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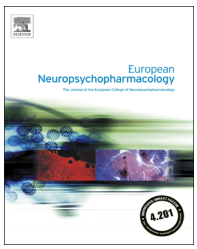

A human tendency to anthropomorphize is enhanced by oxytocin

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Abstract
In the course of human evolution, the brain has evolved into a highly sensitive detector of social signals. As a consequence of this socially driven adaptation, humans display a tendency to anthropomorphize, that is they attribute social meaning to non-social agents. The evolutionarily highly conserved hypothalamic peptide oxytocin (OXT) has been identified as a key factor attaching salience to socially relevant cues, but whether it contributes to spontaneous anthropomorphism is still elusive. In the present study involving 60 healthy female participants, we measured salivary OXT concentrations and explored the effect of a single intranasal dose of synthetic OXT (24 IU) or placebo (PLC) on anthropomorphic tendencies during participants' verbal descriptions of short video clips depicting socially and non-socially moving geometric shapes. Our results show that endogenous OXT concentrations at baseline positively correlated with the attribution of animacy to social stimuli. While intranasal OXT had no modulatory effect on arousal ratings and did not make the participants more talkative, the treatment boosted anthropomorphic descriptions specifically for social stimuli. In conclusion, we here provide first evidence indicating that spontaneous anthropomorphism in women is facilitated by oxytocin, thereby enabling a context-specific upregulation of the propensity to anthropomorphize environmental cues.

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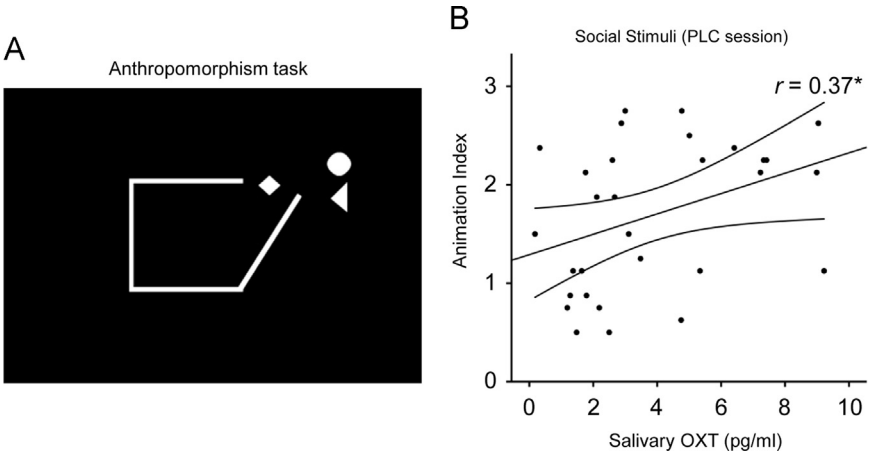

Figure 1 Endogenous oxytocin (OXT) concentrations and anthropomorphism. Anthropomorphism was assessed by asking participants to describe short videos depicting an ensemble of white geometric shapes (a triangle, a diamond, and a circle) moving either socially or non-socially within a static environment. (A) Shown is a still frame from a social stimulus. When the shapes move, they seem to have goals, intentions, and emotions: in short – to have minds (Feldman and Tremoulet, 2008). (B) For social stimuli in the placebo session, higher salivary baseline OXT concentrations were associated with a higher Animation Index measuring the general level of social attribution. Abbreviations: OXT, oxytocin; PLC, placebo; $^{*}P<0.05$.

1. Introduction

Current perspectives on the evolution of the human brain suggest that its extraordinary size and complexity reflect an adaptive response to the immense cognitive demands emerging from social group living and monogamous pair-bonding (Dunbar and Shultz, 2007). A unique consequence of this social adaption may be human consciousness (Graziano and Kastner, 2011), and along with it the inherent propensity to anthropomorphize, that is to imbue animacy and social meaning to various non-social agents (Epley et al., 2007).

Pre-historic art (e.g. the "Löwenmensch" figurine; Conard, 2003) dating back to the upper paleolithic represents the most ancient evidence of anthropomorphism, suggesting that it constitutes a social attribution bias intrinsically tied to the functional architecture of human perceptual machinery. At present, surprisingly little is known about the molecular substrates of anthropomorphism, but one can assume that the underlying biological signals are deeply rooted in pathways intimately linked to human sociality and sexual reproduction.

