The effects of oxytocin on self-related processing and cognition

Inaugural-Dissertation

zur Erlangung

des Doktorgrades der Philosophie

an der Ludwig-Maximilians-Universität München

vorgelegt von

Jessica Burgstaller

München, 2020

Erste Gutachterin	Prof. Dr. Michaela Pfundmair
Zweiter Gutachter:	Prof. Dr. Dieter Frey
Prüfer im Nebenfach:	Prof. Dr. Thomas Bonk
Datum der Disputation:	02. Juli 2020

To Dorit Helene Burgstaller & Josef Paul Marschall

Contents

Summary

The neuropeptide oxytocin (OT) has been suggested to facilitate social cognition and behavior. Therefore, published literature mainly focuses on the study of OT in a social context or in relation to others. But how we think, act and feel in social situations might strongly depend on our own state of being – the self. Thus, the present three studies examine the effects of OT on self-related processing and cognition.

The first study explores the idea that OT might decrease self-related information processing, even when individuals are specifically exposed to being self-aware. We could show that public self-awareness was increased when participants were placed in front of a mirror. Moreover, in the placebo group, lower scores in self-esteem were associated with increased self-awareness. This was not the case in the OT group in which self-esteem was unrelated to self-awareness. The results suggest that OT might function as a buffer against the negative consequences of enhanced self-related processing.

The second study of this dissertation explores OT's effects on self-related processing in a more physiological approach. Participants were to conduct a heartbeat perception task in front of a mirror (vs. no mirror) and we hypothesized OT to inhibit interoceptive awareness. Usually, people become more attuned to bodily responses in front of a mirror due to increased self-awareness. In line with the concept of de-individuation under OT, we could show that heartbeat accuracy, and thus interoceptive accuracy, was increased among participants under placebo who were placed in front of the mirror, but no such effect occurred after treatment with OT.

The third study provides empirical evidence testing OT's effect on situational self-awareness when attentional focus is shifted, either to external sensory perception or explicit self-related cognition, using a categorization vs. introspection task. The results suggest that situational self-awareness was reduced after OT treatment compared to placebo, when participants had previously been instructed to introspect about their feelings. In sum, all findings support the idea of OT being significantly involved in self-related processing and cognition by enhancing de-individuation.

Detailed german summary

Ausführliche deutsche Zusammenfassung

Der Einfluss von Oxytocin auf selbstbezogene Informationsverarbeitung und Kognition

Soziale Kognition und soziales Verhalten prägen unser Miteinander auf fundamentale Art und Weise. Nicht zuletzt deshalb rückte das Neuropeptid Oxytocin (OT), welches soziale Kognition und Verhalten maßgeblich beeinflussen kann, in den Fokus psychologischer Forschung. Aktuelle Studien beziehen sich vorwiegend auf OTs Rolle im sozialen Kontext. Wie wir im sozialen Miteinander denken, fühlen und handeln hängt aber auch davon ab, in welchem Zustand wir uns mit uns selbst befinden. Die vorliegende Arbeit untersucht deshalb den Effekt von OT auf selbstbezogene Informationsverarbeitung und Kognition.

Theorien über die Beschaffenheit des Selbst *in* Abgrenzung zu Anderen, oder Gedanken zur Bewusstheit über unser Selbst *durch* Abgrenzung zu Anderen beschäftigen die Menschheit seit Beginn der Entwicklung einer höheren Bewusstseinsstufe und werden seit jeher in philosophischen Arbeiten diskutiert. Aber auch andere Disziplinen, von der Psychologie bis zur neurobiologischen Forschung, widmen sich mehr der Frage, welche Gehirnareale und zugrunde liegende Neurotransmitter unsere Bewusstheit über unser Selbst vermitteln.

Der Einfluss von Neuropeptiden wie OT auf selbstbezogene Informationsverarbeitung und Kognition wurde lange nicht beachtet aber tritt nun in den Vordergrund der Forschungsarbeiten, die bereits vielversprechende Ergebnisse liefern. In der vorliegenden Arbeit möchte ich methodologische Ansätze präsentieren, die es uns erlauben, OTs Rolle in der Modulation selbstbezogener Informationen und Kognitionen zu beleuchten.

In der ersten Studie untersuche ich, ob OT die Verarbeitung selbstbezogener Informationen reduziert, selbst dann, wenn sich die Probanden in einem Zustand erhöhter Selbstbewusstheit (i.e. sich seiner Selbst bewusst sein, beispielsweise seiner äußeren Erscheinung und Wirkung auf andere) befinden. Im Einklang mit veröffentlichten Arbeiten konnten wir zeigen, dass Selbstbewusstheit gesteigert wird, wenn die Probanden vor einem Spiegel platziert werden (Bales & Flanders, 1954; Carver & Scheier, 1978; Davis & Brock, 1975). Darüber hinaus war, wie in Bezug auf veröffentlichte Studien zu erwarten (Bourgeois & Leary, 2001; Leary, Haupt, Strausser & Chokel, 1998), diese erhöhte Selbstbewusstheit mit geringeren Werten an Selbstachtung verbunden, wenn die Probanden ein Placebo bekamen. Dieser Effekt konnte nicht in der OT Gruppe beobachtet werden; hier ergab sich kein Zusammenhang zwischen erhöhter Selbstbewusstheit und negativen Auswirkungen auf die Selbstachtung. Auf Basis der Ergebnisse nehmen wir an, dass OT als eine Art emotionaler Puffer fungiert, um negative Konsequenzen selbstbezogener Informationsverarbeitung abzufedern.

Die Zweite Studie untersucht den Einfluss von OT auf selbstbezogene Informationsverarbeitung und Kognition unter Einbezug einer physiologischen Komponente. Die Probanden wurden angeleitet ihren eigenen Herzschlag zu zählen während sie sich vor einem Spiegel befinden (im Vergleich zur Kontrollbedingung ohne

Spiegel). Obwohl ein Spiegel die Bewusstheit über eigene körperliche Zustände erhöht (Ainley at al., 2012) gehen wir davon aus, dass selbstbezogene Informationsverarbeitung und Kognition auch in diesem Experiment durch OT reduziert wird. Wie erwartet deuten unsere Ergebnisse darauf hin, dass Probanden vor dem Spiegel bessere Herzwahrnehmer sind (Ainley at al., 2012; Bales & Flanders, 1954), unter OT scheint die Wahrnehmung des Herzschlags allerdings beeinträchtigt zu sein.

In einem weiteren Experiment testen wir, welchen Effekt OT auf die Selbstbewusstheit hat, wenn die Aufmerksamkeit der Probanden gezielt auf die explizite Wahrnehmung innerer emotionaler Vorgänge (Introspektion), im Vergleich zu rein sensorischer Wahrnehmung gelenkt wird. Die Ergebnisse deuten an, dass OT im Vergleich zu einem Placebo die Selbstbewusstheit reduziert, wenn die Probanden zuvor zur Introspektion über ihre Gefühle angeleitet wurden. Zusammengenommen verfestigen diese Studien die Idee von OT als Hormon, das eine maßgebliche Rolle bei der Verarbeitung selbstbezogener Informationen spielt, indem es die Grenze des eigenen Selbst aufzulösen vermag (de-individuation; LeBon, 1895).

Methode

In allen Studien erhielten die Probanden 24 I.U. OT oder ein Placebo ohne darüber informiert zu werden, in welcher Bedingung sie sich befinden. Im ersten Experiment wurden die Probanden nach 40 Minuten, die das Hormon braucht um seine maximale Wirkkonzentration im Körper zu erreichen vor einem Spiegel platziert. In der entsprechenden Kontrollbedingung wurde kein Spiegel verwendet. Als Manipulationscheck diente ein Fragebogen zur Erfassung von Selbstbewusstheit (Situational Self-Awareness Scale (SSAS): Govern & Marsch, 2001). Dieser umfasst 3

Items, die auf einer 7-stufigen Skala von 1 (*nicht zutreffend*) bis 7 (*sehr zutreffend*) beantwortet werden (alpha = .79). Außerdem wurde die Selbstachtung erhoben (Self-Esteem Scale (SES): Rosenberg, 1965). Die verwendete Skala besteht aus 10 Items, die auf einer 4-stufigen Skala von 1 (*sehr zutreffend*) bis 4 (*nicht zutreffend*) beantwortet werden (alpha = .77).

In der zweiten Studie wurde ebenfalls ein Spiegel verwendet, um die Selbstbewusstheit der Probanden zu erhöhen. Die Probanden wurden dann instruiert, ihren eigenen Herzschlag zu zählen. Nach einer Ruhephase von 5 min wurde die Herzwahrnehmung analog zu den Arbeiten von Schandry (1981) erhoben. Die Aufgabe, den eigenen Herzschlag ohne Hilfsmittel (Pulsmessung am Handgelenk) zu erspüren wurde in 3 randomisierte Intervalle unterschiedlicher Dauer (25, 35 und 45 Sekunden mit 60 Sekunden Pause zwischen den Blöcken) aufgeteilt. Am Ende eines jeden Intervalls berichten die Probanden die gezählten Herzschläge und die Abweichung von den mit einem Pulsoximeter gemessenen Schlägen wird als Fehler quantifiziert und ausgewertet.

Im dritten Experiment wurde die Aufmerksamkeit der Probanden gezielt auf die Wahrnehmung der inneren Gefühlswelt (Introspektion) gelenkt, um einen Zustand erhöhter selbstbezogener Kognition zu induzieren. In der Kontrollbedingung wurde die Wahrnehmung auf neutrale sensorische Reize gelenkt, die keinen Einfluss auf die Selbstbewusstheit der Probanden haben (Goldberg, Harel, & Malach, 2006). Im Anschluss wurde die Selbstbewusstheit mit der in Studie 1 beschriebenen Skala erhoben (SSAS: Govern & Marsch, 2001).

Ergebnisse

In der ersten Studie konnten wir zeigen, dass Probanden die vor einem Spiegel platziert wurden sich ihrer Selbst mehr bewusst waren, unabhängig davon, ob sie OT oder ein Placebo erhalten hatten. Erhöhte Selbstbewusstheit wird meist als unangenehm empfunden, da das Gefühl von anderen beobachtet oder bewertet zu werden verstärkt wird, und geht deshalb mit Unsicherheit oder verringerter Selbstachtung einher (Bourgeois & Leary, 2001; Buss, 1980; Leary, Haupt, Strausser & Chokel, 1998). In der Tat war erhöhte Selbstbewusstheit in der Placebo Bedingung mit niedrigerer Selbstachtung assoziiert. Bekamen die Probanden OT, war der Grad an Selbstbewusstheit nicht mit Fluktuationen der Selbstachtung in Verbindung zu bringen. Trotz des Spiegels und der erhöhten Selbstbewusstheit konnte in der OT Bedingung keine Korrelation mit Werten der Selbstachtung beobachtet werden. Auch die statistischen Analysen mit OT als Moderator des Zusammenhangs zwischen Selbstbewusstheit und Selbstachtung ergaben nur für die Placebo Bedingung eine signifikante negative Korrelation.

Die Ergebnisse der zweiten Studie deuten darauf hin, dass OT die Wahrnehmung physiologischer Prozesse, wie beispielsweise den eigenen Herzschlag, erschwert. Nur Probanden in der Placebo Bedingung konnten von der erhöhten Selbstbewusstheit durch den Spiegel profitieren und erzielten genauere Werte beim Zählen des eigenen Herzschlags (Ainley et al., 2012; Ainley et al., 2013). Probanden in der OT Gruppe konnten nicht von dem Spiegel profitieren, da OT ihre Aufmerksamkeit auf externe Stimuli zu lenken scheint, sodass die körpereigene, nach innen gerichtete Wahrnehmung in den Hintergrund tritt (Abu-Akel et al., 2015; Shamay-Tsoory & Abu-Akel, 2016; Brodmann, Gruber & Goya-Maldonado, 2017; Yao et al., 2018).

Die dritte Studie deutet ebenfalls darauf hin, dass OT den Grad an Selbstbewusstheit reduziert, insbesondere dann, wenn die Probanden sich explizit mit ihren Gefühlen und Introspektion konfrontieren sollten. Die Ergebnisse implizieren, dass OT den Fokus der Aufmerksamkeit weg vom Selbst, und stattdessen verstärkt auf externe Stimuli lenkt. In dieser Arbeit soll diese Begebenheit als De-individuation (LeBon, 1895) durch OT beschrieben werden. Besonders wenn das Grundlevel an selbstbezogener Kognition erhöht ist (durch die gezielte Manipulation und Instruktion zur Introspektion), werden die entgegen gerichteten Effekte des OT messbar.

Diskussion

Zusammengenommen deuten unsere Studien darauf hin, dass OT die Auflösung der Grenzen des Selbst (De-individuation) in selbstbezogener Informationsverarbeitung und Kognition begünstigt. Im Fokus der ersten Studie steht selbstbezogene Informationsverarbeitung im Sinne einer impliziten Verarbeitung des eigenen Spiegelbildes, um die Selbstbewusstheit zu erhöhen. Die zweite Studie umfasst die grundlegende selbstbezogene Informationsverarbeitung vor dem Spiegel sowie eine höhere Ebene selbstbezogener Kognition, induziert durch das explizite und bewusste Fokussieren auf den eigenen Herzschlag. Die letzte Studie bezieht sich auf die höchste Form selbstbezogener Kognition, unsere einzigartig menschliche Fähigkeit zur Introspektion. Beide experimentellen Manipulationen (der Spiegel und die gezielte Instruktion zur Introspektion) wurden gewählt um ein Gefühl des Dualismus, einer scharfen Grenze zwischen dem Selbst und Anderen, zu induzieren. OT als Manipulation wirkt interessanterweise in die entgegengesetzte Richtung. Die Ergebnisse unserer Studien deuten an, dass OT die Grenze zwischen Selbst und Anderen aufzulösen vermag, indem selbstbezogene Informationsverarbeitung und Kognition gezielt reduziert werden. Das Aufdecken des Effektes von OT auf das Selbst in dieser Forschungsarbeit dient als mögliche Erklärung und schärft unser Verständnis über den zugrundeliegenden Mechanismus von OTs prosozialer Wirkung.

Konklusion

Die empirischen Ergebnisse und das neue theoretische Rahmenwerk beschreiben OTs prosoziale Effekte als Konsequenz der zugrunde liegenden Verminderung selbstbezogener Informationsverarbeitung und Kognition, bzw. einer verstärkten De-individuation. Damit bieten die beschriebenen Studien eine wertvolle Erweiterung der bestehenden Literatur und vertiefen unsere Erkenntnisse über OTs Einfluss auf die, der selbstbezogenen Informationsverarbeitung und Kognition zugrunde liegende Gehirnaktivität. Diese Dissertation liefert eine mögliche Erklärung der paradoxen und kontextabhängigen Effekte des Neuromodulators OT und dessen Einfluss auf unser Sozialverhalten.

Literatur

Abu-Akel, A., Palgi, S., Klein, E., Decety, J., & Shamay-Tsoory, S. (2015). Oxytocin increases empathy to pain when adopting the other-but not the self-perspective. *Social Neuroscience*, *10*(1), 7-15. https://doi.org/10.1080/17470919. 2014.948637

Ainley, V., Tajadura-Jiménez, A., Fotopoulou, A., & Tsakiris, M. (2012). Looking into myself: Changes in interoceptive sensitivity during mirror self-observation. *Psychophysiology*, *49*(11), 1672-1676. https://doi.org/10.1111/j.1469-8986.2012.01468.x

Ainley, V., Maister, L., Brokfeld, J., Farmer, H., & Tsakiris, M. (2013). More of myself: Manipulating interoceptive awareness by heightened attention to bodily and narrative aspects of the self. *Consciousness and Cognition*, *22*(4), 1231-1238. https://doi.org/10.1016/j.concog.2013.08.004

Bales, R. F., & Flanders, N. A. (1954). Planning an observation room and group laboratory. *American Sociological Review*, *19*, 771-781. doi: 10.2307/2087925

Bourgeois, K. S., & Leary, M. R. (2001). Coping with rejection: Derogating those who choose us last. *Motivation and Emotion*, *25*(2), 101-111.

Brodmann, K., Gruber, O., & Goya-Maldonado, R. (2017). Intranasal oxytocin selectively modulates large-scale brain networks in humans. *Brain connectivity*, *7*(7), 454-463. https://doi.org/10.1089/brain.2017.0528

Buss, A. H. (1980). *Self-consciousness and social anxiety*. Freeman.

Carver, C. S., & Scheier, M. F. (1978). Self-focusing effects of dispositional self-consciousness, mirror presence, and audience presence. *Journal of Personality and Social Psychology*, *36*, 324-332. https://doi.org/10.1037/0022-3514.36 3.324

Davis, D., & Brock, T. C. (1975). Use of first person pronouns as a function of increased objective self-awareness and performance feedback. *Journal of Experimental Social Psychology*, *11*, 381-388. https://doi.org/10.1016/0022-1031(75)90017-7

Goldberg, I. I., Harel, M., & Malach, R. (2006). When the brain loses its self: prefrontal inactivation during sensorimotor processing. *Neuron*, *50*(2), 329-339.https://doi.org/10.1016/j.neuron.2006.03.015

Govern, J. M., & Marsch, L. A. (2001). Development and validation of the situational self-awareness scale. *Consciousness and Cognition*, *10*(3), 366-378. https://doi.org/10.1006/ccog.2001.0506

Leary, M. R., Haupt, A. L., Strausser, K. S., & Chokel, J. T. (1998). Calibrating the sociometer: The relationship between interpersonal appraisals and the state self-esteem. Journal of Personality and Social Psychology, 74(5), 1290–1299. https://doi.org/10.1037/0022-3514.74.5.1290

LeBon, G. (1895). The crowd: a study of the popular mind. London: 1920. *Psychologie des foules*.

Rosenberg, M. (1965). Rosenberg self-esteem scale (SES). *Society and the adolescent self-image*.

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The social salience hypothesis of oxytocin. *Biological Psychiatry*, *79*(3), 194-202. https://doi.org/10.1016/j.biopsych.2015.07.020

Schandry, R. (1981). Heartbeat perception and emotional experience. *Psychophysiology*, 18, 483-488. https://doi.org/10.1111/j.1469-8986.1981.tb02486.x

Yao, S., Becker, B., Zhao, W., Zhao, Z., Kou, J., Ma, X., ... & Kendrick, K. M. (2018). Oxytocin modulates attention switching between interoceptive signals and external social cues. *Neuropsychopharmacology*, *43*(2), 294. doi:10.1038/npp.2017.189

1 Chapter 1

1.1 Overview

The aim of this introductory chapter is to provide a brief critical review of the relationship between the neuropeptide hormone and neurotransmitter oxytocin (OT) and different aspects of the self and self-related processing or cognition. After introducing the concepts I will describe how my research has attempted to integrate these approaches to gain further insight into the boundaries of the self as opposed to others, OT's mechanism of action and the hormone's role in human's social behavior.

1.2 Introduction

Unconsciously, the lonely soul seems to trigger the urge to search for answers to a question unknown, until with her own conscious appearance the question resolves.

In recent years, interest in exploring the self from neuroscience and psychobiological perspectives has flourished rapidly. Questions such as: "What is the self, and where to find it?" have ever since been topic in philosophic literature. Mankind has evolved to such a high level of consciousness, that life might even seem meaningless without knowing. Thus, researchers from a variety of disciplines are eager to investigate which brain areas are involved in the awareness of one's self and the neurotransmitters involved in generating a sense of self.

Despite this, it has been ignored how self-related processing and cognition might be influenced by neuropeptides. Only recently, attempts to understand the psychobiological foundation of the self focused on the neuropeptide OT and many studies provide promising results. In the present work, I introduce methods to advance the study of the oxytonergic system to explore the compound's role in modulating self-related processing and cognition.

1.2.1 Self-related processing and cognition

In this work, I distinguish between self-related processing and cognition based on the following conceptualization: With the term self-related processing I aim to describe a bottom-up approach involving a lower level of implicit perception tied to lower levels of self-awareness, which will be explained in further detail below. Self-related cognition refers to a more sophisticated and explicit top-down concept involving memory, experience, mind wondering or introspection that constitute a higher form of self-awareness. In my research, I exploit the availability of OT as a nasal spray to test its effect on self-related processing and cognition in a variety of experimental paradigms. Using a mirror in the first and second experimental setup, thus implicitly confronting subjects with their own reflection, is a powerful tool to explore OT's effect on self-related processing. Specifically, with this manipulation, I investigated self-esteem, self-awareness and interoceptive awareness, after application of OT. Using a validated task to induce a state of introspection in the last experiment, I aim to explore OT's role in affecting higher levels of explicit self-related cognition. Together, these fundamental studies are designed to explore OT's modulatory role in shaping the boundary between self and others, ranging from a dualistic view, in which self and other a clearly distinct from each other, to de-individuation, when the boundary between self and others vanishes, as if the self is lost in the crowd (Diener & Wallbom, 1976; LeBon, 1895). These studies aim to deepen our understanding of the hormone's mechanism of action in promoting human prosocial behavior.

1.2.2 The self in oxytocin research

OT's central role in social cognition has been addressed in several studies (Heinrichs & Domes, 2008; Heinrichs et al., 2009). For example, application of OT sharpens mind-reading skills (Domes et al., 2007), enhances understanding of other's perspective (Ditzen et al., 2009), and modulates evaluation of other's trustworthiness (Kosfeld et al., 2005). When exploring social cognition, it has always been crucial to study an individual under OT in relation to others. However, how we think, act and feel in social situations might strongly depend on our own state of being – on the self.

