109) = 1.68$, $p = 0.20$, $d = 0.24$, 0.95%CI[−0.13, 0.61], or warmth condition, $F(1, 109) = 2.64$, $p = 0.11$, $d = 0.30$, 0.95%CI[−07, 0.67]. However, it is interesting that in the neutral condition LSAT performance was better in the OT administration condition ($M = 52.36$; $SD = 28.33$) compared with the placebo condition ($M = 40.00$; $SD = 18.72$), whereas in both the pride and warmth conditions, performance was worse in the OT administration condition (pride: $M = 45.11$; $SD = 23.80$; warmth: $M = 30.88$; $SD = 16.40$) compared with the placebo condition (pride: $M = 55.63$; $SD = 28.33$; warmth: $M = 43.84$; $SD = 25.16$). Although non-significant, the effects

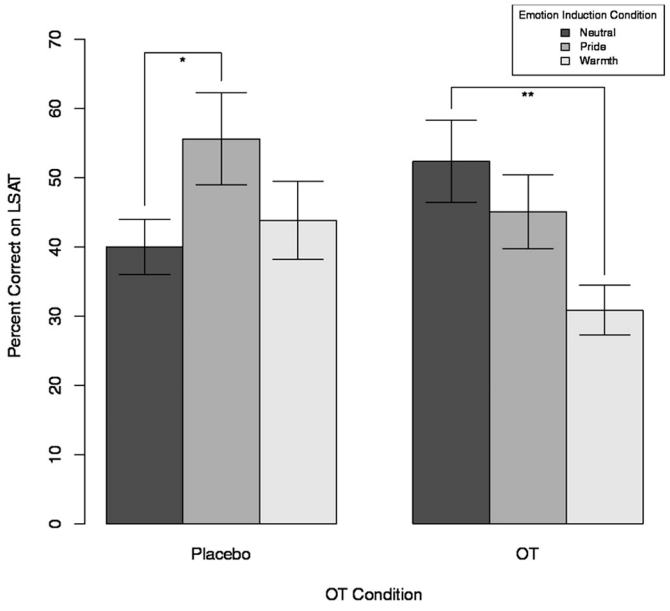

Fig. 3. Law School Admission Test (LSAT) performance (percent correct out of those attempted) in the social warmth, pride, and neutral emotion inductions, as a function oxytocin (OT) condition. Error bars represent standard errors. Statistically significant comparisons are depicted. $^{**}p < 0.01$, $^{*}p < 0.05$.

were moderate in magnitude and in line with the results above, suggesting that combining OT administration with positive emotion inductions is more likely to hinder than benefit analytical performance.

4. General discussion

Both OT administration and positive emotion inductions have been tentatively linked to positive social and cognitive processes but what happens when they are paired together? In the first study we are aware of that manipulates both OT administration and positive emotions we examined their independent and interactive effects on social and analytical performance. Of note, we did not find evidence that either OT administration or positive emotion inductions were associated with better social perception task performance, nor did they interact with one another in their associations with social perception. There were also no main effects of OT condition and positive emotion inductions on analytical performance; however, we did observe a significant interaction, such that, when combined with OT administration, the pride induction was no longer associated with better performance and the social warmth induction was associated with worse analytical performance relative to the neutral condition. Specifically, whereas in the placebo condition, the pride and warmth inductions appeared to be beneficial and benign, respectively, when paired with OT administration, the pride induction was no longer beneficial and warmth became detrimental. Thus, in line with evidence that high levels of positive emotions (Gruber et al., 2011) and higher dosages of administered OT (Cardoso et al., 2013, 2014) can have diminishing returns or even negative consequences, we found that combining OT administration with positive emotions inductions results in a similar pattern, with potential negative consequences for analytical thinking.

It is noteworthy that OT administration did not significantly improve social perception, given previous literature suggesting that OT administration enhances the accuracy of social perception (e.g., Bartz et al., 2010a) and performance on the RMET in particular (Domes et al., 2007; Feeser et al., 2015; Guastella et al., 2010), a task we also examined here. However, the effects of OT administration on social perception (and many other outcomes) are often highly context dependent (for review see Bartz et al., 2011; Van IJzendoorn and Bakermans-Kranenburg, 2012). Indeed, OT administration has been shown to have greater benefits for social cognition for individuals lower in social-emotional functioning and has generally been observed in male or clinical samples (e.g., Bartz et al., 2010a; Guastella et al., 2010), which may contribute to the lack of associations with the current gender-diverse and healthy sample. However, other work has recently failed to replicate this effect (Radke and de Bruijn, 2015) and our sample was reasonably well powered to detect effects of at least medium size, which have been observed in prior studies finding positive effects (e.g., Feeser et al., 2015). This suggests that this null main effect of OT administration on social perception in healthy adults may indeed be meaningful or that, if an effect does exist, it is smaller than previously suggested. Indeed, a recent review paper concluded that the average effect size in OT administration studies on social cognition and behavior is $d = 0.28$ (Walum et al., 2016), although even this estimate is likely to be inflated due to factors such as reporting and publication bias (Lane et al., 2016; Walum et al., 2016). Thus, it is important that future work continues to examine the proposed association between OT administration and social perception with even more highly powered studies.