Since the seminal experiments by Heider and Simmel (1944) in female volunteers, anthropomorphism has been examined in a plethora of neuroimaging and lesion studies, collectively showing that the fusiform face area and amygdala are engaged by the perception of human-like interactions among non-social agents (Heberlein and Adolphs, 2004; Moran et al., 2012; Schultz et al., 2003). Consistent with this neurocircuitry model are recent posits that anthropomorphism has evolved to avoid social exclusion (Epley et al., 2008) as well as findings of impoverished social attributions in populations with amygdala dysfunction, including autism (Klin and Jones, 2006) and schizophrenia (Pedersen et al., 2011).

Central to human sociality and sexual reproduction is the evolutionarily highly conserved hypothalamic peptide oxytocin (OXT), which modulates neural activity in both the fusiform face area (Petrovic et al., 2008) and amygdala (Domes et al., 2010; Eckstein et al., 2014a; Striepens et al., 2012) and is currently being assessed for its potential to ameliorate the social deficits associated with autism (Aoki et al., 2014) and schizophrenia (Feifel et al., 2010). OXT has been implicated in mediating a diverse social behavioral repertoire ranging from basic approach-avoidance tendencies (Scheele et al., 2012) and monogamous pair-bonding (Scheele et al., 2013) to the domains of morality (Scheele et al., 2014b), empathy (Hurlemann et al., 2010), and mentalizing (Domes et al., 2007). Furthermore, OXT promotes social biases including ethnocentric in-group favoritism (De Dreu et al., 2011) and induces human-like interactions with non-living entities in women (Rilling et al., 2014). Given this empirical background, we sought to establish directly whether a propensity to anthropomorphize would be augmented by elevated OXT signaling. Specifically, the rationale was to present brief social and non-social animations based on the classic Heider and Simmel task (Figure 1A) to 60 healthy female subjects administered with either 24 IU of synthetic OXT or placebo (PLC) intranasally. The verbal descriptions of the depicted scenarios served as behavioral index of anthropomorphism and were complemented by salivary measures of OXT concentrations before and after the experiment. We hypothesized that if anthropomorphism is inherent to the perceptual machinery of the social brain, then the attribution of animacy and social meaning should vary as a function of endogenous OXT activity at baseline and be susceptible to its exogenous elevation.

2. Experimental procedures

2.1. Subjects

Sixty healthy, non-smoking adult females (mean age $\pm$S.D.: 23.68 $\pm$ 2.67 years) participated in the present study after giving written, informed consent. Subjects were free of

current and past physical or psychiatric illness, as assessed by medical history and the Mini-International Neuropsychiatric Interview (Sheehan et al., 1998). None of the female participants were pregnant or lactating, and all used oral contraceptives. Furthermore, all participants were naive to prescription-strength psychoactive medication and had not taken any over-the-counter psychoactive medication in the past 4 weeks. Participants were asked to maintain their regular bed and wake times and to abstain from caffeine and alcohol intake on the day of the experiment. Tobacco smokers were excluded from participation. OXT -and PLC-treated groups showed no a priori differences regarding age, education, pre-treatment verbal IQ assessed with the Mehrfach-Wortschatz-Intelligenztest Teil B (MWT-B) (Lehrl et al., 1995), or pre-treatment anthropomorphism assessed with the Individual Differences in Anthropomorphism questionnaire (IDAQ) (Waytz et al., 2014) (all P values >0.05; cf. Table 1). The study was approved by the institutional review board (IRB) of the Medical Faculty of the University of Bonn and carried out in compliance with the latest revision of the Declaration of Helsinki.

2.2. Experimental design

In this study, we applied a randomized, PLC-controlled, double-blind, between-group design. Subjects were randomly assigned to either intranasal administration of OXT (24 IU; Syntocinon-Spray, Novartis; three puffs per nostril, each with 4 IU OXT) or PLC (0.9% sodium chloride solution) 45 min before the start of the experiment.