There is still no consensus on what the self is or how it works. Several models have been proposed in an attempt to theoretically approach what we call the self and/or consciousness (Panksepp, 1998; Damasio, 1999; Gallagher, 2000; Metzinger, 2003; Morin, 2006; Edelman et al., 2011; Vandekerckhove & Panksepp, 2011). In this work, I want to adopt a prominent psychobiological and evolutionarily based framework that conceptualizes consciousness levels as developing in a continuum throughout phylogenesis (Tulving, 1985; Vandekerckhove & Panksepp, 2011). I choose to elaborate on this framework because insights from OT research in animal and human studies nicely align with the different stages of the self as well as with the continuum ranging from implicit self-related processing to explicit self-related cognition. This model proposes three interdependent levels of self-consciousness: (1) the non-reflective, affectively rich anoetic (unknowing) self; (2) the noetic (knowing) learning-based self; and (3) the reflective, metacognitive autonoetic (self-knowing) self.

OT receptors have been found in several brain areas, including the periacqueductal gray, putamen, insula, amygdala, nucleus accumbens, and prefrontal cortex (Sofroniew, 1983; Tribollet et al., 1992; Meyer-Lindenberg et al., 2011).

Biological correlates from lower to higher levels of the self involve (1) the basal subcortical system, extending from brainstem to hypothalamus to central thalamic nuclei, (2) lower subcortical ganglia and upper limbic cortical midline structures and (3) associative neocortical brain areas. These brain regions might therefore give rise to lower levels of self-related processing (e.g. anoetic) and higher levels of self-related cognition (e.g. autonoetic), respectively. Interestingly, OT is released from dendrites in evolutionarily ancient areas primarily involved in arousal states and emotion expression into extracellular space, from where it diffuses to several distant areas in the brain that are involved in cognitively mediated processes. Thus, the continuum ranging from lower to higher states of the self, accompanied by self-related processing or cognition, is also reflected on the physiological level.

The anoetic, unknowing self is characterized by a lack of self-observation of one's own action. It is the direct, unreflective affective and sensorial-perceptual experience of the world and self. Interestingly, humans and animals share the subcortical emotional brain systems giving rise to this primary form of self-experience (Vandekerckhove & Panksepp, 2009). Attention can be directed toward the external environment rather than the self, but there is still a minimal unifying implicit instance of self that, based on affective experiences, allows to perceive and to approach, or avoid, the surrounding environment (Tulving, 1985; Vogeley & Fink, 2003; Vandekerckhove & Panksepp, 2009). The neuropeptide OT has been shown to modulate the affective experience and the unreflective/instinctual border between the self and unfamiliar others. For example, OT modulates social affiliation (Nelson & Panksepp, 1998), enhances social motivation in adult male rats and mice (Lukas et al., 2011), facilitates approach toward unfamiliar pups in female rats (Pedersen et al., 1992), enhances confidence behavior in chicks (Panksepp, 2009), reduces separation distress vocalizations in abruptly isolated rat pups (Insel & Winslow, 1991) and facilitates partner-preference formation in voles (Insel & Hulihan, 1995). These studies suggest that OT influences the unreflective anoetic form of the self and associated instinctual affective behaviors even when self-reflective abilities are limited. In studies with human subjects, OT has been shown to facilitate the sensitivity and processing of explicit and masked emotional expressions (Leknes et al., 2012; Domes et al., 2013; Prehn et al., 2013; Kanat et al., 2015) and words with evolutionarily self-relevant values before their full cognitive evaluation (Heinrichs et al., 2004; Unkelbach et al., 2008). It has been suggested that OT facilitates the processing of evolutionarily self-relevant social stimuli and by increasing the salience of such stimuli it modulates approach behavior to novel, self-unrelated social situations (Prehn et al., 2013). At the same time stress-reactivity is reduced (Heinrichs et al., 2003) and individuals feel self-confident (Colonnello & Heinrichs, 2014).

In conclusion, the previous paragraph suggests that OT modulates the affective experience and the unreflective/instinctual border between the self and unfamiliar others. With our work outlined in Chapter 2 we aimed to contribute to the literature addressing the implicit perception of dualism and the aforementioned association with the affective experience. For clarification of terms, Figure 1 serves to visualize the concepts referred to throughout this work. More specifically, Figure 1 depicts the continuum between the perception (implicit and explicit) of dualism between self and other as opposed to de-individuation in self-related processing or cognition and OT's hypothesized effect of shifting perception towards de-individuation.

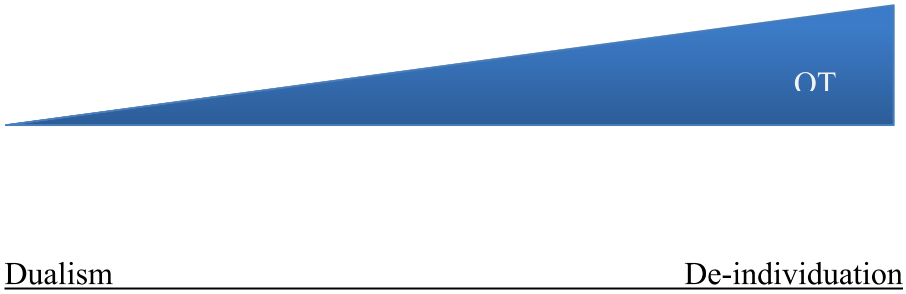


Figure 1. OT's hypothesized potential to shift the boundary between self and other from dualism to de-individuation.

In our study, we specifically manipulated the unreflective/instinctual border between self and others by confronting subjects with their own reflection in front of a mirror. This manipulation affects the natural border between self and other by enhancing public self-awareness (i.e. the feeling of being in other people's focus or appraisal, which implicitly emphasizes the distinction between self and other). At the same time we explored OT's effects on the subjects' affective experience measured in terms of self-esteem scores. In line with the research outlined in this chapter we could show that OT modulates the association between public self-awareness (i.e. the implicitly perceived distinction between self and others) and self-esteem scores (i.e. the affective experience) in that it acts as an emotional shield to buffer negative affective consequences of the implicit and enhanced perception of dualism between self and other.

The next higher level of the self, the noetic form, is also affected by application of OT. This stage is associated with learning-based self-awareness and the recognition of oneself as "me". It makes the self the object of one's own observation and shapes the boundary between "me" as distinct from "other". OT has been shown to influence such implicit descriptions of the self. For example, it facilitates the tendency to associate self-related words with positive adjectives (Colonnello & Heinrichs, 2014). Moreover, research revealed that the hormone sharpens explicit self- and other-recognition. This has been tested with the presentation of videos showing photos of one's own face morphing into those of an unfamiliar individual, and vice versa. Specifically, participants who received OT were facilitated in the self-other distinction of one's own and other's facial features, regardless of the morphing direction. Because this effect was associated with rating both faces as comparably pleasant, the authors assume the acceptance of self and others is facilitated (Colonnello et al., 2013). Another study explored the self- and other distinction more deeply. In a pain perception task, individuals receiving OT rated their imaginings of personally experienced pain as less stressful than their thoughts of pain experienced by others (Abu-Akel et al., 2015). Thus, it seems that OT reduces reactivity to stress, affects self-other distinction, and directs attention to others' needs.

Therefore, we hypothesize that the hormone might naturally reduce the perception of dualism between self and other. In our second study we therefore address the explicit perception of self by instructing subjects to count their heartbeat. We expect OT to reduce interoceptive ability because the dualist perspective of self as distinct from other (i.e. the salience of self-cues) vanishes. We assume this effect to be rather weak and therefore enhanced baseline levels of implicit perception of dualism by placing participants in front of a mirror, which served to enhance self-cues.

When individuals are involved with metacognitive tasks, reflection of experiences and mental time traveling to the own past or future, they employ what is described as most complex form of self-consciousness, the autonoetic self (Suddendorf & Corballis, 1997; Vandekerckhove & Panksepp, 2009). Research has shown that OT has the potential to modulate this uniquely human state of the self. For example, OT facilitates the recollection of personal memories and positive social affiliation memories (Cardoso et al., 2014). Moreover, the hormone seems to influence ratings of one's own personality, in that it induces reporting more positive traits in self-report questionnaires (Cardoso et al., 2012). Interestingly, these modulations by OT are based on individual differences and attachment styles (Bartz et al., 2011).

To explore OT's effect on this level of self-related cognition we provide a theoretical framework and designed a study in which we shifted participants' attentional focus, either to external sensory perception or self-related cognition, using a categorization vs. introspection task. We hypothesized situational self-awareness (i.e. the perception of dualism between self and other) to be reduced after OT treatment compared to placebo, when participants had previously been instructed to introspect about their feelings. This design serves to test the assumption of OT enhancing de-individuation, especially in a setting promoting a sense of dualism based on self-related cognition during introspection.

Taken together, the research outlined in this paragraph suggests that OT is among the neuromodulators implicated in self-consciousness and more specifically, in modulating self-related processing and cognition (e.g. in self-other distinction). This research area is still in its infancy and it remains to be elucidated, how OT could be integrated as potential treatment option in clinical conditions presenting alterations in the perception of the self.

1.2.3 Aims of the thesis

The neuropeptide OT has been suggested to facilitate social cognition and behavior. Methodological tools, like tasks to trigger introspection or utilizing a mirror to enhance self-cues, enable us to explore OT's effects on self-related processing and cognition and its implication for social interaction. In the framework of this dissertation, I contributed to three publications:

In the first study, I aimed to test the idea whether OT decreases self-related information processing, even when individuals are specifically exposed to being self-aware. I assumed that, after application of OT, the level of self-esteem, a concept related to self-related processing which usually decreases with enhanced self-awareness, would remain unaffected by varying degrees of self-awareness only in the OT condition. The aim was to test OT's function as a buffer against the negative consequences of enhanced self-related processing. Our results support the idea of OT being significantly involved in processing of self-related information enhancing de-individuation.

In the second study of this dissertation, I tried to understand OT's effects on self-related processing in a more physiological approach. OT receptors can be found in central and peripheral tissues, including the brain, heart, gastrointestinal tract and uterus. Thus, I assumed OT might also be involved in interoceptive processing. The aim of this study was to test the hypothesis that people become more attuned to bodily responses in front of a mirror due to increased self-awareness, and only participants under placebo, but not under OT, perform better in heartbeat perception. The results provide further evidence supporting the idea of OT being involved in inhibiting interoception and enhancing de-individuation.

In the third study, I provide a broad literature review and new theoretical framework in which we assume that de-individuation, a state of reduced self-related cognition, might be upstream of any OT effects. The aim was to provide empirical evidence testing OT's effect on situational self-awareness when attentional focus is shifted, either to external sensory perception or explicit self-related cognition, using a categorization vs. introspection task. We tested the hypothesis that OT functions as a buffer and reduces situational self-awareness, when participants had previously been instructed to introspect (i.e. when they are in a state of enhanced self-related cognition promoting a sense of dualism between self and other). The following chapters of my dissertation contain the manuscripts for these three studies.

1.3 References

Abu-Akel, A., Palgi, S., Klein, E., Decety, J., & Shamay-Tsoory, S. (2015). Oxytocin increases empathy to pain when adopting the other-but not the self-perspective. *Social Neurosciences,* 10, 7–15. doi: 10.1080/17470919.2014.948637

Bartz, J. A., Zaki, J., Bolger, N., & Ochsner, K. N. (2011). Social effects of oxytocin in humans: context and person matter. *Trends in Cognitive Science,* 15, 301–309. doi: 10.1016/j.tics.2011.05.002

Cardoso, C., Ellenbogen, M. A., & Linnen, A. M. (2012). Acute intranasal oxytocin improves positive self-perceptions of personality. *Psychopharmacology, (Berl).* 220, 741–749. doi: 10.1007/s00213-011-2527-6

Cardoso, C., Orlando, M. A., Brown, C. A., & Ellenbogen, M. A. (2014). Oxytocin and enhancement of the positive valence of social affiliation memories: an autobiographical memory study. *Social Neuroscience,* 9, 186–195. doi: 10.1080/17470919.2013.873079

Colonnello, V., Chen, F. S., Panksepp, J., & Heinrichs, M. (2013). Oxytocin sharpens self-other perceptual boundary. *Psychoneuroendocrinology,* 38, 2996–3002. doi: 10.1016/j.psyneuen.2013.08.010

Colonnello, V., & Heinrichs, M. (2014). Intranasal oxytocin enhances positive self-attribution in healthy men. *Journal of Psychosomatic Research,* 77, 415–419. doi: 10.1016/j.jpsychores.2014.06.016

Damasio, A. R. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*, New York, NY: Harcourt Brace.

Ditzen, B., Schaer, M., Gabriel, B., Bodenmann, G., Ehlert, U., & Heinrichs, M. (2009). Intranasal oxytocin increases positive communication and reduces cortisol levels during couple conflict. *Biological Psychiatry,* 65, 728–731. doi: 10.1016/j.biopsych.2008.10.011

Domes, G., Heinrichs, M., Michel, A., Berger, C., & Herpertz, S. C. (2007). Oxytocin improves “mind-reading” in humans. *Biol. Psychiatry* 61, 731–733. doi: 10.1016/j.biopsych.2006.07.015

Domes, G., Sibold, M., Schulze, L., Lischke, A., Herpertz, S. C., & Heinrichs, M. (2013). Intranasal oxytocin increases covert attention to positive social cues. *Psychological Medicine,* 43, 1747–1753. doi: 10.1017/S0033291712002565

Edelman, G. M., Gally, J. A., & Baars, B. J. (2011). Biology of consciousness. *Frontiers in Psychology,* 2:4. doi: 10.3389/fpsyg.2011.00004

Gallagher, I. (2000). Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Science.* 4, 14–21. doi: 10.1016/S13646613(99)01417-5

Heinrichs, M., Baumgartner, T., Kirschbaum, C., & Ehlert, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological Psychiatry,* 54, 1389–1398. doi: 10.1016/-S0006-3223(03)00465-7

Heinrichs, M., & Domes, G. (2008). Neuropeptides and social behavior: effects of oxytocin and vasopressin in humans. *Progress in Brain Research.* 170, 337–350. doi: 10.1016/S0079-6123(08)00428-7

Heinrichs, M., Meinlschmidt, G., Wippich, W., Ehlert, U., & Hellhammer, D. H. (2004). Selective amnesic effects of oxytocin on human me-mory. *Physiological Behavior,* 83, 31–38. doi: 10.1016/S0031-9384(04)00346-4

Heinrichs, M., von Dawans, B., & Domes, G. (2009). Oxytocin, vasopressin, and human social behavior. *Frontiers in Neuroendocrinology,* 30, 548–557. doi: 10.1016/j.yfrne.2009.05.005

Insel, T. R., & Hulihan, T. J. (1995). A gender-specific mechanism for pair bonding: oxytocin and partner preference formation in monogamous voles. *Behavioral Neuroscience,* 109, 782–789. doi: 10.1037/0735-7044.109.4.782

Insel, T. R., & Winslow, J. T. (1991). Central administration of oxytocin modulates the infant rats response to social isolation. *European Journal of Pharmacology,* 203, 149–152. doi: 10.1016/0014-2999(91)90806-2

Kanat, M., Heinrichs, M., Schwarzwald, R., & Domes, G. (2015). Oxytocin attenuates neural reactivity to masked threat cues from the eyes. *Neuropsychopharmacology,* 40, 287–295. doi: 10.1038/npp.2014.183

LeBon, G. (1895). The crowd: a study of the popular mind. London: 1920. *Psychologie des foules*.

Leknes, S., Wessberg, J., Ellingsen, D. M., Chelnokova, O., Olausson, H., & Laeng, B. (2012). Oxytocin enhances pupil dilation and sensitivity to 'hidden'emotional expressions. *Social Cognitive and Affective Neuroscience.* 8, 741–749. doi: 10.1093/scan/nss062

Lukas, M., Toth, I., Reber, S. O., Slattery, D. A., Veenema, A. H., & Neumann, I. D. (2011). The neuropeptide oxytocin facilitates pro-social behavior and prevents social avoidance in rats and mice. *Neuropsychopharmacology,* 36, 2159–2168. doi: 10.1038/npp.2011.95

Metzinger, T. (2003). *Being No One*. Cambridge, MA: MIT Press.

Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nature Reviews Neuroscience,* 12, 524–538. doi: 10.1038/nrn3044

Morin, A. (2006). Levels of consciousness and self-awareness: a comparison and integration of various neurocognitive views. *Consciousness and Cognition,* 15, 358–371. doi: 10.1016/j.concog.2005.09.006

Nelson, E. E., & Panksepp, J. (1998). Brain substrates of infant–mother attachment: contributions of opioids, oxytocin, and norepinephrine. *Neuroscience and Biobehavioral Reviews,* 22, 437–452. doi: 10.1016/S0149-7634(97)00052-3

Panksepp, J. (1998). *Affective Neuroscience: The Foundations of Human and Animal Emotions*. Oxford: Oxford university press.

Panksepp, J. (2009). Primary process affects and brain oxytocin. *Biological Psychiatry,* 65, 725–727. doi: 10.1016/j.biopsych.2009.02.004

Prehn, K., Kazzer, P., Lischke, A., Heinrichs, M., Herpertz, S. C., & Domes, G. (2013). Effects of intranasal oxytocin on pupil dilation indicate increased salience of socioaffective stimuli. *Psychophysiology,* 50, 528–537. doi: 10.1111/psyp.12042

Sofroniew, M. V. (1983). Vasopressin and oxytocin in the mammalian brain and spinal cord. *Trends in Neuroscience,* 6, 467–472. doi: 10.1016/0166-2236(83)90221-7

Suddendorf, T., & Corballis, M. C. (1997). Mental time travel and the evolution of the human mind. *Genetic, Social and General Psychology Monographs*, 123, 133–167.

Tribollet, E., Dubois-Dauphin, M., Dreifuss, J. J., Barberis, C., & Jard, S. (1992). Oxytocin receptors in the central nervous system. *Annals of the New York Academy of Sciences,* 652, 29–38. doi: 10.1111/j.1749-6632.1992.tb34343.x

Tulving, E. (1985). Memory and consciousness. *Can. Psychology,* 26, 1–12. doi: 10.1037/h0080017

Unkelbach, C., Guastella, A. J., & Forgas, J. P. (2008). Oxytocin selectively facilitates recognition of positive sex and relationship words. *Psychological Science,* 19, 1092–1094. doi: 10.1111/j.1467-9280.2008.02206.x

Vandekerckhove, M., & Panksepp, J. (2009). The flow of anoetic to noetic and autonoetic consciousness: a vision of unknowing (anoetic) and knowing (noetic) consciousness in the remembrance of things past and imagined futures. *Consciousness and Cognition.* 18, 1018–1028. doi: 10.1016/j.concog. 2009.08.002

Vandekerckhove, M., & Panksepp, J. (2011). A neurocognitive theory of higher mental emergence: from anoetic affective experiences to noetic knowledge and autonoetic awareness. *Neuroscience and Biobehavioral. Reviews,* 35, 2017–2025. doi: 10.1016/j.neubiorev.2011.04.001

Vogeley, K., & Fink, G. R. (2003). Neural correlates of the first-person-perspective. *Trends in Cognitive Science,* 7, 38–42. doi: 10.1016/S1364-6613 (02)00003-7

2 Chapter 2: Oxytocin and the emotional shield of de-individuation

Jessica Burgstaller[1], Dieter Frey[1], Michaela Pfundmair[2]

[1]Ludwig-Maximilians-University of Munich

j.burgstaller@campus.lmu.de, dieter.frey@psy.lmu.de

[2]HS Bund, Berlin

michaela.pfundmair@hsbund-nd.de

Author Note

Correspondence concerning this article should be addressed to Jessica Burgstaller, Department of Psychology, Ludwig-Maximilians-University of Munich, Leopoldstr. 13, 80802 Munich, Germany, Tel. +49 89 21803002, Fax +49 21805238, Email: j.burgstaller@campus.lmu.de

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Keywords: oxytocin; self-focus; self-awareness; self-esteem; social cognition

Article body: 3465 words
Abstract: 193 words
Figures: 3
Table: 1
Supplemental information: 0

2.1 Abstract

OT has been suggested to reduce self-related processing and cognition. In this study, we aimed to test if OT decreases self-related information processing, even when individuals are specifically exposed to being self-aware. We specifically hypothesized that, after application of OT, the level of self-esteem, a concept related to self-related processing which usually decreases with enhanced self-awareness, would remain unaffected by varying degrees of self-awareness only in the OT condition. In this study, 76 male and female healthy participants self-administered OT or placebo intranasally. After that, participants' attentional focus was shifted towards increased self-awareness by placing them in front of a mirror or not. We found that public self-awareness was increased when participants were placed in front of the mirror compared to the no mirror condition, consistent to previous research. Moreover, in the placebo group, lower scores in self-esteem were associated with increased self-awareness. This was not the case in the OT group in which self-esteem was unrelated to self-awareness. We conclude that OT might function as a buffer against the negative consequences of enhanced self-related processing. These findings support the idea of OT being significantly involved in processing of self-related information enhancing de-individuation.