We similarly did not find that the positive emotion inductions had strong effects on social perception, either independently or as a function of OT administration condition. However, we did find an interactive association between positive emotion inductions and OT administration with LSAT performance. Specifically, within the placebo condition, the pride induction was associated with better performance on the LSAT relative to the neutral condition. This finding is consistent with prior work on positive emotions (see Isen, 2000), and could be driven by a broadened mindset (Fredrickson, 2001) and/or enhanced motivation (Forgas and Vargas, 2000). However, this effect was no longer observed within the OT administration condition. Further, within the placebo condition, the social warmth induction was not significantly associated with differential analytical performance compared with the neutral condition, but was associated with significantly worse performance when paired with OT administration. Indeed, the social warmth induction and OT administration combined together were associated with the lowest analytical task performance of all conditions. Taken together, these findings suggest that combining positive emotion states with acute increases in OT may have negative consequences for analytical thinking – reducing the potential benefits of pride and creating detriments for warmth.

These findings are somewhat in line with prior research suggesting that OT administration can hinder analytical thinking (De Dreu et al., 2013), although rather than a main effect we instead only found such a pattern in combination with positive emotion inductions. In contrast, within the neutral emotion condition, OT administration was actually moderately positively associated with analytical performance, although this effect was non-significant. Thus, additional research examining the context-specific effects that OT administration may have for analytical thinking is needed. Indeed, it seems plausible that in some contexts OT administration could benefit analytical task performance, perhaps via anxiety-reducing mechanisms (see Churchland and Winkielman, 2012; Neumann, 2008; Uvnäs-Moberg, 1998) or an enhanced approach orientation (De Dreu et al., 2013; Kubzansky et al., 2012).

Interestingly, the pattern of results was similar for both the pride and social warmth emotion inductions. In particular, although the pride and social warmth inductions differed from each other in terms of their effects on analytical task performance (with pride being associated with better performance than warmth), their interaction with OT administration was highly similar. That is, the pride and social warmth inductions were both associated with worse performance when paired with OT administration compared with placebo. Thus, despite the arguably more social nature of OT, its interactive effects with positive emotions did not differ as a function of how social the emotion induction was. Thus, OT administration may interact with positive emotion states more generally. Alternatively, pride may actually be more social in nature than previously described (Kitayama et al., 2006); indeed, pride is relevant to a range of social processes, such as social status and influence, and has even been linked to prosocial tendencies, such as greater positivity towards out-group members (see Tracy et al., 2014 for review).

At present, it is unclear why it is that combining OT administration with positive emotion inductions would be associated with worse analytical performance. One possibility is that the psychological inductions may have resulted in higher circulating levels of OT. Prior work suggests that psychological inductions involving emotional stimuli may increase plasma OT levels, within just several minutes of induction (e.g., Barraza and Zak, 2009), although there are issues with peripheral OT measurement approaches that cast doubt on such findings (see McCullough et al., 2013 for a review). Nevertheless, one potential explanation for the current results is that the positive emotion inductions combined with the administration of OT increased levels past the peak of OT-induced positive effects (see Cardoso et al., 2013, 2014), towards less positive outcomes. However, it is unclear whether positive emotion inductions could sufficiently alter circulating OT levels, and this possibility cannot be directly tested in the current study.

It is also possible that combining OT administration and the positive emotion inductions resulted in a subjective state that in turn hindered performance. Although we did not see that combining OT administration and positive emotion inductions interacted in their associations with positive affect, it is possible that other aspects of participants' subjective experiences, not measured or within explicit awareness, were altered. For example, the combination of OT administration and the social warmth induction may have lessened motivation. In turn, lowered motivation may be especially detrimental for analytical tasks. Additional

research is needed to better understand the psychological and biological mechanisms underlying these effects.

There are several limitations to the current study that should be noted. First, these results must be interpreted in light of the sample size of the current study – although a relatively large sample overall, particularly in comparison to the broader OT administration literature (Walum et al., 2016), the sample size within conditions (roughly 20 per cell) was smaller than ideal, making the simple effects less strongly powered. Further, as noted above, we did not correct for multiple comparisons in our analyses. Thus, even though we are encouraged that the pattern of associations with OT administration and analytical performance was consistent across the two positive emotion conditions, these results should be interpreted as preliminary and will hopefully be replicated and extended in future research with larger samples.

Further, given recent dose-response findings indicating that administration of higher dosages of OT can be less beneficial (Cardoso et al., 2013, 2014), it is important to note that our dosage of OT (40 IU), although common (e.g., Zak et al., 2007), was higher than the often-used 24 IU. This could play a role in why OT administration was not associated with better performance on social perception tasks in the current study. This higher dosage may have also made it more likely to detect negative associations with analytical performance when combining OT administration and positive emotion inductions. It would be interesting for future research to examine these associations at different dosages of OT.

Finally, the benefits of relying on the administration of OT in a double-blind experiment are the clear elimination of demand characteristics, but emotion inductions using film, music, and images, like we used here, are often transparent manipulations that may signal to participants the intended behavior or actions. Though this criticism can be leveled at most emotion induction studies that do not use subliminal, below awareness manipulations, it is still an important limitation to acknowledge. That noted, the fact that the key effects on analytic performance were interactions with OT/placebo reduces some concern with the demand characteristics inherent in the emotion manipulations.

In sum, we examined the interplay between OT administration and positive emotion inductions by manipulating both within a single study. Even though both OT administration and positive emotion inductions have been suggested to have positive effects on social perception and cognition, we found little evidence of direct or interactive benefits of either for social perception. Further, combining positive emotion inductions with OT administration appeared to have detrimental effects for analytical thinking. Overall, these findings are in line with suggestions that there are limits to the benefits of both OT administration and positive emotion and suggest that, when combined together, they may even have negative implications.

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