2.3. Anthropomorphizing task

All subjects viewed eight social and eight non-social videos which were randomly chosen from 16 social and 16 non-social videos used in a previous study (Moran et al., 2012; Schultz et al., 2003) and based on the classic Heider and Simmel movie (Heider and Simmel, 1944). Each video lasted for 15.1 s and contained three types of white geometric figures (a triangle, a diamond, and a circle) that moved around the outline of a larger rectangle (cf. Figure 1A). The social videos were scripted to follow a social story (e.g. hide-and-seek or a fight) and the non-social videos depicted the same geometric figures moving around like "bumper cars". Subjects were asked to tell the experimenter after each video what they saw; no further information about the content of the videos or the aim of the study was given. Subsequently, the videos were presented a second time and the participants were asked to use a visual analog scale to rate their emotional arousal (0=minimum, 100=maximum) while watching the video.

The verbal reports of the participants were voice-recorded and later transcribed. In line with previous research, anthropomorphizing was assessed by coding each narrative (Klin, 2000) and by using the computer program Linguistic Inquiry and Word Count 2007 (LIWC2007) with a German dictionary. We used a previously established (Klin, 2000) detailed coding system to quantify the sophistication of social attributions. The Animation Index provides an overall summary of the participant's capacity for attributing social meaning (0=no social attribution; 6=very high level of social attribution). The rater was unaware of the participants' treatment, and 50% of the protocols were scored by a second rater, which yielded a high inter-rater reliability (intraclass correlation using an absolute agreement definition=0.79).

The program LIWC2007 counts the percentage of words per sample in each of 74 categories. In line with previous studies (Heberlein and Adolphs, 2004), we focused on a target category "Social Processes" including social pronouns (e.g. "he") or communications verbs (e.g. "share") and a control category "Movement" including words such as "move" or "go". Most anthropomorphic measurements showed high internal consistency (Animation Index: social stimuli Cronbach's $\alpha=0.86$; non-social stimuli Cronbach's $\alpha=0.83$; Social Processes: social stimuli Cronbach's $\alpha=0.80$; non-social stimuli Cronbach's $\alpha=0.73$; Motion: social stimuli Cronbach's $\alpha=0.58$; non-social stimuli Cronbach's $\alpha=0.75$). For an additional item-based analysis, all narratives of the PLC group were evaluated with regard to the LIWC2007 category "Positive Emotion" (e.g. "nice",

Table 1 Demographics, pre-treatment neuropsychological performance and pre-treatment salivary oxytocin concentrations.

	OXT group mean (±SD)	PLC group mean (±SD)	t	P
Age (years)	23.50 (2.64)	23.87 (2.74)	−0.53	0.60
Education (years)	15.90 (3.70)	16.48 (4.26)	−0.55	0.59
Verbal IQ[a]	30.24 (2.61)	31.34 (2.76)	−1.57	0.12
Depressive symptoms[b]	3.12 (2.77)	3.42 (4.08)	−0.31	0.76
Trait anxiety[c]	38.51 (6.85)	39.00 (7.01)	−0.26	0.80
Anthropomorphism[d]	53.70 (25.07)	48.05 (22.99)	0.75	0.46
Baseline OXT concentration (pg/ml)	4.98 (2.49)	3.88 (2.69)	1.62	0.11

OXT, oxytocin; PLC, placebo.

[a]Verbal IQ based on lexical decisions was assessed by the Mehrfachwahl-Wortschatz-Intelligenz-Test Teil B (MWT-A) (maximum possible score 37).

[b]Depressive symptoms were assessed by the self-report Beck's Depression Scale (BDI, Version II).

[c]Anxiety symptoms were assessed by the State Trait Anxiety Inventory (STAI).

[d]Pre-treatment individual differences in anthropomorphism were assessed by the individual differences in anthropomorphism questionnaire (IDAQ).

"sweet"). Subsequently, social and non-social videos were separately median-dichotomized in high and low positive items.

2.4. Salivary oxytocin collection and analysis

Saliva samples were collected before the nasal spray administration and after the experiment using pre-chilled Salivettes (Sarstedt, Rommelsdorf, Germany). Salivettes were immediately centrifuged at 4180*g* for 2 min and aliquoted samples were stored at −80 °C until assayed. Salivary OXT was extracted and quantified using a highly sensitive and specific radioimmunoassay (RIAgnosis, Munich, Germany) (Kagerbauer et al., 2013). The limit of detection was 0.1–0.5 pg depending on the age of the tracer. Intra-assay and inter-assay coefficients of variability were <10%. All samples to be compared were assayed in the same batch, i.e. under intra-assay conditions. One participant in the OXT group did not provide saliva samples, hence yielding 29 pre-treatment and 29 post-treatment measurements in the OXT group.