2.2 Introduction

According to William James, one of the founding fathers of Western psychology, self-esteem is the product of "perceived competence in domains of personal importance" (James, 1890). It is the evaluation of our worthiness as individuals, our thinking that we are good at things that mean something to us, and guides us to feel like good, valuable people. Research on self-esteem has a long history because it powerfully impacts cognition, motivation, emotion and behavior.

Scientists have developed many different definitions of self-esteem (Swann, Chang-Schneider & McClarty, 2007) and distinguish between various subtypes (e.g. domain specific self-esteem (Harter, 1999), contingent self-esteem (Crocker, Luhtanen, Cooper & Bouvrette, 2003) or stable self-esteem (Kernis, 2005)). Self-worth is influential in how it affects psychological functioning (Tafarodi & Swann, 1995) and its definition is still consistent with early formulations proposed by William James (1890/1984). Interestingly, Charles Horton Cooley (1902/1964) proposed that self-esteem arises not (only) from self-evaluations but also the perceived evaluations of others. Thus, feelings of self-worth are associated with the 'looking glass self' – our perceptions of how we appear in the eyes of others (Cooley, 1902). It is the opinion of close others and that of acquaintances that powerfully impacts our sense of self-esteem (Harter, 1999). This idea is also represented in the more recent sociometer theory (Leary & Baumeister, 2000). In this theory, self-esteem is understood as part of a psychological system (the sociometer) that monitors the social environment for cues indicating low or declining relational evaluation (e.g., lack of interest, disapproval, rejection). When detected, such cues function as a warning signal to the individual. According to the sociometer theory, many kinds of events can lower people's self-esteem (e.g. failure, rejection, embarrassing situations, negative evaluations, being outperformed by others), which are tied to people experiencing lower relational value in the eyes of others (Bourgeois & Leary, 2001; Leary, Haupt, Strausser & Chokel, 1998). Previously, it has been assumed that people are motivated to maintain their self-esteem per se. The theory, however, suggests that individuals seek to increase their relational value and social acceptance, using self-esteem as an indicator of their social effectiveness (Leary, 2005).

Related to the idea that humans regularly monitor the interpersonal value of themselves is the concept of self-awareness, which is a process that monitors how we may appear in the eyes of others. Directing attention to features of one's self that are obvious to others, e.g. physical appearance, is increased self-related processing in terms of the public aspect of self-awareness. Its extent depends on individual differences (e.g., Alden, Teschuk & Tee, 1992; Bales & Flanders, 1954; Webb, Marsh, Schneiderman & Davis, 1989). However, self-awareness can also be raised situationally. It is assumed to be transient and susceptible to manipulation (Carver & Glass, 1976). One of the simplest manipulations operationalizations of self-awareness has been the presence of a mirror, which increases self-related processing (Bales & Flanders, 1954). Importantly, increased self-awareness triggers discomfort because individuals feel as if they are in the focus of others' evaluation (Buss, 1980; Davis & Franzoi 1999; Fenigstein, Scheier & Buss, 1975; Franzoi & Brewer, 1984, Carver & Glass, 1976).

Thus, when being confronted with the own reflection, the increased self-awareness induces a feeling of being evaluated by others and, thus, lowers self-esteem (Bourgeois & Leary, 2001; Leary, Haupt, Strausser, & Chokel, 1998). However, self-awareness does not only deflect upwards but also downwards: Decreased public self-awareness is the crucial element for the occurrence of de-individuation, a feeling of being "lost in the crowd" (Diener & Wallbom, 1976; LeBon, 1895).

Thus, depending on person and context, public self-awareness varies. We propose that a specific endocrine feature may also affect this concept: the OT system. The neuropeptide OT functions as hormone and neurotransmitter and is synthesized in the hypothalamus. It plays a crucial role in social behavior and cognition (Insel, 1992; Donaldson & Young, 2008; De Dreu, 2012). Interestingly, OT has been shown to shift attention from self-related information processing to external cues. For example, OT has been shown to facilitate perception of other- but not self-experienced pain, and generally increased other-orientation (Bartz et al., 2011; Chen & Johnson, 2012).

More specifically, Ruissen and de Bruijn (2015) could show that OT promoted a reduction in self-related processing. In a placebo-controlled double-blind between-subjects design they investigated whether OT facilitates self-other integration using a social Simon task. In the original task, visual stimuli are presented left and right of a fixation cross and subjects are instructed to respond to the stimuli with a left or right located button depending on a feature of the stimulus (e.g., color). In this task, people are faster in responding to a stimulus when stimulus and response location are compatible – this is known as the compatibility effect. When participants are instructed to respond to only one color with one of the buttons, the task is turned into a Go/NoGo version in which the compatibility effect is no longer present. In the social Simon task, two participants sitting next to each other perform a complementary Go/NoGo version of it together, i.e., each participant responds to only one color with one button. Interestingly, the compatibility effect re-emerges in this situation (Dolk et al., 2014; Sebanz, Knoblich & Prinz, 2003). Simultaneously, Ruissen and de Bruijn (2015) performed electrophysiological measurements. They could show that after OT treatment, the stimulus-locked N2 component, reflecting response conflict, was increased in the social compared to the individual context for Go trials. The same pattern of results, however irrespective of condition, emerged for the P3 component, reflecting response inhibition. These findings suggest that OT enhances self-other integration and modulates processes that play a central role in joint task performance. Importantly, the results also point to a decrease in self-related processing under OT and add to our understanding of the neurocognitive mechanisms underlying the diverse social effects of OT.

Even more profoundly, Zhao et al. (2016) suggest that OT not only reduces self-related processing, but also decreases self-centered behavior. They hypothesized that OT might act either to increase or blur the distinction between self and other and thereby promote either more selfish or altruistic behaviors. To test these ideas, they investigated the effect of OT on self and other (mother, classmate, or stranger) trait judgments in conjunction with functional magnetic resonance imaging. Because of the link between self-perception and self-esteem, which in turn is influenced by the perception of social standing and evaluations individuals make about their personal worth (Somerville et. al., 2010), participants were asked to complete the Self-Esteem Scale (SES: Rosenberg, 1965). Zhao et al. (2016) could show that, especially in individuals with a more independent self-concept (i.e. those with higher self-esteem) OT improves speed of decision-making in self vs. other trait judgments and blunts the normal bias towards remembering self-attributes. The authors conclude that OT decreases the distinction between self and others by reducing self-interest; a potentially weak effect that only becomes apparent in individuals with a higher baseline level of self-esteem. Overall, the hormone reduces brain activity and connectivity between regions involved in self-processing. In conclusion, the results are consistent with the view that OT not only reduces self-related processing but also self-centred behavior.

In our work, we suggest that OT might spare self-esteem, especially when individuals are specifically exposed to being self-aware and in other people's appraisal, due to a reduction in self-related information processing.

2.3 The current study

In our study, we expected a reduction in self-related information processing among participants with artificially increased levels of OT, even when self-awareness is experimentally increased. More specifically, we assumed that OT would buffer against the negative consequences of enhanced self-awareness sparing the individual's self-esteem. To this end, self-esteem was measured after participants intranasally administered OT or placebo and were placed in front of a mirror to increase self-awareness.

2.4 Methods and materials

2.4.1 Participants

A total of 76 participants (60 female, 16 male; mean age = 27.36 years, *SD* = 6.95) participated in the study for research credit.

Those who regarded themselves as having major depression, bipolar, panic and psychotic disorders, substance dependence, epilepsy, or (if female) pregnancy were not allowed to take part. Participants were instructed to abstain from alcohol and caffeine on the day of testing, and from food and drink, except water, for 2 hours before drug administration. The study was approved by the local ethics committee.

2.4.2 Design

The study followed a 2 (substance: OT vs. placebo) x 2 (mirror: yes vs. no) between-subjects design with random and double-blind (for substance) assignment to conditions. Public situational self-awareness served as manipulation check and self-esteem as dependent variable. In another study, the same sample served to reveal how enhanced self-awareness in front of a mirror affects interoceptive ability (Burgstaller, Pfundmair & Frey, under prep.). However, due to interruptions in physiological recordings in the interoception experiment, sample sizes vary.

2.4.3 Procedure and materials

After written informed consent was obtained, participants received 24 I.U. of OT (Syntocinon Spray, Defiante; three puffs per nostril, n = 40) or a placebo (sodium chloride solution, n = 36). Participants were uninformed about the content of the spray; they were only told that they would receive a hormone or placebo in low dosage. After a 40 min waiting period that served to allow the substances to reach their maximum, participants were placed in front of a mirror in one of the experimental conditions (n = 39). In the other condition, there was no mirror present (n = 37). A mirror is known to increase self-awareness (Bales & Flanders, 1954; Carver & Scheier, 1978; Davis & Brock, 1975). Therefore, as manipulation check, participants completed the public dimension of the Situational Self-Awareness Scale (SSAS: Govern & Marsch, 2001). The public dimension of the Situational Self-Awareness Scale consists of 3 items to be rated on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) such as: 1) Right now, I am concerned about the way I present myself, 2) Right now, I am self-conscious about the way I look and, 3) Right now, I am concerned about what other people think of me (alpha = .79). Thereafter, participants completed the Self-Esteem Scale (SES: Rosenberg, 1965). The scale consists of 10 items to be rated on a 4-point scale ranging from 1 (*strongly agree*) to 4 (*strongly disagree*) such as for example: 1) I feel that I am a person of worth, at least on an equal plane with others, or 2) I feel that I have a number of good qualities (alpha = .77). At the end, female participants were asked about their ovarian cycle stage (mean day of cycle = 13.90, SD = 7.45; as similarly done in Pfundmair et al., 2017). Debriefing followed after unrelated tasks.

2.4.4 Data analysis

The following analysis was run: To check the impact of a mirror on self-awareness, a 2 (substance: OT vs. placebo) x 2 (mirror: yes vs. no) between-subjects ANOVA was conducted on public situational self-awareness. To investigate how self-esteem would vary in dependence of when participants had administered OT or placebo and were seated in front of a mirror or not, correlational analyses were employed between self-awareness and self-esteem in the different conditions. Statistical testing of this relationship employing OT as a moderator between self-awareness and self-esteem and including the mirror/no mirror condition as covariate served as second test of the hypothesized effect of OT decreasing self-related processing. All statistical tests were performed using the SPSS 23.0.0.0 Software, analysis of the moderation was done with the PROCESS tool provided by Hayes (2012).

2.5 Results

Descriptive statistics are to be found in Table 1.

Manipulation check. A 2 (substance) x 2 (mirror) between-subjects ANOVA on public situational self-awareness showed no significant main effect of substance, $F(1,71) = 0.24$, $p = .623$, $\eta^2 < .001$, 95%CI = [0.00,0.07]. However, a significant main effect of mirror emerged, $F(1,71) = 5.77$, $p = .019$, $\eta^2 = .08$, 95%CI = [0.00,0.21], revealing more self-awareness when seated in front of a mirror than when not. The interaction of substance and mirror showed no significant effect, $F(1,71) = 2.51$, $p = .118$, $\eta^2 = .03$, 95%CI = [0.00,0.15].

Table 1. Means and standard deviations (in parenthesis) of public self-awareness and self-esteem as a function of substance (OT vs. placebo) and condition (Mirror vs. no mirror).

	OT		Placebo	
	Mirror (N = 22)	No mirror (N = 18)	Mirror (N = 17)	No mirror (N = 19)
Public self-awareness	2.47 (1.06)	1.59 (0.65)	2.11 (1.16)	1.82 (0.76)
Self-esteem	3.09 (0.61)	3.25 (0.61)	3.34 (0.65)	3.13 (0.70)

Main analysis. Within the placebo group, there was a negative correlation between self-awareness and self-esteem when no mirror was present, $r = -.527$, $n = 19$, $p = .020$, as well as when participants were confronted with their own reflection, $r = -.824$, $n = 17$, $p < .001$. These results imply that in both conditions higher values on the public dimension of self-awareness were associated with lower scores on self-esteem when participants received a placebo, see Figure 1 (top).

In the OT group, we did not find a correlation between self-awareness and self-esteem when participants were confronted with a mirror, $r = -.308$, $n = 22$, $p = .163$, or when no mirror was present, $r = -.145$, $n = 18$, $p = .565$. These results suggest that, public situational self-awareness was not associated with any fluctuations in self-esteem scores when participants had previously received OT, even when public situational self-awareness was increased in front of the mirror, see Figure 1 (bottom).

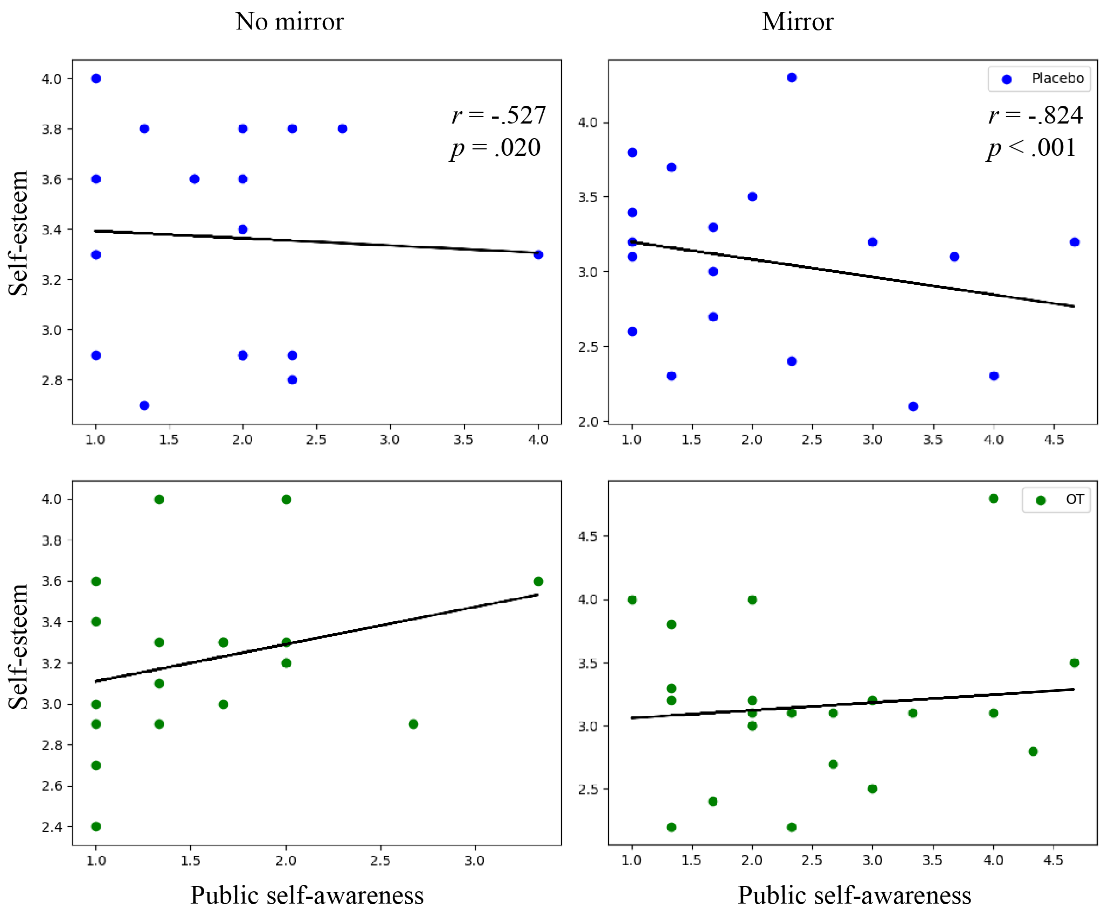


Figure 1. Scatter plots showing the correlation between public self-awareness and self-esteem in the condition without a mirror to be present (panels on the left) and when placed in front of a mirror (panels on the right) for the placebo group (blue, top panels) and after treatment with OT (green, bottom panels).

For a deeper understanding of the data, a regression-based analysis was performed using the SPSS PROCESS tool (Hayes, 2012). In this analysis, the moderating effect of OT on the relationship between public self-awareness and self-esteem was tested, see Figure 2.

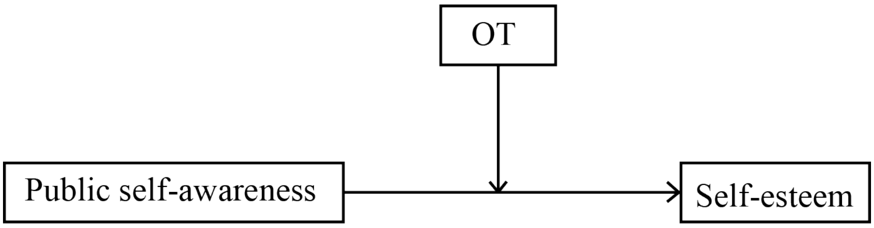


Figure 2. PROCESS model 1 for regression-based analysis to test the moderating effect of OT on the relationship between public self-awareness and self-esteem.

To investigate whether participants with a higher level of public self-awareness would experience a decrease in their level of self-esteem, only after application of the placebo but not OT, we conducted a regression analysis (Hayes, 2012; model 1), entering public self-awareness as independent variable, OT as moderator, and self-esteem as dependent variable. There was no significant main effect of OT, $b = -0.01$, $SE = .13$, $t(72) = -0.04$, $p = .969$, 95%CI = [-.26, .25]. However, a significant main effect of public self-awareness, $b = -0.31$, $SE = .07$, $t(72) = -4.60$, $p < .001$, 95%CI = [-.44, -.17], emerged. Moreover, the regression analysis revealed a significant interaction, $b = 0.27$, $SE = .13$, $t(72) = 2.03$, $p = .046$, 95%CI = [.00, .54]. To break down this interaction effect, we checked the conditional effect of public self-awareness on self-esteem at different values of the moderator: Participants in the placebo group reported significantly lower levels of self-esteem when their public self-awareness was high compared to when they were not particularly self-aware, $b = -0.45$, $SE = .10$, $t(72) = -4.56$, $p < .001$, 95%CI = [-.65, -.25]. After application of OT, on the other hand, participants did not differ in their levels of self-esteem when their public self-awareness was high or low, $b = -0.18$, $SE = .09$, $t(72) = -1.97$, $p = .053$, 95%CI = [-.36, .00], see Figure 3.

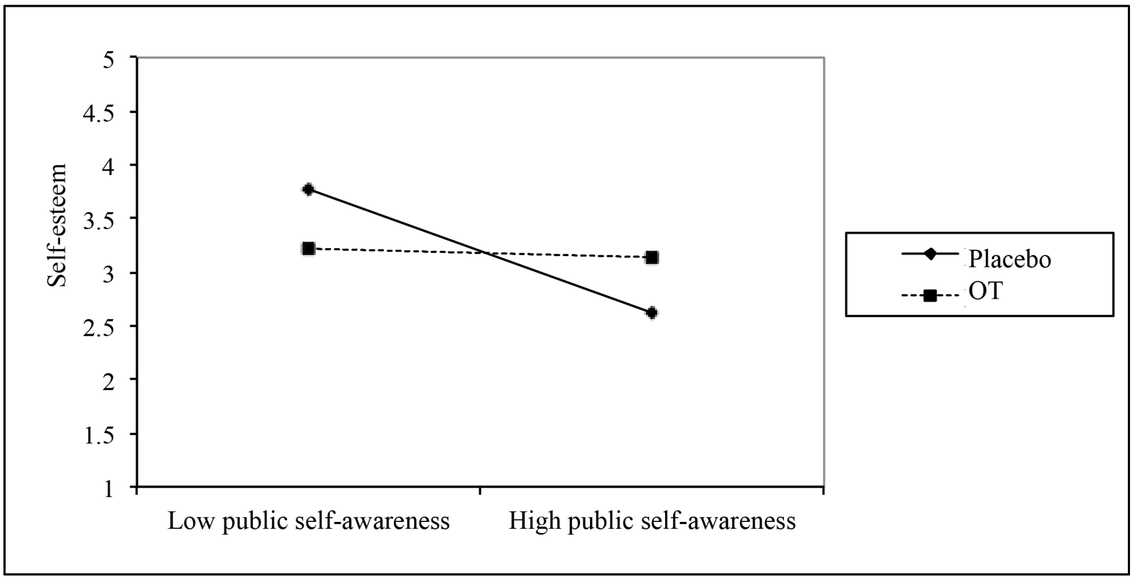


Figure 3. OT moderates the relationship between public-self-awareness and self-esteem with higher values in public self-awareness being associated with lower levels of self-esteem in the placebo condition, $p < .001$.

2.6 Discussion

In this study, a mirror increased public situational self-awareness - participants were perceptually more aware of themselves -, when placed in front of a mirror (vs. when not placed in front of a mirror) regardless of whether they had administered OT or not. Higher scores on the public dimension of situational self-awareness are often associated with discomfort and, in consequence, lower self-esteem because people are more aware of features that are obvious to others, e.g. physical appearance (Bourgeois & Leary, 2001; Buss, 1980; Leary, Haupt, Strausser & Chokel, 1998). Indeed, in the placebo group, public self-awareness was negatively correlated to self-esteem. (Notably, we observed this negative correlation independently of whether a mirror was present or not. However, as expected, the effect when confronted with the own reflection was stronger.) Importantly, our results revealed that, after application of OT, self-awareness was not associated with fluctuations in self-esteem. Despite the presence of the mirror and the associated increase in self-awareness, there was no correlation between self-awareness and self-esteem to be observed in the OT group. Also, when testing OT's effects as moderator between self-awareness and self-esteem, a direct correlation between the variables could only be observed in the placebo condition.

Thus, OT seemed to act as a protective shield to stabilize the individual's self-esteem even in situations of increased self-awareness. We assume that even though perceptual salience of the self was enhanced in front of the mirror, our participants were able to focus rather on the external world and worry less about themselves in relation to others after application of OT. This can be defined as increased de-individuation. Importantly, we did not find a direct effect of OT on self-esteem. Only when the baseline level of self-related processing was high (in our case, experimentally increased via the own reflection in the mirror), OT's effect on stabilizing self-esteem scores became apparent. We chose to artificially induce higher levels of self-related processing to control for varying degrees of baseline self-awareness. However, as this manipulation was necessary to observe a buffering effect of OT on self-esteem, we conclude that the effect might not be easily observable but rather subtle.

Our results are in line with the previously discussed idea of OT increasing attention to the external (social) world (Andari et al., 2010; Guastella, Mitchell & Dadds, 2008; Pfundmair et al., 2017) and reducing being emotionally involved in the processing of self-related representations (Liu et al., 2013; Liu et al., 2017; Zhao et al., 2016; Zhao et al., 2020). Based on these results, it could be speculated that the underlying mechanism of OT is de-individuation. By reducing self-related information processing, OT might allow people to get more easily involved with the outside world, subsequently increasing the salience of social cues and facilitating affiliative motivation. This, in turn, could lead to enhanced social cognition and prosocial behavior. However, the results could also be explained by an anxiolytic approach. If OT buffers any negative impact on an individual, then it might also save self-esteem and allow people to attend to the social cues they might otherwise avoid.

Using a validated paradigm, we observed that the own reflection in the mirror increased self-awareness but did not affect people under OT in their level of self-esteem. However, there are several limitations that should be addressed. In the current study, we concluded de-individuation processes to take place despite an increase in perceptual self-awareness. In line with previous work (Diener & Wallbom, 1976; Festinger et al., 1952; Prentice-Dunn & Rogers, 1980), we assume that de-individuation promoted by OT stabilized self-esteem scores. However, it would be fruitful to directly operationalize de-individuation in futures OT experiments, e.g. using methods that have already been implemented with success (as similarly done in Prentice-Dunn & Rogers, 1982) and then measure its effect on self-esteem. Such research should be able to provide clearer insights into OT's basic effect.

In the past, doubt has increased concerning the conventional doses, time frame of application (Leng and Ludwig, 2016), and effect sizes of intranasally applied OT research (Walum, Waldman & Young, 2016). Moreover, a publication bias was suggested in OT research (Lane, Luminet, Nave & Mikolajczak, 2016). Although our analysis revealed a nearly large to large effect for our main research question (correlation coefficients: $|r| = .527$; $|r| = .824$ and interaction effect, $b = 0.27$; Cohen, 2013: small ($|r| = 0.10$), medium ($|r| = 0.30$) and large ($|r| = 0.50$) effects), the serious problem of underpowered studies in OT is an issue which deserves closer attention as it easily leads to an overestimation of effects. Because null results (Lane et al., 2016) and replication failures (Nave, Camerer & McCullough, 2015; Radke & de Bruijn, 2015) have been reported in the past, we suggest to perform further experiments relying on additional methods to substantiate our finding of an association between OT, self-awareness and self-esteem.

Taken together, our results suggest that OT reduces self-related information processing, even in situations of increased self-awareness. With the underlying de-individuation effect possibly pointing to a common ground explanation for OT's paradoxical and context dependent effects, the current work might have implications to understand the neuromodulator's function in brain activation and the hormone's role in human's social behavior.

2.7 References

Alden, L. E., Teschuk, M., & Tee, K. (1992). Public self-awareness and withdrawal from social interactions. *Cognitive Therapy and Research*, *16*(3), 249-267. https://doi.org/10.1007/BF01183280

Andari, E., Duhamel, J. R., Zalla, T., Herbrecht, E., Leboyer, M., & Sirigu, A. (2010). Promoting social behavior with oxytocin in high-functioning autism spectrum disorders. *Proceedings of the National Academy of Sciences, 107*(9), 4389-4394. doi.org/10.1073/pnas.0910249107

Bales, R. F., & Flanders, N. A. (1954). Planning an observation room and group laboratory. *American Sociological Review*, *19*, 771-781. doi: 10.2307/2087925

Bartz, J.A., Zak, J., Bolger, N., & Ochsner, K.N. (2011). Social effects of oxytocin in humans: context and person matter. *Trends in Cognitive Science, 15*(7), 301-309. doi: 10.1016/j.tics.2011.05.002

Bourgeois, K. S., & Leary, M. R. (2001). Coping with rejection: Derogating those who choose us last. *Motivation and Emotion*, *25*(2), 101-111.

Burgstaller, J., Pfundmair, M., & Frey, D. (in prep). Can you feel your heart? Oxytocin inhibits interoceptive awareness.

Buss, A. H. (1980). *Self-consciousness and social anxiety*. Freeman.

Carver, C. S., & Glass, D. C. (1976). The self-consciousness scale: A discriminant validity study. *Journal of Personality Assessment*, *40*(2), 169-172. https://doi.org/10.1207/s15327752jpa4002_8

Carver, C. S., & Scheier, M. F. (1978). Self-focusing effects of dispositional self-consciousness, mirror presence, and audience presence. *Journal of Personality and Social Psychology*, *36*, 324-332. https://doi.org/10.1037/0022-3514.363.324

Chen, F. S., & Johnson, S. C. (2012). An oxytocin receptor gene variant predicts attachment anxiety in females and autism-spectrum traits in males. *Social Psychological and Personality Science*, *3*(1), 93-99. https://doi.org/10.1177/1948550611410325

Cohen, J. (2013). Statistical power analysis for the behavioral sciences. Routledge.

Cooley, C. H. (1902). Looking-glass self. *The Production of Reality: Essays and Readings on Social Interaction*, *6*.

Crocker, J., Luhtanen, R. K., Cooper, M. L., & Bouvrette, A. (2003). Contingencies of self-worth in college students: theory and measurement. *Journal of Personality and Social Psychology*, *85*(5), 894.

Davis, D., & Brock, T. C. (1975). Use of first person pronouns as a function of increased objective self-awareness and performance feedback. *Journal of Experimental Social Psychology*, *11*, 381-388. https://doi.org/10.1016/0022-1031(75)90017-7

Davis, M. H., & Franzoi, S. L. (1999). Self-awareness and self-consciousness.

De Dreu, C. K. (2012). Oxytocin modulates cooperation within and competition between groups: an integrative review and research agenda. *Hormones and Behavior*, *61*(3), 419-428. https://doi.org/10.1016/j.yhbeh.2011.12.009

Diener, E., & Wallbom, M. (1976). Effects of self-awareness on antinormative behavior. *Journal of Research in Personality*, *10*(1), 107-111. https://doi.org /10.1016/0092-6566(76)90088-X

Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., & Liepelt, R. (2014). The joint Simon effect: a review and theoretical integration. *Frontiers in Psychology*, *5*, 974. https://doi.org/10.3389/fpsyg.2014.00974

Donaldson, Z. R., & Young, L. J. (2008). Oxytocin, vasopressin, and the neurogenetics of sociality. *Science*, *322*(5903), 900-904. doi: 10.1126/science .1158668

Fenigstein, A., Scheier, M. F., & Buss, A. H. (1975). Public and private self-consciousness: Assessment and theory. *Journal of Consulting and Clinical Psychology*, *43*(4), 522. https://doi.org/10.1037/h0076760

Festinger, L., Pepitone, A., & Newcomb, T. (1952). Some consequences of de-individuation in a group. *The Journal of Abnormal and Social Psychology*, *47*(2S), 382. https://doi.org/10.1037/h0057906

Franzoi, S. L., & Brewer, L. C. (1984). The experience of self-awareness and its relation to level of self-consciousness: An experiential sampling study. *Journal of Research in Personality*, *18*(4), 522-540.https://doi.org/10.1016/0092-6566(84)90010-2

Govern, J. M., & Marsch, L. A. (2001). Development and validation of the situational self-awareness scale. *Consciousness and Cognition*, *10*(3), 366-378. https:// doi.org/10.1006/ccog.2001.0506

Guastella, A.J., Mitchell, P.B., & Dadds, M.R. (2008). Oxytocin increases gaze to the eye region of human faces. *Biological Psychiatry* 63(1), 3-5. doi:10.1016/j.biopsych.2007.06.026

Harter, S. (1999). The construction of the self. New York: Guilford.

Hayes, A. F. (2012). PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling.

Insel, T. R. (1992). Oxytocin—a neuropeptide for affiliation: evidence from behavioral, receptor autoradiographic, and comparative studies. *Psychoneuro-endocrinology*, *17*(1), 3-35. https://doi.org/10.1016/0306-4530(92)90073-G

James, W., Burkhardt, F., Bowers, F., & Skrupskelis, I. K. (1890). *The Principles of Psychology* (Vol. 1, No. 2). London: Macmillan.

James, W. What is an emotion? *Mind*, 1884, 9, 188-205.

Kernis, M. H. (2005). Measuring self-esteem in context: The importance of stability of self-esteem in psychological functioning. *Journal of Personality*, *73*(6), 1569-1605. https://doi.org/10.1111/j.1467-6494.2005.00359.x

Lane, A., Luminet, O., Nave, G., & Mikolajczak, M. (2016). Is there a Publication Bias in Behavioural Intranasal Oxytocin Research on Humans? Opening the File Drawer of One Laboratory. *Journal of Neuroendocrinology*, 28(4). doi:10.1111/jne.12384

Leary, M. R., & Baumeister, R. F. (2000). The nature and function of self-esteem: Sociometer theory. In *Advances in Experimental Social Psychology* (Vol. 32, pp. 1-62). Academic Press. https://doi.org/10.1016/S0065-2601(00)80003-9

Leary, M. R. (2005). Sociometer theory and the pursuit of relational value: Getting to the root of self-esteem. *European Review of Social Psychology*, *16*(1), 75-111. https://doi.org/10.1080/10463280540000007

Leary, M. R., Haupt, A. L., Strausser, K. S., & Chokel, J. T. (1998). Calibrating the sociometer: The relationship between interpersonal appraisals and the state self-esteem. Journal of Personality and Social Psychology, 74(5), 1290–1299. https://doi.org/10.1037/0022-3514.74.5.1290

Leng, G., & Ludwig, M. (2016). Intranasal oxytocin: myths and delusions. *Biological Psychiatry,* 79, 243–250. doi: 10.1016/j.biopsych.2015.05.003

Liu, Y., Sheng, F., Woodcock, K. A., & Han, S. (2013). Oxytocin effects on neural correlates of self-referential processing. *Biological Psychology*, *94*(2), 380-387. https://doi.org/10.1016/j.biopsycho.2013.08.003

Liu, Y., Wu, B., Wang, X., Li, W., Zhang, T., Wu, X., & Han, S. (2017). Oxytocin effects on self-referential processing: behavioral and neuroimaging evidence. *Social Cognitive and Affective Neuroscience*, *12*(12), 1845-1858. https://doi.org/10.1093/scan/nsx116

Nave, G., Camerer, C., McCullough, M., 2015. Does oxytocin increase trust in humans? A critical review of research. *Perspectives on Psychological Science*. 10, 772–789. doi: 10.1177/1745691615600138

Pfundmair, M., Zwarg, C., Paulus, M., & Rimpel, A., 2017. Oxytocin promotes attention to social cues regardless of group membership. *Hormones and Behavior*, 90, 136-140. doi: 10.1016/j.yhbeh.2017.03.006

Prentice-Dunn, S., & Rogers, R. W. (1980). Effects of deindividuating situational cues and aggressive models on subjective deindividuation and aggression. *Journal of Personality and Social Psychology, 39*, 104–113. doi:10.1037//0022-3514.39.1.104

Prentice-Dunn, S., & Rogers, R. W. (1982). Effects of public and private self-awareness on deindividuation and aggression. *Journal of Personality and Social Psychology*, *43*(3), 503. https://doi.org/10.1037/0022-3514.43.3.503

Radke, S., & de Bruijn, E.R. (2015). Does oxytocin affect mind-reading? A replication study. *Psychoneuroendocrinology*, 60, 75-81. doi:10.1016/j.psyneuen. 2015.06.006

Rosenberg, M. (1965). Rosenberg self-esteem scale (SES). *Society and the adolescent self-image*.

Ruissen, M. I., & de Bruijn, E. R. (2015). Is it me or is it you? Behavioral and electrophysiological effects of oxytocin administration on self-other integration during joint task performance. *Cortex*, *70*, 146-154. https://doi.org/10.1016/ j.cortex.2015.04.017

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: just like one's own? *Cognition*, *88*(3), B11-B21. https://doi.org/10.1016/S0010-0277(03)00043-X

Somerville, L. H., Kelley, W. M., & Heatherton, T. F. (2010). Self-esteem modulates medial prefrontal cortical responses to evaluative social feedback. *Cerebral Cortex*, *20*(12), 3005-3013. https://doi.org/10.1093/cercor/bhq049

Swann Jr, W. B., Chang-Schneider, C., & Larsen McClarty, K. (2007). Do people's self-views matter? Self-concept and self-esteem in everyday life. *American Psychologist*, *62*(2), 84. https://doi.org/10.1037/0003-066X.62.2.84

Tafarodi, R. W., & Swann Jr, W. B. (1995). Self-linking and self-competence as dimensions of global self-esteem: initial validation of a measure. *Journal of Personality Assessment*, *65*(2), 322-342. https://doi.org/10.1207/s15327 752jpa6502_8

Walum, H., Waldman, I.D., & Young, L.J. (2016). Statistical and methodological considerations for the interpretation of intranasal oxytocin studies. *Biological Psychiatry*, 79, 251–257. doi: 10.1016/j.biopsych.2015.06.016

Webb, W. M., Marsh, K. L., Schneiderman, W., & Davis, B. (1989). Interaction between self-monitoring and manipulated states of self-awareness. *Journal of Personality and Social Psychology*, *56*(1), 70. https://doi.org/10.1037/0022-3514.56.1.70

Zhao, W., Luo, R., Sindermann, C., Li, J., Wei, Z., Zhang, Y., ... & Becker, B. (2020). Oxytocin modulation of self-referential processing is partly replicable and sensitive to oxytocin receptor genotype. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *96*, 109734. https://doi.org /10.1016/j.pnpbp.2019.109734

Zhao, W., Yao, S., Li, Q., Geng, Y., Ma, X., Luo, L., ... & Kendrick, K. M. (2016). Oxytocin blurs the self-other distinction during trait judgments and reduces medial prefrontal cortex responses. *Human Brain Mapping*, *37*(7), 2512-2527. https://doi.org/10.1002/hbm.23190

3 Chapter 3: Can you feel your heart? Oxytocin inhibits interoceptive awareness

Jessica Burgstaller[1], Dieter Frey[1], Michaela Pfundmair[2]

[1]Ludwig-Maximilians-University of Munich

j.burgstaller@campus.lmu.de, dieter.frey@psy.lmu.de

[2]HS Bund, Berlin

michaela.pfundmair@hsbund-nd.de

Author Note

Correspondence concerning this article should be addressed to Jessica Burgstaller, Department of Psychology, Ludwig-Maximilians-University of Munich, Leopoldstr. 13, 80802 Munich, Germany, Tel. +49 89 21803002, Fax +49 21805238, Email: j.burgstaller@campus.lmu.de

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Keywords: oxytocin; interoception; self-awareness; sensory perception; self-observation

Article body: 3322 words

Abstract: 192 words

Figures: 1

Table: 1

Supplemental information: 0

3.1 Abstract

Oxytocin (OT) is a neuropeptide hormone that is mostly synthesized in the hypothalamus and impacts social cognition and emotion regulation. Because there are OT receptors in central and peripheral tissues, including the brain, heart, gastrointestinal tract and uterus, OT might also be involved in interoceptive processing. Since OT reduces self-related cognition, we particularly suggested that it inhibits interoceptive awareness. To investigate this, participants under OT (vs. placebo) were to conduct a heartbeat perception task in front of a mirror (vs. no mirror). Usually, people become more attuned to bodily responses in front of a mirror due to increased self-awareness. Because of inhibition of interoceptive awareness, we hypothesize that only participants under placebo, but not under OT, would increase accuracy of heartbeat perception. In this study, 56 male and female healthy participants self-administered OT or placebo intranasally. Whereas heartbeat accuracy, and thus interoceptive accuracy, was increased among participants under placebo who were placed in front of the mirror (compared to no mirror), no such effect occurred after treatment with OT. These findings support the idea of OT being involved in inhibiting interoception and enhancing de-individuation, which might mediate other emotional and cognitive processes.

3.2 Introduction

"[…] our feelings of the changes [in body functions] as they occur, *is* the emotion." With this statement, James (1884, p. 189) directed researchers' attention for the first time to the relationship between visceral perception and emotional experience. Today, the assumption that the perception of "bodily" changes composes one key element of emotional experience is widely accepted. The term interoception comprises signaling, representation and perception of sensations coming from the viscera. It is the sensory system that communicates the internal state of the body through signals originating from within the visceral organs (Cameron, 2001; Craig, 2009; Sherringtin, 1948). The signals comprise, for example, information about the functional state and health of organs, gastric distensions, visceral pain, but also heartbeats (Cameron, 2001). Interoception can be broadly distinguished from exteroception, the perception of the external world, and proprioception, the position of the body in space (Sherrington, 1948).

Interoception plays a key role in sensing and integrating not only the body's physiology but also motivational needs through monitoring blood chemistry, skin and body temperature, or even interpersonal touch (Craig, 2009). Serving homeostatic control and adaptation, interoceptive processes also contribute to motivational and affective behaviors through feelings such as hunger or thirst (Berntson, Cacioppo & Quigley, 1993; Tsakiris & Critchley, 2016). All in all, these signals seem to impact cognition, influence attention and perception, and even shape decisions, memory and emotion (Critchley & Harrison, 2013; Critchley & Garfinkel, 2015). This makes interoception an intriguing target to study.

3.2.1 The effects of interoception

The relationship between bodily physiology, emotions and cognition has been explored to some extent in previous pieces of research. For example, studies have shown that the experience of emotion is intensified in individuals who are more attuned to bodily responses (Lange & James, 1967; Wiens, Mezzacappa & Katkin, 2000). Imaging studies have also highlighted the role of interoception in emotional experience

(Critchley & Harrison, 2013; Seth, 2013). These studies have provided consistent evidence for an overlap between core networks involved in emotional and interoceptive processing. Previous research has also found a link between self-awareness and body awareness in that heightened attention to the self leads to more accurate awareness of bodily signals (Ainley, Maister, Brokfeld, Farmer, & Tsakiris, 2013; Ainley, Tajadura-Jiménez, Fotopoulou, & Tsakiris, 2012). With intracranial electroencephalography and magnetoencephalography recordings, it was even shown that the neural monitoring of visceral organs provides a unifying mechanism underlying both the cognitive and bodily self (Babo-Rebelo, Wolpert, Adam Hasboun & Tallon-Baudry, 2016). Thus, interoceptive processes might not only underlie emotion and cognition, but are also associated with a coherent representation of a conscious sense of the self.

3.2.2 The link between OT and interoception

OT plays an important role in human social cognition and motivation (Bartz et al., 2011; Striepens et al., 2011). For example, it has been shown that OT can improve attention towards and recognition of emotional faces (Fischer-Shofty et al., 2010; Domes et al., 2013; Shahrestani et al., 2013; Xu et al., 2015) and facilitates emotional memory and empathy (Guastella et al., 2008; Hurlemann et al., 2010). Because there are OT receptors in a number of visceral organs (e.g. the heart and stomach) as well as in core interoceptive brain regions (the insula and cingulate cortex), there is reason to believe that OT also plays a role in interoceptive processing (Gimpl & Fahrenholz, 2001; Jankowski et al., 2004). It seems plausible that these receptors inhibit or increase interoception. However, the influence of OT on behavioral or neural sensitivity to interoceptive information has not been investigated so far.

A line of research which aims to identify OT's functional effects proposes that it might enhance the salience of external social cues involving the insula and anterior cingulate (Bartz et al., 2011; Gao et al., 2016; Shamay-Tsoory & Abu-Akel, 2016). Similarly, Quattrocki and Friston (2014) hypothesize that OT facilitates the integration of external cues and switches attention between them. Consistently, it has been shown that OT shifts the normal self-bias (internal) towards consideration of the value of others (external) (Abu-Akel et al., 2015; Bartz et al., 2015; Striepens et al., 2011; Zhao et al., 2016). In a very new piece of research, OT was found to reduce self-related processing and instead promote de-individuation (Burgstaller, Pfundmair & Frey, submitted 2020). Thus, it seems plausible that OT might also switch attention away from internal interoceptive cues and, thereby, reduces interoceptive awareness.