2.5. Statistical analysis

Demographic, neuropsychological, and behavioral data were analyzed using IBM SPSS Statistic 21 (IBM, New York, NY, USA). Quantitative behavioral data were compared using dependent *t*-tests and Pearson's product-moment correlation was used for correlation analysis. Eta-squared and Cohen's *d* were calculated as measures of effect size. For qualitative variables, Pearson's chi-squared tests were used. All reported *P*-values are two-tailed if not otherwise noted, and *P*-values of $P<0.05$ were considered significant.

3. Results

To control for potentially confounding effects of OXT on mood and anxiety, all subjects completed the Positive and Negative Affective Scale (PANAS) (Watson et al., 1988) and the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970) immediately before the nasal spray administration and after the experimental task. Analysis of these variables revealed no significant differences between the PLC- and OXT-treated subjects (all *P* values >0.05; cf. Table 2). Thus, between-group differences cannot be attributed to potential confounding effects of OXT on mood or anxiety. After the experiments, participants were asked to guess whether they had received OXT or PLC; again, there was no significant group difference ($\chi^2_{(1)}=2.59$, $P=0.11$).

3.1. Baseline oxytocin concentrations

A repeated measures analysis of variance (ANOVA) with the within-subject variable "time" (pre, post), the between-subject factor "treatment" (OXT, PLC), and the salivary OXT concentrations as dependent variable yielded main effects of time ($F_{(1,57)}=69.66$, $P<0.01$, $\eta^2=0.55$) and treatment ($F_{(1,57)}=54.91$, $P<0.01$, $\eta^2=0.49$) as well as an interaction of time and treatment ($F_{(1,57)}=58.13$, $P<0.01$, $\eta^2=0.51$). Post hoc *t*-tests showed a significant increase in OXT concentrations in the OXT group (pre: "Mean ± SD" 4.98 ± 2.49 pg/ml, post: 21.43 ± 10.53 pg/ml, $t_{(28)}=8.70$, $P<0.01$, $d=2.15$), but not in the PLC group (pre: 3.88 ± 2.69 pg/ml, post: 4.63 ± 5.08 pg/ml, $t_{(29)}=0.85$, $P=0.40$, $d=0.18$). These findings have to be interpreted cautiously since elevated salivary OXT concentrations following intranasal OXT administration could be partially attributed to OXT draining from the nasal cavity into the saliva. Intriguingly, however, in the PLC group the baseline OXT concentration positively correlated with the Animation Index for social stimuli ($r=0.37$, $P=0.04$, cf. Figure 1B), but not for non-social ones ($r=0.26$, $P=0.16$). There were no significant associations with the use of words of the Social Processes category (all *P*s >0.15).

3.2. Intranasal oxytocin administration

A repeated measures ANOVA with the within-subject variable "sociality" (social, non-social), the between-subject factor "treatment" (OXT, PLC), and the Animation Index as dependent variable revealed a main effect of sociality ($F_{(1,58)}=247.89$, $P<0.01$, $\eta^2=0.81$) and an interaction of sociality and treatment ($F_{(1,58)}=5.02$, $P=0.03$, $\eta^2=0.08$). The general level of social attribution was higher for the narratives of social (1.86 ± 0.64) than non-social videos (0.84 ± 0.58), and OXT selectively enhanced the attribution of animacy to social stimuli ($t_{(48.65)}=2.13$, $P=0.04$, $d=0.56$, cf. Figure 2A), but not non-social stimuli ($t_{(58)}=0.33$, $P=0.74$, $d=0.09$). Social scenarios were also rated as more arousing than non-social ones ($t_{(52)}=7.59$, $P<0.01$, $d=0.74$), but the treatment had no influence on self-report arousal ratings (all *P*s >0.38). Importantly, a thesaurus-based computer analysis confirmed that participants in the OXT group compared to the PLC group used significantly more words of the Social Processes category to describe social videos ($t_{(41.83)}=2.59$, $P=0.01$, $d=0.68$; cf. Figure 2B), but not non-social stimuli ($t_{(58)}=0.03$, $P=0.98$, $d=0.01$). An analysis with the additional factor "valence" (high and low positive items) did not yield any significant interactions with the treatment (Animation Index: all *P*s >0.71; Social Processes: all *P*s >0.72). Furthermore, OXT had no effect on the Movement control category (all *P*s >0.18) and did not alter the number of words used to describe social (OXT: 23.82 ± 13.66 words, PLC: 29.21 ± 19.55, $t_{(58)}=-1.24$, $P=0.22$, $d=-0.32$) or non-social videos (OXT: 17.49 ± 10.10, PLC: 19.85 ± 12.28, $t_{(58)}=-0.82$, $P=0.42$, $d=-0.21$).