3.2.3 The current study

Accordingly, we hypothesized OT to inhibit interoceptive awareness. To investigate this, we adapted the experimental paradigm described by Schandry (1981). In this procedure, participants performed a heartbeat perception task in front of a mirror (vs. no mirror). Usually, people confronted with their own reflection are more self-aware and, thus, more accurate in their interoception. The presence of a mirror (Bales & Flanders, 1954) has been shown to be one of the simplest manipulation operationalizations of self-awareness. For example, studies found that first-person pronouns are used more often when faced with a mirror (Carver & Scheier, 1978; Davis & Brock, 1975). Beaman, Klentz, Diener, and Svanum (1979) reported that children on Halloween were less likely to "steal" extra candy in the presence of a mirror. Importantly, self-observation also enhances interoceptive sensitivity. Ainley at al. (2012) tested the performance of participants on heartbeat detection while looking at their own face in a mirror. They could find a significant improvement in interoceptive sensitivity in the mirror condition, particularly for participants with lower interoceptive sensitivity at baseline.

All in all, people should become more attuned to bodily responses in front of a mirror due to increased self-awareness. However, when self-awareness is (artificially) inhibited, then even the presence of a mirror should not be able to activate interoception. In this study, we expected an according pattern (an increase of interoceptive awareness in front of a mirror) for the placebo condition. For the OT condition, however, we hypothesized a different pattern. As OT is known to decrease self-awareness and increase de-individuation (Liu, Sheng, Woodcock & Han, 2013; Liu et al., 2017; Zhao et al., 2016), we expected participants in the OT condition to not benefit from the effect of their reflection on accuracy of heartbeat perception. Thus, OT should inhibit interoceptive awareness.

3.3 Methods and materials

3.3.1 Participants and design

A total of 56[1] participants (44 female, 12 male; mean age = 27.86 years, *SD* = 8.45) participated in the study for research credit. Because of technical failure during one session, one participant had to be discarded from the analysis when including the number of actual heartbeats per minute as control variable.

Those who regarded themselves as having major depression, bipolar, panic and psychotic disorders, substance dependence, epilepsy, or (if female) pregnancy were not

[1] Reduced sample size compared to first study because the technical equipment (pulse oximeter) was not available at all times during the project

allowed to take part. Participants were instructed to abstain from alcohol and caffeine on the day of testing, and from food and drink, except water, for 2 hours before drug administration. The study was approved by the local ethics committee.

The study followed a 2 (substance: OT vs. placebo) x 2 (mirror: yes vs. no) between-subjects design with random assignment to conditions and double-blind assignment to the substances.

3.3.2 Procedure and experimental task

When participants arrived in the laboratory, they were informed about the equipment, the measures that were to be taken and the general procedure. After written informed consent was obtained, participants received 24 I.U. of OT (Syntocinon Spray, Defiante; three puffs per nostril, $n = 29$) or a placebo (sodium chloride solution, $n = 27$). After 40 min that allowed the substances to reach their maximum, a pulse oximeter was clipped to the participants' finger. Then, they were either placed in front of a mirror ($n = 22$) or not ($n = 34$). Participants were provided with an instruction for the perception task and were asked to sit quietly during the whole session. After a 5 min resting period, the task was performed as follows: During a certain time interval, the participant was instructed to count his or her heartbeats by concentrating on bodily feelings. Taking the pulse or trying any other physical manipulation which might had facilitated the perception was not allowed. The task was performed 3 times in random order with time intervals of 25, 35 and 45 seconds with alternating periods of 60 seconds at rest in between (as similarly done in Schandry, 1981). Participants were not informed about the time span of each trial. At the end of each interval, participants reported the counted or estimated number of heartbeats. At the end, female participants were asked about ovarian cycle stage (mean day of cycle = 13.90, $SD = 7.45$; as similarly done in

Pfundmair et al., 2017). Debriefing followed after unrelated tasks.

3.3.3 Recording of physiological data

The pulse oximeter clipped to the participants' finger was used to record physiological data. Pulse oximetry is a widely accepted noninvasive procedure for measuring the oxygen saturation level of arterial blood, an indicator of oxygen supply. It typically provides a numerical readout of the patient's oxygen saturation and a numerical readout of heart rate (in beats per minute). The participant's pulse is displayed as small light flash on the monitor (Al Ali, Breed, & Novak, 2003). Manual counting of the blinking light served to measure the actual heartbeats of the participant in the given time interval. A comparison between the experimenter's counting and the subject's interoception of heartbeats served as dependent variable. Specifically, accuracy of perception of heartbeats was quantified as a difference score between reported and actual number of heartbeats. This score was obtained as the mean of the three perception phases. A high error score reflected a poor accuracy of perception, a lower score a higher accuracy (0 would be the most accurate value).

3.3.4 Data analysis

A 2 (substance: OT vs. placebo) x 2 (mirror: yes vs. no) between-subjects ANOVA was conducted to test the effect of OT vs. placebo on accuracy of heartbeat perception when seated in front of a mirror or without a mirror to be present. Moreover, we conducted the same analysis on accuracy of heartbeat perception controlling for variability of the heart rate (beats per minute) between participants. Because low heart rate is associated with increased accuracy on heartbeat perception, and beliefs about heart rate may further influence performance on heartbeat counting (Ring & Brener, 1996; Ring, Brener, Knapp & Mailloux, 2015), we included heart rate as a co-variable in our additional analysis to account for its bias on interoception. Further, we used ovarian cycle stage as covariate due to fluctuations of internal OT concentrations in female participants.

All statistical tests were performed using the SPSS 23.0.0.0 Software.

3.4 Results

Descriptive statistics can be found in Table 1.

Table 1. Means and standard deviations (in parenthesis) of heart rate and error score of heartbeat perception as a function of substance (OT vs. placebo) and condition (mirror vs. no mirror).

	OT (N = 29)		Placebo (N = 27)	
	Mirror	No mirror	Mirror	No mirror
Heart rate (beats per minute)	68.67 (11.87)	62.64 (16.87)	73.25 (12.06)	72.08 (11.97)
Error score	16.86 (10.52)	11.66 (9.70)	10.97 (8.68)	18.23 (9.46)

Main effects. A 2 (substance) x 2 (mirror) between-subjects ANOVA on heartbeat perception showed no significant main effect of substance, $F(1,52) = 0.02$, $p = .899$, $\eta^2 < .001$, 95%CI = [0.00,0.13] and no main effect of mirror $F(1,52) = 0.15$, $p = .699$, $\eta^2 = .003$, 95%CI = [0.00,0.09]. However, a significant interaction of substance and mirror emerged, $F(1,52) = 5.56$, $p = .022$, $\eta^2 = .10$, 95%CI = [0.00,0.26].

Post-hoc testing revealed that, when participants received the placebo, accuracy of heartbeat perception was marginally enhanced in the mirror condition compared to the no mirror condition, $t(25) = 2.06$, $p = .050$, $d = 0.81$, 95%CI = [0.00,1.60]. In the OT condition, however, accuracy of heartbeat perception did not significantly differ between participants who sat in front of a mirror or not, $t(27) = -1.33$, $p = .195$, $d = 0.51$, 95%CI = [-0.26,1.27], see Figure 1.

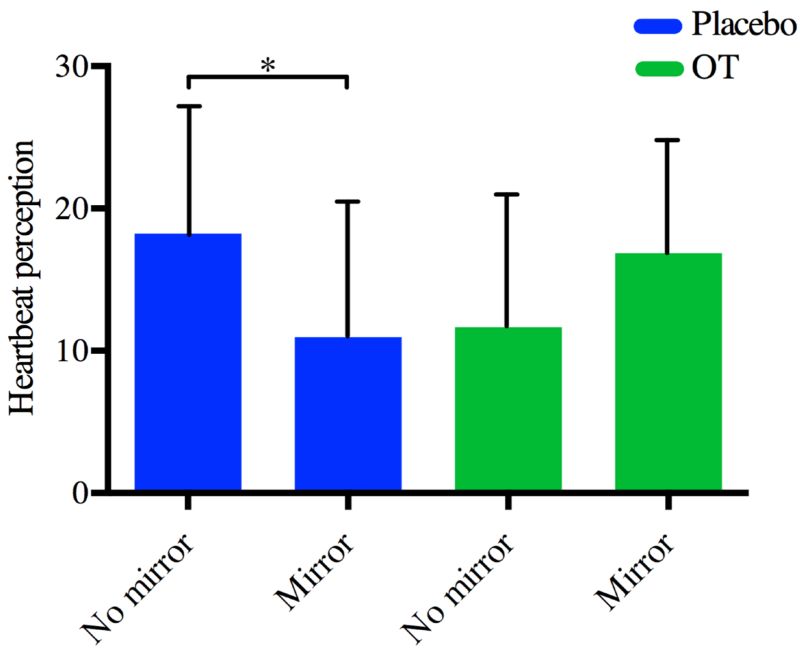


Figure 1. In the placebo condition (blue), accuracy of heartbeat perception (Mean ± SD) was enhanced in participants in front of the mirror compared to accuracy of perception without a mirror (a lower score indicates a higher accuracy). With OT, accuracy of heartbeat perception did not differ between the mirror and no mirror condition (green).

Control variables. The same between-subjects ANOVA on heartbeat perception when controlling for the variability of the heart rate between participants (number of heartbeats per minute) revealed the same results. There was no significant main effect of substance, $F(1,51) = 2.76$, $p = .103$, $\eta^2 = .05$, 95%CI = [0.00,0.20], and no main effect of mirror $F(1,51) = 1.51$, $p = .225$, $\eta^2 = .03$, 95%CI = [0.00,0.16]. However, a significant interaction of substance and mirror emerged, $F(1,51) = 5.44$, $p = .024$, $\eta^2 = .10$, 95%CI = [0.00,0.26].

When performing the same ANOVA including ovarian cycle stage as covariate, the same pattern of results emerged. The 2 (substance) x 2 (mirror) between-subjects ANOVA on heartbeat perception showed no significant main effect of substance, $F(1,51) = 0.19$, $p = .798$, $\eta^2 < .001$, 95%CI = [0.00,0.13] and no main effect of mirror $F(1,51) = 0.21$, $p = .683$, $\eta^2 = .003$, 95%CI = [0.00,0.09]. However, a significant interaction of substance and mirror emerged, $F(1,51) = 5.13$, $p = .041$, $\eta^2 = .10$, 95%CI = [0.00,0.26].

3.5 Discussion

The current study revealed that OT administration inhibited interoceptive accuracy: Accuracy of heartbeat perception increased among participants who administered a placebo and faced their mirror image compared to a condition without a mirror. This is in line with previous findings (Ainley et al., 2012; Ainley et al., 2013). With OT, however, there was no significant difference in accuracy of heartbeat perception between the mirror and no mirror condition.

OT is proposed to direct attentional resources away from internal interoceptive towards external social salient cues (Abu-Akel et al., 2015; Shamay-Tsoory & Abu-Akel, 2016; Brodmann, Gruber & Goya-Maldonado, 2017; Yao et al., 2017). Our findings are in line with findings that attribute the role of OT in decreasing self-orientated behavior (internal) and increasing other-oriented (external) responses (Abu-Akel et al, 2015; Bartz et al, 2015; Zhao et al, 2016).

More profoundly, our results leave room for two lines of interpretation: A) OT might function as a shield to protect individuals from social anxiety that roots in enhanced perception of bodily signals in front of a mirror, and/or B) while reducing self-awareness and promoting de-individuation, OT allocates attentional resources towards social cues which, ultimately, results in enhanced social cognition and prosocial behavior. These two interpretations might both be true and interact in their manifestation of OT's social effects.

The theoretical approach of the first interpretation suggests that OT reduces bodily awareness due to anxiety reduction. Interoceptive awareness classically refers to the representation of afferent bodily physiological sensations (Craig, 2008; Critchley et al., 2004). High interoceptive sensitivity has been associated with emotional disorders (Ehlers & Breuer, 1996; Dunn et al, 2010). Yao et al. (2018) provided evidence that activation of the amygdala is negatively correlated with interoceptive accuracy, suggesting that increased emotional encoding in the amygdala leads to reduced interoceptive awareness. This might be the case under OT. Consistently, studies show that OT is associated with increased amygdala activation (Striepens et al, 2011; Gao et al, 2016).

A shift towards de-individuation, even when a mirror (that usually enhances self-awareness) is present, may be a second possible interpretation for reduced accuracy in interoception. This interpretation is consistent with the predictive coding framework. In this framework, attention to interoceptive or exteroceptive cues is mediated by the precision of ascending prediction errors encoded by the gain of postsynaptic responses. The neuromodulator OT potentially directs attention to external cues by increasing the precision of prediction errors in brain regions high in the hierarchy (e.g., in the AI) and decreasing the precision at lower, sensory, levels (such as the PI). The AI seems to be particularly involved in cognitive and emotional processing, whereas the PI seems to specifically process primary sensory components of interoceptive signals (Critchley et al., 2004; Pollatos et al., 2007b; Kurth et al., 2010; Chang et al., 2012; Zaki et al., 2012; Uddin et al., 2014). This attentional shift may also facilitate associative learning between internal and external cues, a process fundamental to social cognition (Quattrocki and Friston, 2014). Thus, because OT might increase the gain of neuronal populations higher in hierarchy, the hormone and neurotransmitter might increase attention towards awareness of others more than the self and, ultimately, lead to enhanced social cognition and behaviors. In other words, OT might switch attention away from interoceptive cues towards external ones to promote social interactions.

Although these findings are intriguing and consistent with previous research, there are several limitations to this study. Importantly, we did not find a decrease in interoceptive abilities independent of conditions. Only when the baseline level of interoceptive accuracy was high (in our case, experimentally facilitated via increased self-observation in the mirror condition), OT’s effect on reducing accuracy of heartbeat perception became apparent. We chose to artificially support performance in heartbeat perception (via a mirror) to control for varying degrees of interoceptive baseline abilities. However, as this manipulation was necessary to observe a diminishing effect of OT on accuracy of heartbeat perception, one might conclude that the effect might not be easily observable but rather subtle. Moreover, we derived de-individuation processes from reduced accuracy in interoception, which seems valid according to previous work (Diener & Wallbom, 1976; Festinger et al., 1952; Prentice-Dunn & Rogers, 1980). However, a direct operationalization of de-individuation in futures OT experiments is necessary to validate this point, employing methods that have already been used with success (for example, as similarly done in Prentice-Dunn & Rogers, 1982).

Because of reports of a potential publication bias in OT research (Lane, Luminet, Nave, Mikolajczak & Lane, 2016), there has been doubt on OT's true effects. Our data revealed a nearly large effect for our main research question (interoceptive accuracy: $\eta^2 = .10$; Cohen, 2013: small (0.01), medium (0.06) and large (0.14) effects). Nevertheless, the sample sizes per conditions were partly low because data acquisition was terminated with the end of the study semester. It should be taken into account that underpowered studies and an overestimation of effects, as well as null results (Lane et al., 2016) and replication failures (Nave, McCullough & Nave, 2015; Radke & de Bruijn, 2015) are a serious problem in OT experiments (Walum, Waldman & Young Walum, 2016). Performing further experiments, both direct replications and studies with varying methodological approaches, is therefore necessary to substantiate our findings.

Taken together, our results show that OT inhibits interoceptive awareness, even in situations which are highly stimulative in interoception. Exploring OT's mechanism of action, we applied purely physiological parameters. This study might help to distil a common ground explanation for OT's paradoxical and context dependent effects and have implications to understand the hormone's role in human's social behavior.

3.6 References

Abu-Akel, A., Palgi, S., Klein, E., Decety, J., & Shamay-Tsoory, S. (2015). Oxytocin increases empathy to pain when adopting the other-but not the self-perspective. *Social Neuroscience*, *10*(1), 7-15. https://doi.org/10.1080/ 17470919. 2014.948637

Ainley, V., Tajadura-Jiménez, A., Fotopoulou, A., & Tsakiris, M. (2012). Looking into myself: Changes in interoceptive sensitivity during mirror self-observation. *Psychophysiology*, *49*(11), 1672-1676. https://doi.org/10.1111/j.1469-8986.2012.01468.x

Ainley, V., Maister, L., Brokfeld, J., Farmer, H., & Tsakiris, M. (2013). More of myself: Manipulating interoceptive awareness by heightened attention to bodily and narrative aspects of the self. *Consciousness and Cognition*, *22*(4), 1231-1238. https://doi.org/10.1016/j.concog.2013.08.004

Al Ali, A., Breed, D. S., & Novak, J. J. (2003). *U.S. Patent No. 6,606,511*. Washington, DC: U.S. Patent and Trademark Office. Ser. No. 60/115,289 filed Jan. 7, 1999.

Babo-Rebelo, M., Wolpert, N., Adam, C., Hasboun, D., & Tallon-Baudry, C. (2016). Is the cardiac monitoring function related to the self in both the default network and right anterior insula? *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1708), 20160004.doi:10.1098/rstb. 2016.0004

Bales, R. F., & Flanders, N. A. (1954). Planning an observation room and group laboratory. *American Sociological Review*, *19*, 771-781. doi: 10.2307/2087925

Bartz, J. A., Lydon, J. E., Kolevzon, A., Zaki, J., Hollander, E., Ludwig, N., & Bolger, N. (2015). Differential effects of oxytocin on agency and communion for anxiously and avoidantly attached individuals. *Psychological Science*, *26*(8), 1177-1186. https://doi.org/10.1177/0956797615580279

Bartz, J.A., Zak, J., Bolger, N., & Ochsner, K.N. (2011). Social effects of oxytocin in humans: context and person matter. *Trends in Cognitive Science, 15*(7), 301-309. doi: 10.1016/j.tics.2011.05.002

Beaman, A. L., Klentz, B., Diener, E., & Svanum, S. (1979). Self- awareness and transgression in children: Two field studies. *Journal of Personality and Social Psychology*, *37*, 1835-1846. https://doi.org/10.1037/0022-3514.37.10.1835

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993). Cardiac psychophysiology and autonomic space in humans: empirical perspectives and conceptual implications. *Psychological Bulletin*, *114*(2), 296. doi:10.1037/0033-2909.114. 2.296

Bloodstein, O. (1969). *A handbook on stuttering*. Chicago: National Easter Seal Society for Crippled Children and Adults.

Bovasso, G. (1997). The interaction of depersonalization and deindividuation. *Journal of Social Distress and the Homeless*, *6*, 213- 228. https://doi.org/10.1007/BF02939566

Brodmann, K., Gruber, O., & Goya-Maldonado, R. (2017). Intranasal oxytocin selectively modulates large-scale brain networks in humans. *Brain connectivity*, *7*(7), 454-463. https://doi.org/10.1089/brain.2017.0528

Cameron, O. G. (2001). Visceral sensory neuroscience: Interoception. New York, USA: Oxford University Press.

Carver, C. S., & Scheier, M. F. (1978). Self-focusing effects of dispositional self-consciousness, mirror presence, and audience presence. *Journal of Personality and Social Psychology*, *36*, 324-332. https://doi.org/10.1037/0022-3514.36.3.324

Chang, L. J., Yarkoni, T., Khaw, M. W., & Sanfey, A. G. (2012). Decoding the role of the insula in human cognition: functional parcellation and large-scale reverse inference. *Cerebral Cortex*, *23*(3), 739-749. https://doi.org/10.1093/cercor/bhs065

Craig, A. D. (2008). Interoception and emotion: a neuroanatomical perspective. *Handbook of emotions*, *3*(602), 272-88.

Craig, A. D. (2009). How do you feel--now? The anterior insula and human awareness. *Nature Reviews Neuroscience*, *10*(1). doi:10.1038/nrn2555

Critchley, H. D., & Harrison, N. A. (2013). Visceral influences on brain and behavior. *Neuron*, *77*(4), 624-638. doi:10.1016/j.neuron.2013.02.008)

Critchley, H. D., & Garfinkel, S. N. (2015). Interactions between visceral afferent signaling and stimulus processing. *Frontiers in Neuroscience*, *9*, 286. doi:10.3389/ fnins.2015.00286)

Critchley, H. D., Wiens, S., Rotshtein, P., Öhman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience*, *7*(2), 189. doi:10.1038/nn1176

Damasio, A. (2003). Mental self: The person within. *Nature*, *423*(6937), 227. doi:10.1038/423227a

Davis, D., & Brock, T. C. (1975). Use of first person pronouns as a function of increased objective self-awareness and performance feedback. *Journal of Experimental Social Psychology*, *11*, 381-388. https://doi.org/10.1016/0022-1031(75)90017-7

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

De Dreu, C. K. (2012). Oxytocin modulates cooperation within and competition between groups: an integrative review and research agenda. *Hormones and Behavior*, *61*(3), 419-428. https://doi.org/10.1016/j.yhbeh.2011.12.009

Diener, E. (1980). Deindividuation: The absence of self-awareness and self-regulation in group members. In P. Paulus (Ed.), *The Psychology of Group Influence*. Hillsdale, NJ: Lawrence Erlbaum.

Diener, E., & Wallbom, M. (1976). Effects of self-awareness on antinormative behavior. *Journal of Research in Personality*, *10*(1), 107-111.https://doi.org/ 10.1016/0092-6566(76)90088-X

Domes, G., Sibold, M., Schulze, L., Lischke, A., Herpertz, S. C., & Heinrichs, M. (2013). Intranasal oxytocin increases covert attention to positive social cues. *Psychological Medicine*, *43*(8), 1747-1753. doi: https://doi.org/10.1017/ S0033291712002565

Dunn, B. D., Stefanovitch, I., Evans, D., Oliver, C., Hawkins, A., & Dalgleish, T. (2010). Can you feel the beat? Interoceptive awareness is an interactive function of anxiety-and depression-specific symptom dimensions. *Behaviour Research and Therapy*, *48*(11), 1133-1138.https://doi.org/10.1016/j.brat.2010. 07.006

Ehlers, A., & Breuer, P. (1996). How good are patients with panic disorder at perceiving their heartbeats? *Biological psychology*, *42*(1-2), 165-182.https://doi.org/10. 1016/0301-0511(95)05153-8

Festinger, L., Pepitone, A., & Newcomb, T. (1952). Some consequences of de-individuation in a group. *The Journal of Abnormal and Social Psychology*, *47*(2S), 382. https://doi.org/10.1037/h0057906

Fischer-Shofty, M., Shamay-Tsoory, S. G., Harari, H., & Levkovitz, Y. (2010). The effect of intranasal administration of oxytocin on fear recognition. *Neuropsychologia*, *48*(1), 179-184. https://doi.org/10.1016/j.neuro psychologia.2009.09.003

Gao, S., Becker, B., Luo, L., Geng, Y., Zhao, W., Yin, Y., ... & Yao, D. (2016). Oxytocin, the peptide that bonds the sexes also divides them. *Proceedings of the National Academy of Sciences*, *113*(27), 7650-7654. https://doi.org/10. 1073/pnas.1602620113

Gimpl, G., & Fahrenholz, F. (2001). The oxytocin receptor system: structure, function, and regulation. *Physiological Reviews*, *81*(2), 629-683.https://doi.org/10.1152 /physrev.2001.81.2.629

Guastella, A. J., Mitchell, P. B., & Mathews, F. (2008). Oxytocin enhances the encoding of positive social memories in humans. *Biological Psychiatry*, *64*(3), 256-258.https://doi.org/10.1016/j.biopsych.2008.02.008

Hurlemann, R., Patin, A., Onur, O. A., Cohen, M. X., Baumgartner, T., Metzler, S., ... & Kendrick, K. M. (2010). Oxytocin enhances amygdala-dependent, socially reinforced learning and emotional empathy in humans. *Journal of Neuroscience*, *30*(14), 4999-5007.https://doi.org/10.1523/JNEUROSCI.5538-09.2010

James, W. What is an emotion? *Mind*, 1884, 9, 188-205.

Jankowski, M., Danalache, B., Wang, D., Bhat, P., Hajjar, F., Marcinkiewicz, M., ... & Gutkowska, J. (2004). Oxytocin in cardiac ontogeny. *Proceedings of the National Academy of Sciences*, *101*(35), 13074-13079. https://doi.org/10.1073/pnas.0405324101

Johnstone, H. W. (1970). *The problem of the self*. University Park: Penn- sylvania State University.

Kemp, A. H., Quintana, D. S., Kuhnert, R. L., Griffiths, K., Hickie, I. B., & Guastella, A. J. (2012). Oxytocin increases heart rate variability in humans at rest: implications for social approach-related motivation and capacity for social engagement. *PLoS One*, *7*(8), e44014. https://doi.org/10.1371/journal.pone.0044014

Kurth, F., Zilles, K., Fox, P. T., Laird, A. R., & Eickhoff, S. B. (2010). A link between the systems: functional differentiation and integration within the human insula revealed by meta-analysis. *Brain Structure and Function*, *214*(5-6), 519-534.https://doi.org/10.1007/s00429-010-0255-z

Lane, A., Luminet, O., Nave, G., & Mikolajczak, M. (2016). Is there a Publication Bias in Behavioural Intranasal Oxytocin Research on Humans? Opening the File Drawer of One Laboratory. *Journal of Neuroendocrinology*, 28(4). doi:10.1111/jne.12384

Lange, C. G., & James, W. (1967). The emotions. New York/London: Hafner Publishing Co (edited by Knight Dunlap – Reprinted).

Leng, G., & Ludwig, M. (2016). Intranasal oxytocin: myths and delusions. *Biological Psychiatry,* 79, 243–250. doi: 10.1016/j.biopsych.2015.05.003

Liu, Y., Sheng, F., Woodcock, K. A., & Han, S. (2013). Oxytocin effects on neural correlates of self-referential processing. *Biological Psychology*, *94*(2), 380-387.https://doi.org/10.1016/j.biopsycho.2013.08.003

Liu, Y., Wu, B., Wang, X., Li, W., Zhang, T., Wu, X., & Han, S. (2017). Oxytocin effects on self-referential processing: behavioral and neuroimaging evidence. *Social Cognitive and Affective Neuroscience*, *12*(12), 1845-1858. https://doi.org/10.1093/scan/nsx116

Maddox, J. (1938). Studies in the psychology of stuttering. VIII: The role of visual cues in the precipitation of moments of stuttering. *Journal of Speech Disorders*, *3*, 90-94. https://doi.org/10.1044/jshd.0302.90

Mullen, B. (1983). Operationalizing the effect of the group on the individual: A self-attention perspective. *Journal of Experimental Social Psychology*, *19*, 545-559. https://doi.org/10.1016/0022-1031(83)90025-2

Mullen, B. (1986). Stuttering, audience size, and the other-total ratio: A self-attention perspective. *Journal of Applied Social Psychology*, *16*, 141-151. https://doi.org/10.1111/j.1559-1816.1986.tb02284.x

Mullen, B. (1991). Group composition, salience, and cognitive representations: The phenomenology of being in a group. *Journal of Experimental Social Psychology*, *27*, 297-323. https://doi.org/10.1016/0022-1031(91)90028-5

Nave, G., Camerer, C., McCullough, M., 2015. Does oxytocin increase trust in humans? A critical review of research. *Perspectives on Psychological Science*. 10, 772–789. doi: 10.1177/1745691615600138

Park, H. D., & Tallon-Baudry, C. (2014). The neural subjective frame: from bodily signals to perceptual consciousness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1641), 20130208.doi:10.1098/rstb. 2013.0208

Pfundmair, M., Zwarg, C., Paulus, M., & Rimpel, A., 2017. Oxytocin promotes attention to social cues regardless of group membership. *Hormones and Behavior*, 90, 136-140. doi: 10.1016/j.yhbeh.2017.03.006

Pollatos, O., Kirsch, W., & Schandry, R. (2005). On the relationship between interoceptive awareness, emotional experience, and brain processes. *Cognitive Brain Research*, *25*(3), 948-962. https://doi.org/10.1016/j.cogbrainres. 2005.09.019

Pollatos, O., Schandry, R., Auer, D. P., & Kaufmann, C. (2007). Brain structures mediating cardiovascular arousal and interoceptive awareness. *Brain Research*, *1141*, 178-187.https://doi.org/10.1016/j.brainres.2007.01.026

Porter, H. (1939). Studies in the psychology of stuttering, XIV: Stuttering phenomena in relation to size and personnel of audience. *Journal of Speech Disorders*, *4*, 323-333. https://doi.org/10.1044/jshd.0404.323

Prentice-Dunn, S., & Rogers, R. W. (1980). Effects of deindividuating situational cues and aggressive models on subjective deindividuation and aggression. *Journal of Personality and Social Psychology, 39*, 104–113. doi:10.1037//0022-3514.39.1.104

Prentice-Dunn, S., & Rogers, R. W. (1982). Effects of public and private self-awareness on deindividuation and aggression. *Journal of Personality and Social Psychology*, *43*(3), 503. https://doi.org/10.1037/0022-3514.43.3.503

Quattrocki, E., & Friston, K. (2014). Autism, oxytocin and intero-ception. *Neuroscience & Biobehavioral Reviews*, *47*, 410-430. https://doi.org/10.1016/j.neubiorev.2014.09.012

Radke, S., & de Bruijn, E.R. (2015). Does oxytocin affect mind-reading? A replication study. *Psychoneuroendocrinology*, 60, 75-81. doi:10.1016/j.psyneuen.2015.06.006

Ring, C., & Brener, J. (1996). Influence of beliefs about heart rate and actual heart rate on heartbeat counting. *Psychophysiology*, *33*(5), 541-546.https://doi.org/10.1111/j.1469-8986.1996.tb02430.x

Ring, C., Brener, J., Knapp, K., & Mailloux, J. (2015). Effects of heartbeat feedback on beliefs about heart rate and heartbeat counting: A cautionary tale about interoceptive awareness. *Biological Psychology*, *104*, 193-198.https://doi.org/10.1016/j.biopsycho.2014.12.010

Schandry, R. (1981). Heartbeat perception and emotional experience. *Psychophysiology*, 18, 483-488. https://doi.org/10.1111/j.1469-8986.1981.tb02486.x

Schoemaker, S. (1963). Self-knowledge and self identity. Ithaca, NY: Cornell University Press.

Seth, A. K. (2013). Interoceptive inference, emotion, and the embodied self. *Trends in Cognitive Sciences*, *17*(11), 565-573. https://doi.org/10.1016/j.tics.2013.09.007

Shahrestani, S., Kemp, A. H., & Guastella, A. J. (2013). The impact of a single administration of intranasal oxytocin on the recognition of basic emotions in humans: a meta-analysis. *Neuropsychopharmacology*, *38*(10), 1929. doi:10.1038/npp.2013.86

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The social salience hypothesis of oxytocin. *Biological Psychiatry*, *79*(3), 194-202. https://doi.org/10.1016/j.biopsych.2015.07.020

Sherrington, C. S. (1948). The integrative action of the nervous system. Cambridge, UK: Cambridge Univ. Press.

Striepens, N., Kendrick, K. M., Maier, W., & Hurlemann, R. (2011). Prosocial effects of oxytocin and clinical evidence for its therapeutic potential. *Frontiers in Neuroendocrinology*, *32*(4), 426-450. https://doi.org/10.1016/j.yfrne.2011.07.001

Suzuki, K., Garfinkel, S. N., Critchley, H. D., & Seth, A. K. (2013). Multisensory integration across exteroceptive and interoceptive domains modulates self-experience in the rubber-hand illusion. *Neuropsychologia*, *51*(13), 2909-2917. https://doi.org/10.1016/j.neuropsychologia.2013.08.014

Swallow, R. W. (1937). Ancient Chinese bronze mirrors. Peiping, China: Henri Vetch.

Tsakiris, M., Jiménez, A. T., & Costantini, M. (2011). Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1717), 2470-2476. doi:10.1098/rspb.2010.2547

Tsakiris, M., & Critchley, H. (2016). Interoception beyond homeostasis: affect, cognition and mental health. https://doi.org/10.1098/rstb.2016.0002

Turner, J. C. (1981). The experimental social psychology of intergroup behavior. In J. C. Turner & H. Giles (Eds.), *Intergroup Behavior*. Oxford, UK: Basil Blackwell.

Uddin, L. Q., Kinnison, J., Pessoa, L., & Anderson, M. L. (2014). Beyond the tripartite cognition–emotion–interoception model of the human insular cortex. *Journal of cognitive neuroscience*, *26*(1), 16-27. https://doi.org/10.1162/jocn_a_00462

Walum, H., Waldman, I.D., & Young, L.J. (2016). Statistical and methodological considerations for the interpretation of intranasal oxytocin studies. *Biological Psychiatry*, 79, 251–257. doi: 10.1016/j.biopsych.2015.06.016

Wiens, S., Mezzacappa, E. S., & Katkin, E. S. (2000). Heartbeat detection and the experience of emotions. *Cognition & Emotion*, *14*(3), 417-427.https://doi.org/10.1080/026999300378905

Xu, L., Ma, X., Zhao, W., Luo, L., Yao, S., & Kendrick, K. M. (2015). Oxytocin enhances attentional bias for neutral and positive expression faces in individuals with higher autistic traits. *Psychoneuroendocrinology*, *62*, 352-358. https://doi.org/10.1016/j.psyneuen.2015.09.002

Yao, S., Becker, B., Zhao, W., Zhao, Z., Kou, J., Ma, X., ... & Kendrick, K. M. (2018). Oxytocin modulates attention switching between interoceptive signals and external social cues. *Neuropsychopharmacology*, *43*(2), 294. doi:10.1038/npp. 2017.189

Zaki, J., Davis, J. I., & Ochsner, K. N. (2012). Overlapping activity in anterior insula during interoception and emotional experience. *Neuroimage*, *62*(1), 493-499. https://doi.org/10.1016/j.neuroimage.2012.05.012

Zhao, W., Luo, R., Sindermann, C., Li, J., Wei, Z., Zhang, Y., ... & Becker, B. (2020). Oxytocin modulation of self-referential processing is partly replicable and sensitive to oxytocin receptor genotype. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *96*, 109734. https://doi.org/ 10.1016/j.pnpbp.2019.109734

Zhao, W., Yao, S., Li, Q., Geng, Y., Ma, X., Luo, L., ... & Kendrick, K. M. (2016). Oxytocin blurs the self-other distinction during trait judgments and reduces medial prefrontal cortex responses. *Human Brain Mapping*, *37*(7), 2512-2527. https://doi.org/10.1002/hbm.23190

Zimbardo, P. G. (1969). The human choice: Individuation, reason, and order versus deindividuation, impulse, and chaos. *Nebraska Symposium on Motivation*, *17*, 237-307.

4 Chapter 4: Oxytocin promotes de-individuation in self-related cognition

Jessica Burgstaller[1], Dieter Frey[1], Michaela Pfundmair[2]

[1]Ludwig-Maximilians-University of Munich

j.burgstaller@campus.lmu.de, dieter.frey@psy.lmu.de

[2]HS Bund, Berlin

michaela.pfundmair@hsbund-nd.de

Author Note

Correspondence concerning this article should be addressed to Jessica Burgstaller, Department of Psychology, Ludwig-Maximilians-University of Munich, Leopoldstr. 13, 80802 Munich, Germany, Tel. +49 89 21803002, Fax +49 21805238, Email: j.burgstaller@campus.lmu.de

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Keywords: oxytocin; self-related cognition; self-awareness; sensory perception; social cognition

Article body: 5596 words

Abstract: 150 words

Figures: 2

Table: 1

Supplemental information: 0

4.1 Abstract

The neuropeptide oxytocin (OT) has been suggested to facilitate social cognition and behavior. Based on a broad literature review, we assumed that de-individuation, a state of reduced self-related cognition, might be upstream of any OT effects. In addition to providing a new theoretical framework, the current work aimed to conduct a direct test of its core assumption. In this study, 77 male and female healthy participants self-administered OT or placebo intranasally and their attentional focus was shifted, either to external sensory perception or self-related cognition, using a categorization vs. introspection task. We found that situational self-awareness was reduced after OT treatment compared to placebo, when participants had previously been instructed to introspect about their feelings. These findings supported the idea of OT being significantly involved in enhancing de-individuation. In providing a new theoretical framework and first empirical results, we aimed to contribute to solving the mystery of OT's basic functioning.

4.2 Introduction

It is more wide ranging and influential than ever thought before: the effect of the self in cognition. Cues in the environment that seem to have relevance to the self (e.g., someone saying your name in a loud and crowded room) are difficult to ignore (Bargh, 1982; Brédart, Delchambre & Laureys, 2006). Cognitive psychologists have found these attention-capturing properties of the self to be among the earliest robust findings in their research (Cherry, 1953; Moray, 1959). But not only that, these cues are also among the most evocative of environmental cues and give rise to significant memory advantages (Conway & Dewhurst, 1995; Rogers, Kuiper & Kirker, 1977; Symons & Johnson, 1997). Many studies have investigated the attentional and memorial effects of self-relevant cues, but only recently, scientists have started to explore self-processing more widely. Humphreys and Sui (2016) have suggested that self-relevant stimuli activate a neural “self-attention network”. They could show that perception of self-relevant stimuli induce activity in areas such as ventromedial prefrontal cortex (vmPFC) and the left posterior superior temporal sulcus (LpSTS), which then elicits attentional and perceptual biases.

Scarce self-awareness, on the other hand, can also influence behaviors. When people become a part of the group in an extreme way, they experience de-individuation, a loss of individual self-awareness (Festinger, Pepitone & Newcomb, 1952; Zimbardo, 1969). In this case, self-related cognition is faded out and people only feel obliged to stick to the specific social norms of the group. Depending on the group’s norm, even aggressive and racist behaviors are possible, as the case among members of the Ku Klux Klan who even hide their identities under white robes and hats. The famous neuropeptide OT has not only been observed to increase trust and cooperation but also ethnocentrism and racism (De Dreu et. al., 2010; 2011). In an attempt to explain its paradoxical effects, we suppose that OT might work by reducing self-related cognition and increasing de-individuation.

This article will give a broad theoretical overview of OT’s role in social cognition and provide insights into research on self-related processing and cognition. We will discuss how these findings indicate that OT might work through reduced self-awareness and increased de-individuation and how OT’s theoretical framework might need to be expanded. In the end, we report a first experimental test for the idea of reduced self-awareness and de-individuation as potential explanations for OT’s known effects.

4.2.1 The effect of OT on human cognition and behavior

The neuropeptide OT functions as hormone and neurotransmitter and is synthesized in the hypothalamus. Not just for animals but also humans, it plays a crucial role in social behavior and cognition (Insel, 1992; Donaldson & Young, 2008; De Dreu, 2012). Studies in animals could show that it promotes maternal behavior (Pedersen, Ascher, Monroe & Prange, 1982; Keverne & Kendrick, 1992) and enhances social attachments with conspecifics (Young & Wang, 2004). But also, human social behavior and the underlying cognitions and emotions are influenced by OT. Intranasal administration of OT compared with placebo in human adults improves recognition memory for faces and identification of facial expressions (Domes, Heinrichs, Michel, Berger & Herpertz, 2007; Rimmele, Hediger, Heinrichs & Klaver, et al., 2009), facilitates the ability to recognize emotions (Schulze et al., 2011), and enhances positive social communication and the understanding of others' perspective (Ditzen et al., 2009). In the ultimatum game, OT spurs generosity and increases inter-personal coordination (Arueti et al., 2013; Mu, Guo & Han, 2016; Zak, Stanton & Ahmadi, 2007). Moreover, ingroup favouritism in economic decisions seems to be regulated by the neuropeptide (De Dreu et al., 2010; Ma, Liu, Rand, Heatherton & Han, 2015).

Besides these positive OT effects on social cognition and behavior, the findings of other studies suggest negative OT effects. For instance, when a participant gained less money or more money than others in an economic game, OT increased feelings of envy and gloating, respectively (Shamay-Tsoory et al., 2009). With a known game partner, OT enhances cooperation. In anonymous conditions, however, it promotes intrinsic self-interested behavior (Declerck, Boone & Kiyonari, 2014). In a simple coin-toss prediction task in which participants could dishonestly report their performance levels, adults lied more in the OT condition to benefit the ingroup's outcome (Shalvi &

De Dreu, 2014). These findings seem to suggest that OT effects on social cognition and behavior strongly depend on social contexts (Bartz, Zak, Bolger & Ochsner, 2011). However, they could also be explained by reduced self-awareness instead: When self-awareness is reduced and de-individuation is increased, people act extremely favourable toward the own group and extremely unfavourable toward others. De-individuation could therefore serve as a framework and common ground explanation of OT's effects. The same explanation could plausibly explain the results of brain imaging studies.

4.2.2 The effect of OT on brain activity

Research investigating amygdala responses reports that OT downregulates activity when experiencing social trust betrayal or when faced with social or non-social threats (Baumgartner, Heinrichs, Vonlanthen, Fischbacher & Fehr, 2008; Grimm et al., 2014; Kirsch et al., 2005; Kanat, Heinrichs, Schwarzwald & Domes, 2015). However, during positive social-affective processes, when cooperating, or in response to social feedback or happy faces, OT increases amygdala activity (Gamer, Zurowski & Büchel, 2010; Hu et al., 2015; Rilling et al., 2012). Additionally, activity in the reward system in response to happy faces or when anticipating social reward is increased after treatment with OT (Gamer et al., 2010; Groppe et al., 2013). During non-social judgments however, activity in the reward circuits is suppressed (Gordon et al., 2013). Further, empathic neural responses to perceived pain expressions of racial ingroup members but not of racial outgroup members are enhanced after application of OT (Sheng, Liu, Zhou, Zhou & Han, 2013). OT vs. placebo treatment also increased pleasantness and neural responses in the insula, anterior cingulate, and orbital frontal cortex in heterosexual males when they believed to be touched by a woman but not by a man (Scheele et al., 2014).

One of the most prominent theories explaining OT effects on human behavior and brain activity suggests that it orients attention to and increases salience of external contextual social cues (Bartz et al., 2011; Shamay-Tsoory & Abu-Akel, 2016) by interacting with the dopaminergic system (Bartz et al., 2011). Thereby, OT promotes motivation for social interactions (Stavropoulos & Carver, 2013), and facilitates social adaptation (Ma, Shamay-Tsoory, Han & Zink, 2016). The so-called social salience hypothesis proposes that OT modulates behavior and brain activity toward others that are important for social interaction and adaptation. This explanation is able to explain the differentiating effects of OT on brain activities. However, the results can also be explained by reduced self-awareness or increased de-individuation. The latter would also enhance the processing of stimuli but only, when they are associated with relevant others.

All in all, there has been increasing interest in exploring OT effects on social cognition and its influence on other-oriented mental processes (e.g. empathy) underlying social behavior (Bartz et al., 2011; Meyer-Lindenberg, Domes, Kirsch & Heinrichs, 2011; Shamay-Tsoory & Abu-Akel, 2016; Ma et al., 2016). It seems that OT is primarily involved in social processes. However, there is reason to assume that OT might also be associated with a specific kind of self-related processing or cognition since appropriate and efficient social interactions require not only other-oriented emotion/motivation but also appropriate cognitive/affective processes of oneself (Banaji & Prentice, 1994; Cross & Vick, 2001; Gardner & Stough, 2002). It is stunning that we know so little about how OT influences processing of self-related information even though self-concept and self-reflection tremendously affect human motivation and behavior (Triandis, 1989; Markus & Kitayama, 1991). Before exploring the functional role of OT in the light of self-related information and the underlying neural mechanism, the next paragraph serves to explain the different aspects of self-related processing and cognition.