4. Discussion

The present study aimed at elucidating the modulatory role of OXT in the behavioral expression of spontaneous anthropomorphism. Our results indicate that higher endogenous OXT concentrations are associated with more pronounced anthropomorphic tendencies and that exogenous OXT can further potentiate this anthropomorphic attribution bias if there are social features inherent to the stimulus material. Our findings thus suggest that OXT constitutes a biological signal involved in the contextual framing and regulatory adjustment of anthropomorphism.

Table 2 State measurement of anxiety and mood.

	OXT group mean (±SD)	PLC group mean (±SD)	*t*	*P*
STAI - pre[a]	32.80 (4.49)	34.00 (4.60)	−1.02	0.31
STAI - post[a]	34.67 (5.61)	34.41 (4.74)	0.19	0.85
PANAS - positive - pre[b]	30.37 (4.85)	28.53 (6.68)	1.22	0.23
PANAS - positive - post[b]	25.97 (7.22)	25.50 (6.06)	0.27	0.79
PANAS - negative - pre[b]	10.97 (1.50)	10.80 (1.10)	0.49	0.62
PANAS - negative - post[b]	11.10 (2.19)	11.13 (1.76)	−0.07	0.95

Abbreviations: OXT, oxytocin; PLC, placebo.
[a]State anxiety before and after the experiment was assessed using the State Trait Anxiety Inventory (STAI).
[b]Mood before and after the experiment was assessed using the Positive and Negative Affect Schedule (PANAS).

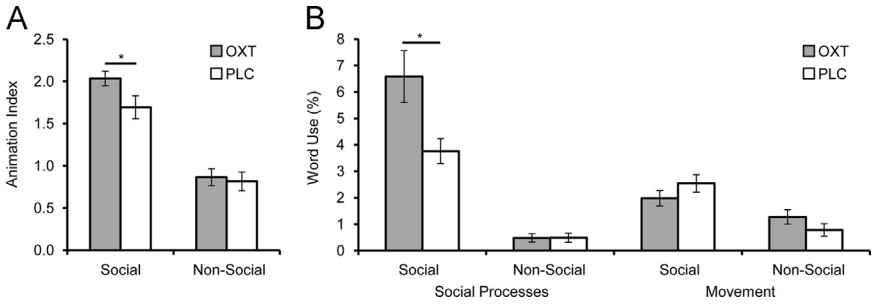

Figure 2 Effects of intranasal oxytocin (OXT) on anthropomorphism. (A) The intranasal administration of 24 IU of OXT selectively increased the Animation Index of narratives for social stimuli. (B) An additional analysis with a dictionary software confirmed that participants described social videos with more words related to social processes under OXT compared to placebo (PLC). In addition, OXT had no effect on the use of movement-related words which served as a control category. Abbreviations: OXT, oxytocin; PLC, placebo; $^{*}P<0.05$.

Current psychological accounts of social attribution emphasize sociality motivation and elicited agent knowledge as theoretical determinants of human anthropomorphism. It has therefore been suggested that the greater likelihood of young children to anthropomorphize is related to their strong concept of "self" (Waytz et al., 2010). Thus, OXT may influence anthropomorphism by increasing sensitivity to the salience of social cues or by modulating interoceptive inference and bodily self-awareness (Eckstein et al., 2014b; Preckel et al., 2014a; Scheele et al., 2014a). Consistent with this view is the observation that social attributions of sensory awareness to other people and to oneself share common neural substrates such as the temporoparietal junction (Cullen et al., 2014; Kelly et al., 2014).