4.2.3 The different kinds of self-related processing and cognition

Self-related processing and/ or cognition, as opposed to directing attention to the environment, is one key human feature (Cooley, 1902; Duval & Wicklund, 1972; Mead, 1934). According to the literature, there are two dimensions of self-related processing and/ or cognition that can be distinguished: public and private self-awareness (e.g., Buss, 1980; Davis & Franzoi 1999; Fenigstein, Scheier & Buss, 1975; Franzoi & Brewer, 1984). Directing attention to features of one's self that are obvious to others, e.g. physical appearance, is defined as the public aspect of self-awareness and increased self-related processing. Attentiveness to internal or personal aspects, e.g. memories and positive or negative feelings falls in the category of private self-awareness also referred to as introspection (Buss, 1980). In the frame of this thesis I will refer to introspection as one facet of self-related cognition, involving a more sophisticated and explicit kind of private self-awareness.

Both dimensions can be dispositional or situational. When referring to the dispositional aspect, the term "self-consciousness" is often used. Self-consciousness, in the public as well as in the private dimension, is thought to be a relatively stable trait of one's personality (Buss & Scheier, 1976; Carver & Glass, 1976). Public and private "self-awareness", on the other hand, is associated with the situational aspect of self-related processing or cognition (Fenigstein et al., 1975) and assumed to be transient and susceptible to manipulation (Carver & Glass, 1976). For example, public self-awareness can be induced by a video camera or a mirror (e.g., Alden, Teschuk & Tee, 1992; Webb, Marsh, Schneiderman & Davis, 1989) and is usually tied to some level of discomfort because individuals feel as if they are in the focus of others' appraisal. The behavior is then modified, independent of internal standards, to meet the perceived expectations. Instruction to focus on personal feelings and thoughts however induces private self-awareness, a state in which the individuals' currently salient values, mood, affect or motives are clearer and more intensified (introspection) (e.g., Webb et al., 1989).

Diener and Wallbom (1976) were the first to explicitly investigate the role of self-awareness in a social context and proposed that a reduction in self-awareness is the crucial element for the occurrence of de-individuation. Because self-related processing or cognition – both an increased and a decreased one – can influence how we behave in social situations and OT affects social cognition and behaviors, it seems plausible that OT also affects such processes.

4.2.4 The interdependence of self-related cognition and de-individuation

LeBon (1895) first introduced the phenomena of de-individuation as explanation for aggressive behavior of individuals in a crowd. He proposed anonymity and reduced self-awareness to be the underlying cause for antinormative and deregulated behavior. Building up on this idea, the theories of Duval and Wicklund (1972), Wicklund (1975), Diener (1979), Ickes, Layden and Barnes (1978) and Prentice-Dunn and Rogers, (1980) especially focused on the relation between de-individuation and self-awareness.

According to Wicklund (1975), the level of self-awareness is determined by the focus of conscious attention. Individual's self-awareness is high when conscious attention is focused on oneself and low when conscious attention is directed outwards. The reduction of self-awareness promotes the occurrence of de-individuation because inner restrictions disappear and make room for antinormative actions (Diener & Wallborn, 1976). This, however, can also work the other way: When de-individuation is caused by environmental factors, it reduces self-awareness, and when self-awareness is reduced, there is no conscious decision about performing a behavior (Diener & Wallbom, 1976; Prentice-Dunn & Rogers, 1980). Thus, the de-individuation process might occur both when self-awareness is reduced internally and when exposed to specific external attentional cues.

Interestingly, OT has been shown to shift attention from self-related information processing or cognition to external cues. De-individuation might therefore play a key role in its functioning (Bartz et al., 2011; Shamay-Tsoory & Abu-Akel, 2016).

4.2.5 Brain structures associated with self-related representations

A common theme in the literature proposes that there is a self-related “observer” or “homunculus” as critical ingredient of sensory perception in the brain that is crucial for subjective perception and awareness. According to Crick and Koch (2003), the homunculus might be located in the front of the brain and observes the sensory back of the brain. Furthermore, they suggest that the self-related homunculus acts automatically and subconsciously so that the process is not accessible. Interestingly, during states of intense sensory perception (e.g. watching a movie), individuals feel absorbed and rather disengaged from self-related reflective representations, as if they are subjectively “losing the self” (Crick & Koch, 2003). Due to advances in functional brain imaging, it is nowadays possible to visualize such subconscious processes in recorded brain activity (Hannula, Simons & Cohen, 2005).

Only recently, the activation pattern in the brain associated with self-related processing or cognition has become the focus of neuroimaging studies and gave rise to a surprisingly consistent picture. Despite the distinction between brain regions that might give rise to lower (e.g. anoetic) as opposed to higher (e.g. autonoetic) levels of self-related processing and cognition, respectively, no clear separation between such brain structures has been proposed in neuroscience literature to date. Thus, when describing patterns of brain activation, I will refer to both - self-related processing and cognition - as self-related representations in the brain.

Results of these studies suggest that activation of cortical regions, such as the dorsal part of the medial prefrontal cortex (PFC) extending somewhat to dorsolateral PFC, the anterior and posterior part of the cingulate cortex, and more laterally the inferior parietal cortex (IPC) play a crucial role in self-related representations (Gusnard, Akbudak, Shulman & Raichle, 2001; Johnson et al., 2002; Keenan, Wheeler, Gallup & Pascual-Leone, 2000; Kelley et al., 2002; Schmitz, Kawahara-Baccus & Johnson, 2004). A hemispheric specialization of certain self-related functions has been proposed, with the right hemisphere being engaged when watching images of the own face as opposed to popular faces, whereas internally cued responses fall into left hemispheric specializations (Gusnard et al., 2001; Keenan et al., 2000; Schmitz et al., 2004). All in all, converging evidence indicates that self-related representations are associated with a consistent and reproducible set of brain regions (Damasio, Grabowski, Frank, Galaburda & Damasio, 1994; Kolb, 1990; Luria, 1976; Morin, 2002; Turk et al., 2002, Turk, Heatherton, Macrae, Kelley & Gazzaniga 2003).

Whereas research has started to identify self-related cortical areas, processes in the course of reduced self-related processing or cognition remain to be elucidated. During an fMRI experiment the activity pattern during an introspection task was compared to brain processes induced by a sensorimotor categorization task. The results suggest that areas involved in self-related introspection can clearly be segregated from cortical regions engaged during sensorimotor processing. Interestingly, enhanced activity in self-related regions during introspection was robustly inhibited during the sensorimotor categorization task (Goldberg, Harel, & Malach, 2006). These observations bear implications to our understanding of processes under reduced subjective awareness. In sensory perception and during demanding sensory tasks, self-representation may not be essential and is even shut off. This activation pattern in the brain might correspond to the occurrence of de-individuation.

4.2.6 OT and self-related representations

In the light of the research outlined so far, a connection between OT's effects and reduced self-related processing and cognition seems to intrude. Previous studies also suggest such.

In the brain, OT seems to modulate medial prefrontal cortex activity (Sripada et al., 2012), an area that is known to be involved in the processing of social stimuli. Interestingly, the same brain network is involved in self-related representations. That is, this brain area is not only involved in a) tasks that demand the understanding of other's mental state (Mitchell, Heatherton & Macrae, 2002; Mitchell, Macrae & Banaji, 2004), but also b) in evaluating one's own personality traits (Johnson et al., 2002). Several other brain regions associated with mentalizing and processing the self-other distinction (Decety & Lamm, 2007), e.g. the posterior temporal sulcus (Pincus et al., 2010; Gordon et al., 2013), seem to be modulated by administration of OT. Thus, basically, the hormone could not only be involved in increased self-related processing and cognition but also contribute to a reduction in self-related processing and cognition. Now, how does this shape out?

Past research suggests that OT might decrease self-related representations in the brain. Liu, Sheng, Woodcock and Han (2013) recorded event-related potentials (ERPs) in a self-referential task (Rogers et al., 1977). During the first phase of their experiment, the encoding phase of the self-referential task, subjects were instructed to judge whether a number of trait adjectives can describe the self or a familiar other (e.g. a movie star). After encoding, participants were presented with the old words used during trait judgments and new words in the so-called retrieval phase. The task is to recall as many of the old words as possible. Self-descriptive words are usually better remembered than those descriptive of others, known as the self-reference effect (Rogers et al., 1977; Symons & Johnson, 1997). Moreover, trait judgments of one- self regularly induces faster responses and increases the amplitude of a frontal positive activity at 220–280ms (P2) in an ERP study (Mu & Han, 2010; Liu et al., 2013). Interestingly, Liu et al. (2013) found that the P2 effect associated with the self-referential representations was not just significantly decreased after treatment with OT, but OT also tended to increase the amplitude of a late positive potential at 520–1000 ms (LPP) during the processing of personality traits of a movie star.

In a fMRI study that employed a similar paradigm (Zhao et al., 2016), OT increased the speed of decision making in self – vs. other trait judgments and blunted the usually observed bias towards remembering self-attributes. Moreover, mPFC responses and connectivity with other regions in the cortical midline involved in self-related representations was reduced after treatment with OT. These results pointed towards a reduction of self-centred behavior under OT (Zhao et al., 2016).

In a more recent study, Liu et al. (2017) manipulated memory encoding and retrieval of trait adjectives related to the self, a friend and a celebrity in a self-referential task. They could show that OT reduced response times during encoding self-related trait adjectives but increased recognition scores of self-related information during memory retrieval compared to placebo. Additionally, Liu et al. (2017) complemented behavioral data with evidence from functional magnetic resonance imaging (fMRI). The results suggested that activity in the medial prefrontal cortex (mPFC) involved in encoding of self-related trait adjectives was decreased after application of OT. Right superior frontal activity during memory retrieval of self- related information was increased due to OT. Taken together, their results provided mixed evidence and a rather complex modulatory effect of OT on self-related representations.

In another study by Zhao et al. (2020), researchers aimed to determine the robustness of OT's effects on self-related representations and explored the role of individual differences in the OT receptor (OTR) genotype. They could replicate that OT abolished the self-referential bias by decreasing reaction times for judging the traits of a stranger (Zhao et al., 2016). Furthermore, their results implied that sensitivity to the effects of OT on the self-referential bias was modulated by individual differences in OTR genotype. Together, the findings supported OT's attenuating effect on self-related representations.

These more recent findings add to a growing number of studies showing that OT promotes a reduction in self-related processing and cognition (Ruissen & de Bruijn, 2015), facilitates perception of other- but not self-experienced pain (Chen & Johnson, 2012), and generally increases other-orientation (Bartz et al., 2011). Also, implicit processing seemed to be affected by OT in that it enhanced other-orientation in a study using eye-tracking (Pfundmair et al., 2018).

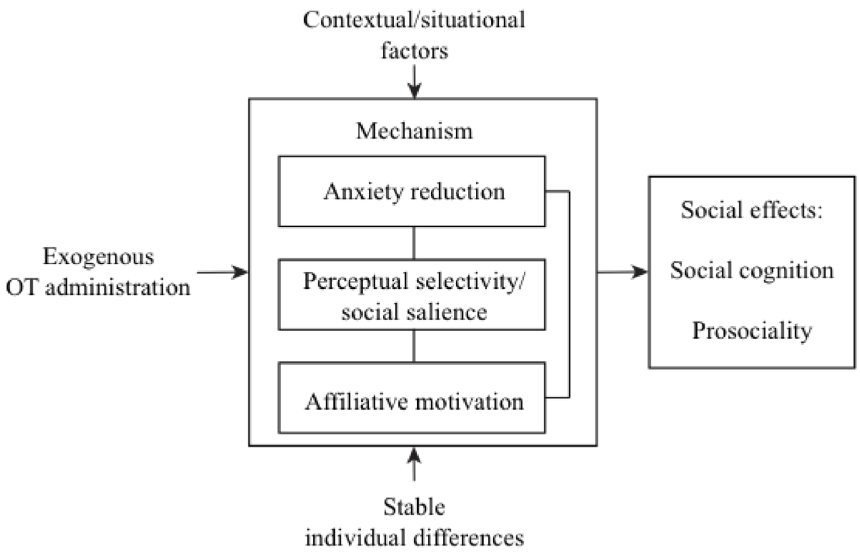
Taken together, behavioral, ERP and fMRI results suggest an inhibitory effect of OT on brain activity underlying self-related representations (Liu et al., 2013; Liu et al., 2017; Zhao et al., 2016; Zhao et al., 2020). This might not only be a distinct effect but could represent an essential underlying mechanism necessary to understand OT's functioning.

4.2.7 Self-related representations as upstream mechanism for OT effects

Previous research suggests that OT might be involved in reduced self-related processing and cognition (Liu et al., 2013; Liu et al., 2017; Zhao et al., 2016; Zhao et al., 2020). Since self-related processing and cognition – both increased and decreased – affects how we behave in social situations (Triandis, 1989; Markus & Kitayama, 1991), we assume that it determines OT action upstream of processing the perceptual salience of social/contextual cues. In other words, the OT-induced cutback in self-awareness might underlie facilitated social attention and prosocial behaviors toward important others.

To illustrate this process, we have amended the model by Bartz et al. (2011, see Figure 1). In the original model, OT is proposed to influence social cognition and prosociality. This effect is likely to be mediated by independent mechanistic processes, such as reduced (social) anxiety, increased social motivation/affiliative drive and/or increased salience of social cues, or a combination thereof. Adding to these assumptions, we suggest that reduced self-related processing and cognition (de-individuation) is the first step before one of the mechanistic processes takes place. For example, the salience of social cues could be activated by focusing on a group's standards in the course of de-individuation. This, in turn, increases people's attention to the social information in the environment.

A



B

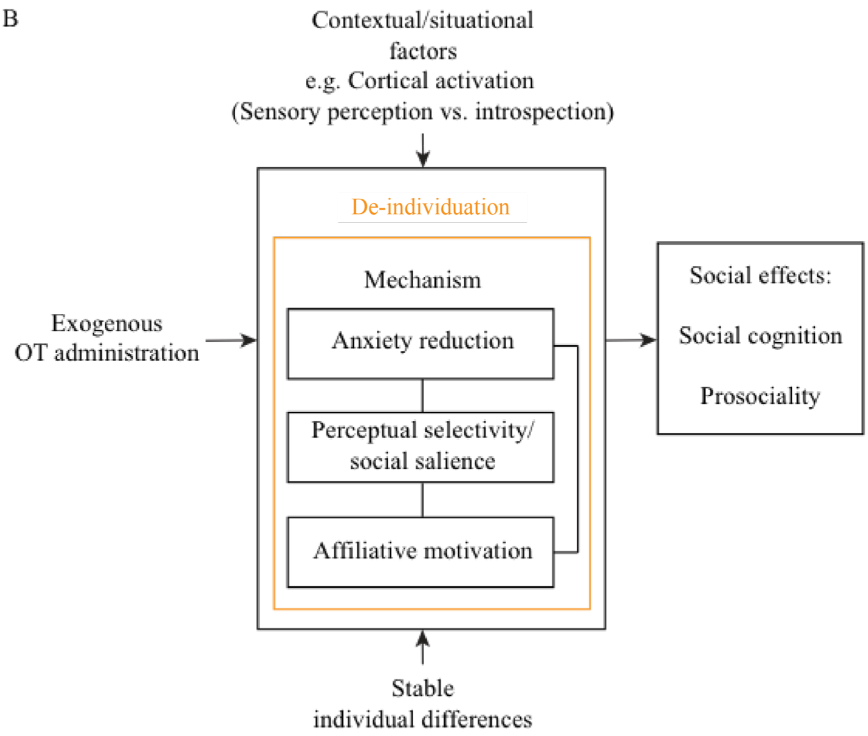


Figure 1. a) Interactionist model of OT's social effects as suggested by Bartz et al. (2011) and b) our extension of the model including reduced self-related representation (de-individuation) that mediates the activation of specific mechanisms

(anxiety, affiliation and the perceptual saliency of social cues), upstream of other processes.

In addition to providing a conceptional framework, the current work aimed to conduct a direct test of its core assumption.

4.2.8 The current study

The following study served as a first test to investigate whether OT has a diminishing effect on self-related representations. We hypothesized OT to reduce the public aspect of situational self-awareness (implicit self-related processing) and, therefore, induce de-individuation. Due to varying baseline differences in self-awareness between participants, we experimentally induced a high baseline level of self-related cognition (using an introspection task) and investigated whether and how OT affected this level.

To this end, participants took a dose of OT or placebo. Then, we used an experimental paradigm described by Goldberg, Harel, and Malach (2006). This procedure can induce certain “states” in individuals depending on the task. In the introspection condition, the individual’s self-related cognition is increased. Participants in the categorization condition, on the other hand, are involved in sensory perception with inhibition of self-related cognition. Self-awareness (implicit self-related processing) was measured using an established questionnaire.

4.3 Methods and materials

4.3.1 Participants

A total of 77[2] participants (61 female, 16 male; mean age = 27.05 years, *SD* = 7.67) participated in the study for research credit.

Those who regarded themselves as having major depression, bipolar, panic and psychotic disorders, substance dependence, epilepsy, or (if female) pregnancy were not allowed to take part. Participants were instructed to abstain from alcohol and caffeine on the day of testing, and from food and drink, except water, for 2 hours before drug administration. The study was approved by the local ethics committee.

4.3.2 Design

The study followed a 2 (substance: OT vs. placebo) x 2 (state: introspection vs. categorization) between-subjects design with random and double-blind assignment to conditions. Situational self-awareness served as dependent variable.

4.3.3 Procedure and materials

After written informed consent was obtained, participants received 24 I.U. of OT (Syntocinon Spray, Defiante; three puffs per nostril, $n = 40$) or a placebo (sodium chloride solution, $n = 37$). Participants were uninformed about the content of the spray; they were only told that they would receive a hormone or placebo in low dosage. After a 40 min waiting period that allowed the substances to reach their maximum, participants started the task designed to shift attention to the external (n = 52) or internal

[2] Sample size similar to the first study with one additional participant that did not complete the Self-Esteem Scale

(n = 25) world via sensorimotor categorization or introspection, respectively. (Due to randomization and terminating data acquisition with the end of the study semester, sample sizes were uneven in the different conditions.) Then, participants completed the Situational Self-Awareness Scale (SSAS: Govern & Marsch, 2001), which involves a public and private subscale. The public dimension of the Situational Self-Awareness Scale consists of 3 items to be rated on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) such as: 1) Right now, I am concerned about the way I present myself, 2) Right now, I am self-conscious about the way I look and, 3) Right now, I am concerned about what other people think of me ($\alpha = .79$). The private dimension consists of 3 items to be rated on the same 7-point scale such as: 1) Right now, I am conscious of my inner feelings, 2) Right now, I am reflective about my life, 3) Right now, I am aware of my innermost thoughts ($\alpha = .65$; α of full scale = .62). At the end, female participants were asked about their ovarian cycle stage (mean day of cycle = 13.90, *SD* = 7.45; as similarly done in Pfundmair et al., 2017). Debriefing followed after unrelated tasks.

4.3.4 Stimuli

The task to induce brain activity during sensory perception or introspection consisted of different pictures. In the categorization condition activating the sensory cortex, subjects were asked to indicate which category a picture belongs to by pressing one of two buttons on the computer keyboard after each stimuli presentation, respectively. In the introspection condition, subjects were asked to self-introspect about their emotional reaction induced by these stimuli and categorize their reaction to the stimuli as high (positive or negative) versus neutral by pressing the according buttons. The colored pictures showed animals, houses, and objects of various levels of emotional arousal (Phan et al., 2004). All pictures were presented on a computer monitor for 200 ms using the python module PsychoPy (Peirce et al., 2019). Stimuli were shown in 12 s blocks (one picture every second) and alternated with 6 s grey field-blanks. Eight blocks for each of the two conditions were pseudorandomly ordered. Participants were explicitly instructed to respond directly after presentation of each picture and were told that their reaction time or number of mistakes during categorization would not play a role for the experiment.

4.3.5 Data analysis

The following analysis was run to test the hypothesized effect: A 2 (substance: OT vs. placebo) x 2 (state: sensory perception vs. introspection) between-subjects ANOVA was conducted to test the effect of OT vs. placebo on private and public situational self-awareness after sensory categorization or introspection. All statistical tests were performed using the SPSS 23.0.0.0 Software.

4.4 Results

Main effects. A 2 (substance) x 2 (state) between-subjects ANOVA on the average situational self-awareness showed no significant main effect of substance, $F(1,72) = 0.00$ $p = .947$, $\eta^2 < .001$, 95%CI = [0.00,0.00], no main effect of state $F(1,72) = 0.62$, $p = .436$, $\eta^2 = .01$, 95%CI = [0.00,0.09], and no significant interaction effect, $F(1,72) = 0.32$, $p = .574$, $\eta^2 < .001$, 95%CI = [0.00,0.08].