An OXT-induced enhancement of anthropomorphism may be evolutionarily adaptive because failures to adequately anthropomorphize could prove even more costly than over-attribution (Guthrie, 1995), but it is also conceivable that this oxytocinergic mechanism subserves alternative functions. According to the "tend-and-befriend" model proposed by Taylor (2006), gaps in positive social relationships can induce elevations in endogenous OXT concentrations, which in turn are believed to prompt affiliative efforts aimed at restoring positive social contacts. We here extend this model by showing that higher OXT concentrations are also linked to a more pronounced inclination to imbue social meaning to non-social agents and actions, thereby providing a means to alleviate the pain of social disconnection (Epley et al., 2008). Our finding that OXT did not alter the number of words used to describe the videos is consistent with observations that OXT increases the willingness to share emotions, but does not make people more talkative (Lane et al., 2013). Likewise, an electroencephalography study demonstrated that OXT enhanced the suppression of mu/alpha and beta rhythms selectively during the perception of continuous biological motion, but not during non-social stimuli (Perry et al., 2010). Since the suppression of mu rhythms over sensor-motor regions may reflect a stronger mirror neuron activity, we tentatively hypothesize that OXT exerts its anthropomorphic effects via recruitment of the human mirror neuron system (Gazzola et al., 2007). Further evidence for a selective effect of OXT on social stimuli also comes from our previous studies documenting that OXT potentiates the social reinforcement advantage in a feedback-guided item-category association task (Hurlemann et al., 2010) and that the peptide modulates approach behavior towards pleasant social, but not non-social, pictures (Scheele et al., 2012).

In the present study, higher arousal values were assigned to videos depicting human-like movements, but the OXT effect on anthropomorphism was not accompanied by an increment of self-report arousal ratings. Thus, it is unlikely that OXT-induced changes in social attribution are mediated by an altered subjective arousal experience. Nevertheless, future studies are warranted to unravel whether a high arousal level is sufficient for the OXT effect to become evident or whether a genuinely social component is necessary. Interestingly, the OXT effect was similar for all social

stimuli and did not differ between high and low emotional social or non-social items. In a previous study utilizing videotapes of interpersonal situations, OXT had a selective effect on improving kinship recognition in women, but did not alter the accuracy of intimacy or competition judgments (Fischer-Shofty et al., 2013). The observed discrepancy between studies could be related to the use of the more global construct "anthropomorphism" in the present study as well as methodological differences (e.g. the videos of the previous study entailed facial expressions and body language).

The present study has several limitations. We recruited only female participants since previous findings have indicated that OXT may cause women, but not men, to treat computer partners more like humans (Rilling et al., 2014). Against this background and given the mounting evidence for sexual dimorphic effects of OXT (Fischer-Shofty et al., 2013; Preckel et al., 2014b; Scheele et al., 2014b), our findings do not necessarily generalize to men and future studies are warranted to specifically explore the effect of OXT on anthropomorphic tendencies in men. Furthermore, all female participants in our study used oral contraceptives. We can therefore exclude that our results are biased by natural variations due the menstrual cycle, but it is possible that contraception-related hormone changes contributed to the observed effects. Finally, the PLC spray did not contain the inactive ingredients of the OXT spray and it cannot be ruled out that this non-active compound influenced our results.

In conclusion, the present findings identify the hypothalamic peptide OXT as a molecular substrate of spontaneous anthropomorphism in women. As such, the OXT system may act as an adaptive regulatory mechanism enabling a flexible, context-dependent adjustment of anthropomorphic attribution. In addition, our findings lend further support to the idea that a dysfunctional OXT system may be involved in social attribution impairments often associated with psychiatric disorders such as autism or schizophrenia.

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Author contributions

D.S. and R.H. designed the experiments; D.S. and C.S. conducted the experiments; D.S., C.S., and R.H. analyzed the data; D.S., C.S., J.T.E., R.S., W.M. and R.H. wrote the paper. All authors gave final approval for publication.

Conflict of interests

The authors report no competing biomedical financial interests or personal affiliations in connection with the content of this manuscript.

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