The same between-subjects ANOVA on the subscale of private situational self-awareness showed no significant main effect of substance, $F(1,72) = 0.23$, $p = .633$, $\eta^2 < .001$, 95%CI = [0.00,0.07], no main effect of state $F(1,72) = 1.82$, $p = .181$, $\eta^2 = .03$, 95%CI = [0.00,0.13], and no significant interaction effect, $F(1,72) = 0.09$, $p = .768$, $\eta^2 < .001$, 95%CI = [0.00,0.05].

The 2 (substance) x 2 (state) between-subjects ANOVA on the dimension of public situational self-awareness showed no significant main effect of substance, $F(1,72) = 0.23$, $p = .633$, $\eta^2 < .001$, 95%CI = [0.00,0.07], and no main effect of state $F(1,72) = 0.07$, $p = .790$, $\eta^2 < .001$, 95%CI = [0.00,0.04]. However, a significant interaction of substance and state emerged, $F(1,72) = 5.26$, $p = .025$, $\eta^2 = .07$, 95%CI = [0.00,0.20]. Post-hoc testing revealed that, when participants were previously instructed to introspect, public situational self-awareness was significantly reduced in the OT condition compared to the placebo condition, $t(13) = 2.04$, $p = .007$, $d = 1.06$, 95%CI = [-0.05,2.13]. After the categorization task, however, public situational self-awareness in the OT condition did not significantly differ from the placebo group, $t(20) = -0.56$, $p = .585$, $d = 0.24$, 95%CI = [-0.60,1.07], see table 1 and Figure 2.

Table 1. Means, standard deviations (in parenthesis) and intercorrelation matrix of public self-awareness as a function of substance (OT vs. placebo) and condition (Introspection vs. categorization), **p* < .05, ***p* <. 01.

	OT (N = 40)		Placebo (N = 37)		1.	2.
	Introspection	Categorization	Introspection	Categorization		
1. Self-awareness	2.82 (0.57)	2.80 (0.53)	2.88 (0.57)	2.73 (0.56)		
2. Private self-awareness	3.05 (0.85)	2.70 (0.81)	2.91 (0.76)	2.65 (0.90)	.685**	
3. Public self-awareness	1.33 (0.38)	1.76 (0.75)	2.13 (0.95)	1.61 (0.51)	.456**	-.116

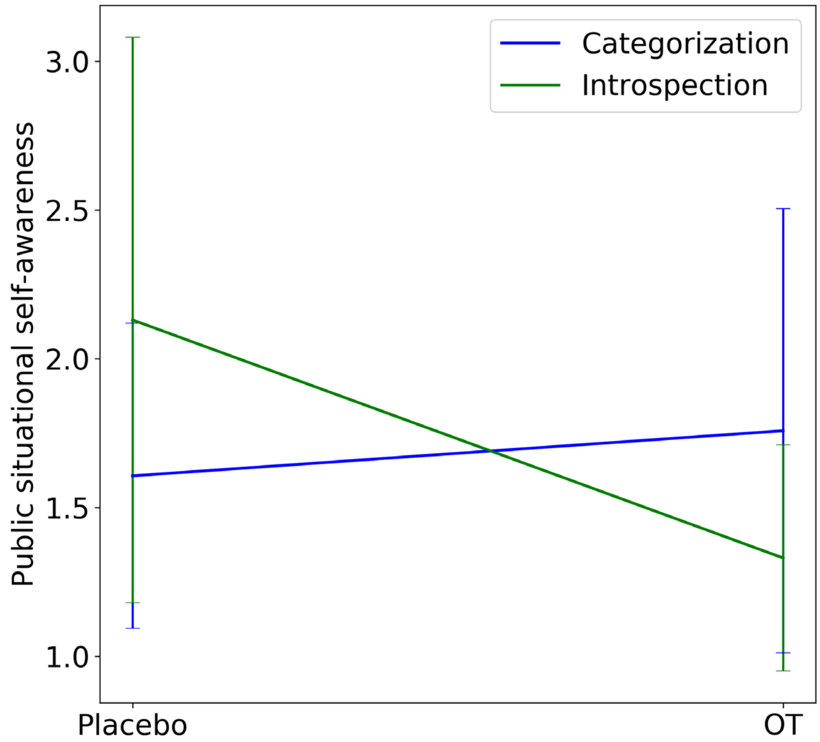


Figure 2. Interaction of OT and induced brain state. Public situational self-awareness (Mean ± SD) was significantly reduced in the OT condition compared to the placebo condition when subjects were instructed to introspect (green line). When subjects were instructed to categorize, on the other hand, participants in the OT and placebo condition did not differ (blue line).

Control variables. When performing the same ANOVA including ovarian cycle stage as covariate, the same pattern of results emerged. No significant effects emerged for the ANOVA with general situational self-awareness, *ps* > .475, and private situational self-awareness, *ps* > .174, as dependent variables. The 2 (substance) x 2 (state) between-subjects ANOVA on the dimension of public situational self-awareness showed no significant main effect of substance, $F(1,64) = 0.16$, $p = .568$, $\eta^2 < .001$, 95%CI = [0.00,0.07], and no main effect of state $F(1,64) = 0.62$, $p = .693$, $\eta^2 < .001$, 95%CI = [0.00,0.10]. However, a significant interaction of substance and state emerged,

$F(1,64) = 4.37$, $p = .031$, $\eta^2 = .07$, 95%CI = [0.00,0.26].

4.5 Discussion

The current study revealed that OT reduces situational self-awareness - participants were less aware of themselves -, specifically, when previously instructed to introspect. This effect was observed on the public dimension of situational self-awareness, not the private one. Higher scores on the public dimension of situational self-awareness are often associated with discomfort because people are more aware of features that are obvious to others, e.g. physical appearance (Buss, 1980). Higher scores on the private dimension, on the other hand, imply intensified internal moral standards, values and moods (Webb et al., 1989). Thus, OT seemed to make our participants to focus rather on the external world and less to worry about themselves in relation to others. This can be defined as increased de-individuation. Importantly, we did not find a decrease in self-awareness independent of conditions. Only when the baseline level of self-related cognition was high (in our case, experimentally increased via the introspection task), OT's effect on reducing public self-awareness became apparent. We chose to artificially induce higher levels of self-related cognition to control for varying degrees of baseline self-awareness. However, as this manipulation was necessary to observe a diminishing effect of OT on self-related processing, we conclude that the effect might not be easily observable but rather subtle.

Our results are in line with the previously discussed idea of OT increasing attention to social information (Andari et al., 2010; Guastella, Mitchell & Dadds, 2008; Pfundmair et al., 2017) and reducing processing of self-related representations (Liu et al., 2013; Liu et al., 2017; Zhao et al., 2016; Zhao et al., 2020). However, they do not exclusively support our reasoning but leave room for two lines of interpretation: A) OT might function as a shield to protect individuals from social anxiety based on discomforting thoughts about themselves in the light of self-related processing that would hinder them in their social interaction, or B) only by reducing self-awareness and promoting de-individuation, OT increases the salience of social cues and facilitates affiliative motivation. This, in turn, leads to enhanced social cognition and prosocial behavior.

The mechanistic approach of the first interpretation suggests that OT protects from social anxiety. If social anxiety arises from the discomfort of being self-aware in the public dimension, OT allows socially anxious people to attend to the social cues they might otherwise avoid.

Referring to the second interpretation, enhanced sensory perception of the outside world in the form of de-individuation might help to establish "perceptual common ground" (Clark, 1996; Clark & Krych, 2004). This promotes the ability to understand others' intentions and allows humans to adequately and successfully interact with others (Sebanz, Bekkering & Knoblich, 2006). Consistently, previous research has shown that OT facilitates correct predictions about someone's future behavior. This is only possible if the social environment provides enough information to eliminate ambiguity and to promote socially adequate effects (Burgstaller, Paulus & Pfundmair, 2019).

Using a validated paradigm, we assume that OT reduces self-related representations. However, there are several limitations to the present study. In the current study, we concluded de-individuation processes from reduced self-awareness, which seems valid according to previous work (Diener & Wallbom, 1976; Festinger et al., 1952; Prentice-Dunn & Rogers, 1980). However, it would be fruitful to directly operationalize de-individuation in futures OT experiments, e.g. using methods that have already been implemented with success (as similarly done in Prentice-Dunn & Rogers, 1982). Notably, such research should be able to differentiate between the outlined interpretations and provide clearer insights into OT's basic effect. On the neurobiological level, it remains to be elucidated how and to what extent, if at all, the hormone and neuromodulator OT affects or shifts cortical activation patterns in relation to self-related representations.

Recently, critical voices have casted doubt on the conventional doses, time frame of application (Leng and Ludwig, 2016), and effect sizes of intranasally applied OT, pointing to a publication bias in OT research (Lane, Luminet, Nave, Mikolajczak & Lane, 2016). Bearing in mind problematic effect sizes in OT research, our sample size was determined by expectations of a medium to large effect, and our data revealed a nearly large effect for our main research question (public situational self-awareness: $\eta^2 = .113$; Cohen, 2013: small (0.01), medium (0.06) and large (0.14) effects). Nevertheless, due to random distribution, sample sizes in the different conditions were unbalanced and seemed rather low in some of them. With regard to the serious problem of underpowered studies in OT research (Walum, Waldman & Young Walum, 2016), this is an issue which deserves closer attention also in future research as it easily leads to an overestimation of effects. Moreover, null results (Lane et al., 2016) and replication failures (Nave, Camerer & McCullough, 2015; Radke & de Bruijn, 2015) have been reported repeatedly in the past. Thus, further research relying on additional methods is warranted to substantiate our finding of an association between OT and self-related cognition.

Taken together, our new theoretical framework and first empirical results suggest that OT's effect on social cognition and prosocial behavior might be a consequence of decreasing self-related representations and, thus, increased de-individuation. Possibly serving as common ground explanation for OT's paradoxical and context dependent effects, the current work might have implications to understand the neuromodulator's function in brain activation and the hormone's role in human's social behavior.

4.6 References

Alden, L. E., Teschuk, M., & Tee, K. (1992). Public self-awareness and withdrawal from social interactions. *Cognitive Therapy and Research*, *16*(3), 249-267.https://doi.org/10.1007/BF01183280

Andari, E., Duhamel, J. R., Zalla, T., Herbrecht, E., Leboyer, M., & Sirigu, A. (2010). Promoting social behavior with oxytocin in high-functioning autism spectrum disorders. *Proceedings of the National Academy of Sciences, 107*(9), 4389-4394. doi.org/10.1073/pnas.0910249107

Arueti, M., Perach-Barzilay, N., Tsoory, M. M., Berger, B., Getter, N., & Shamay-Tsoory, S. G. (2013). When two become one: the role of oxytocin in interpersonal coordination and cooperation. *Journal of cognitive neuroscience*, *25*(9), 1418-1427.https://doi.org/10.1162/jocn_a_00400

Banaji, M. R., & Prentice, D. A. (1994). The self in social contexts. *Annual Review of psychology*, *45*(1), 297-332.

Bargh, J. A. (1982). Attention and automaticity in the processing of self-relevant information. *Journal of Personality and Social Psychology,* 43, 425–436. doi:10.1037/0022-3514.43.3.425

Bartz, J.A., Zak, J., Bolger, N., & Ochsner, K.N. (2011). Social effects of oxytocin in humans: context and person matter. *Trends in Cognitive Science, 15*(7), 301-309. doi: 10.1016/j.tics.2011.05.002

Baumgartner, T., Heinrichs, M., Vonlanthen, A., Fischbacher, U., & Fehr, E. (2008). Oxytocin shapes the neural circuitry of trust and trust adaptation in humans. *Neuron*, *58*(4), 639-650. https://doi.org/10.1016/j.neuron.2008.04.009

Brédart, S., Delchambre, M., & Laureys, S. (2006). One's own face is hard to ignore. *Quarterly Journal of Experimental Psychology*, 59, 46–52. doi: 10.1080/17470210500343678

Burgstaller, J., Paulus, M., & Pfundmair, M. (2019). Oxytocin promotes action prediction. *Hormones and Behavior*, *107*, 46-48. https://doi.org/10.1016/ j.yhbeh.2018.09.004

Buss, A. H. (1980). *Self-consciousness and social anxiety*. Freeman.

Buss, D. M., & Scheier, M. F. (1976). Self-consciousness, self-awareness, and self-attribution. *Journal of Research in Personality*, *10*(4), 463-468.https://doi.org/ 10.1016/0092-6566(76)90060-X

Carver, C. S., & Glass, D. C. (1976). The self-consciousness scale: A discriminant validity study. *Journal of Personality Assessment*, *40*(2), 169-172. https://doi. org/10.1207/s15327752jpa4002_8

Chen, F. S., & Johnson, S. C. (2012). An oxytocin receptor gene variant predicts attachment anxiety in females and autism-spectrum traits in males. *Social Psychological and Personality Science*, *3*(1), 93-99.https://doi.org/1 0.1177/1948550611410325

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and two ears. *Journal of the Acoustical Society of America*, 25, 975–979. doi:10.1121/1.1907229

Clark, H. H. (1996). Using language. Cambridge, England: Cambridge University Press.

Clark, H. H., & Krych, M. A. (2004). Speaking while monitoring addressees for understanding. *Journal of Memory and Language,* 50, 62–81. doi.org/10.1016/j.jml.2003.08.004

Cohen, J. (2013). Statistical power analysis for the behavioral sciences. Routledge.

Conway, M. A., & Dewhurst, S. A. (1995). The self and recollective experience. *Applied Cognitive Psychology*, 9, 1–19. doi:10. 1002/acp.2350090102

Cooley, C. H. (1902). Looking-glass self. *The production of reality: Essays and readings on social interaction*, *6*.

Crick, F., & Koch, C. (2003). A framework for consciousness. *Nature neuroscience*, *6*(2), 119.https://doi.org/10.1038/nn0203-119

Cross, S. E., & Vick, N. V. (2001). The interdependent self-construal and social support: The case of persistence in engineering. *Personality and Social Psychology Bulletin*, *27*(7), 820-832. https://doi.org/10.1177/01461672012 77005

Damasio, H., Grabowski, T., Frank, R., Galaburda, A. M., & Damasio, A. R. (1994). The return of Phineas Gage: clues about the brain from the skull of a famous patient. *Science*, *264*(5162), 1102-1105. doi: 10.1126/science.8178168

Davis, M. H., & Franzoi, S. L. (1999). Self-awareness and self-consciousness.

Decety, J., & Lamm, C. (2007). The role of the right temporoparietal junction in social interaction: how low-level computational processes contribute to meta-cognition. *The Neuroscientist*, *13*(6), 580-593.https://doi.org/10.1177/ 1073858407304654

Declerck, C. H., Boone, C., & Kiyonari, T. (2014). The effect of oxytocin on cooperation in a prisoner's dilemma depends on the social context and a person's social value orientation. *Social cognitive and affective neuroscience*, *9*(6), 802-809.https://doi.org/10.1093/scan/nst040

De Dreu, C. K., Greer, L. L., Handgraaf, M. J., Shalvi, S., Van Kleef, G. A., & Baas, M., et al. (2010). The neuropeptide oxytocin regulates parochial altruism in intergroup conflict among humans. *Science* 328, 1408–1411. doi: 10.1126/science. 1189047

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

De Dreu, C. K. (2012). Oxytocin modulates cooperation within and competition between groups: an integrative review and research agenda. *Hormones and behavior*, *61*(3), 419-428. https://doi.org/10.1016/j.yhbeh.2011.12.009

Diener, E. (1979). Deindividuation, self-awareness, and disinhibition. *Journal of Personality and Social Psychology, 37*, 1160–1171. doi:10.1037/0022-3514.37.7.1160

Diener, E., & Wallbom, M. (1976). Effects of self-awareness on antinormative behavior. *Journal of Research in Personality*, *10*(1), 107-111.https://doi.org/ 10.1016/0092-6566(76)90088-X

Ditzen, B., Schaer, M., Gabriel, B., Bodenmann, G., Ehlert, U., & Heinrichs, M. (2009). Intranasal oxytocin increases positive communication and reduces cortisol levels during couple conflict. *Biological Psychiatry* 65, 728–731. doi: 10.1016/j.biopsych.2008.10.011

Domes, G., Heinrichs, M., Michel, A., Berger, C., & Herpertz, S. C. (2007). Oxytocin improves “mind-reading” in humans. *Biological Psychiatry*, *61*(6), 731-733.https://doi.org/10.1016/j.biopsych.2006.07.015

Donaldson, Z. R., & Young, L. J. (2008). Oxytocin, vasopressin, and the neurogenetics of sociality. *Science*, *322*(5903), 900-904. DOI: 10.1126/science.1158668

Duval, S., & Wicklund, R. A. (1972). A theory of objective self awareness. New York: Academic Press.

Fenigstein, A., Scheier, M. F., & Buss, A. H. (1975). Public and private self-consciousness: Assessment and theory. *Journal of consulting and clinical psychology*, *43*(4), 522. https://doi.org/10.1037/h0076760

Festinger, L., Pepitone, A., & Newcomb, T. (1952). Some consequences of de-individuation in a group. *The Journal of Abnormal and Social Psychology*, *47*(2S), 382. https://doi.org/10.1037/h0057906

Franzoi, S. L., & Brewer, L. C. (1984). The experience of self-awareness and its relation to level of self-consciousness: An experiential sampling study. *Journal of Research in Personality*, *18*(4), 522-540. https://doi.org/10.1016/0092-6566(84)90010-2

Gamer, M., Zurowski, B., & Büchel, C. (2010). Different amygdala subregions mediate valence-related and attentional effects of oxytocin in humans. *Proceedings of the National Academy of Sciences*, *107*(20), 9400-9405.https://doi.org/10.1073/pnas.1000985107

Gardner, L., & Stough, C. (2002). Examining the relationship between leadership and emotional intelligence in senior level managers. *Leadership & Organization Development Journal*, *23*(2), 68-78. https://doi.org/10.1108/014377302 10419198

Goldberg, I. I., Harel, M., & Malach, R. (2006). When the brain loses its self: prefrontal inactivation during sensorimotor processing. *Neuron*, *50*(2), 329-339.https://doi.org/10.1016/j.neuron.2006.03.015

Gordon, I., Vander Wyk, B. C., Bennett, R. H., Cordeaux, C., Lucas, M. V., Eilbott, J. A., ... & Pelphrey, K. A. (2013). Oxytocin enhances brain function in children with autism. *Proceedings of the National Academy of Sciences*, *110*(52), 20953-20958.https://doi.org/10.1073/pnas.1312857110

Govern, J. M., & Marsch, L. A. (2001). Development and validation of the situational self-awareness scale. *Consciousness and Cognition*, *10*(3), 366-378.https://doi.org/10.1006/ccog.2001.0506

Grimm, S., Pestke, K., Feeser, M., Aust, S., Weigand, A., Wang, J., ... & Bajbouj, M. (2014). Early life stress modulates oxytocin effects on limbic system during acute psychosocial stress. *Social Cognitive and Affective Neuroscience*, *9*(11), 1828-1835.https://doi.org/10.1093/scan/nsu020

Groppe, S. E., Gossen, A., Rademacher, L., Hahn, A., Westphal, L., Gründer, G., & Spreckelmeyer, K. N. (2013). Oxytocin influences processing of socially relevant cues in the ventral tegmental area of the human brain. *Biological Psychiatry*, *74*(3), 172-179. https://doi.org/10.1016/j.biopsych.2012.12.023

Guastella, A.J., Mitchell, P.B., & Dadds, M.R. (2008). Oxytocin increases gaze to the eye region of human faces. *Biological Psychiatry* 63(1), 3-5. doi:10.1016/j.biopsych.2007.06.026

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: relation to a default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*(7), 4259-4264.https://doi.org/10.1073/pnas.071043098

Hannula, D. E., Simons, D. J., & Cohen, N. J. (2005). Imaging implicit perception: promise and pitfalls. *Nature Reviews Neuroscience*, *6*(3), 247.https://doi.org/10.1038/nrn1630

Humphreys, G. W., & Sui, J. (2016). Attentional control and the self: The self-attention network (SAN). *Cognitive Neuroscience*, 7, 5– 17. doi:10.1080/17588928.2015.1044427

Hu, J., Qi, S., Becker, B., Luo, L., Gao, S., Gong, Q., ... & Kendrick, K. M. (2015). Oxytocin selectively facilitates learning with social feedback and increases activity and functional connectivity in emotional memory and reward processing regions. *Human Brain Mapping*, *36*(6), 2132-2146.https://doi.org/ 10.1002/hbm.22760

Ickes, W., Layden, M. A., & Barnes, R. D. (1978). Objective self- awareness and individuation: An empirical link. *Journal of Personality, 46*, 146–161. doi:10.1111/j.1467-6494.1978.tb00607.x

Insel, T. R. (1992). Oxytocin—a neuropeptide for affiliation: evidence from behavioral, receptor autoradiographic, and comparative studies. *Psychoneuro-endocrinology*, *17*(1), 3-35.https://doi.org/10.1016/0306-4530(92)90073-G

Johnson, S. C., Baxter, L. C., Wilder, L. S., Pipe, J. G., Heiserman, J. E., & Prigatano, G. P. (2002). Neural correlates of self-reflection. *Brain*, *125*(8), 1808-1814. https://doi.org/10.1093/brain/awf181

Kanat, M., Heinrichs, M., Schwarzwald, R., & Domes, G. (2015). Oxytocin attenuates neural reactivity to masked threat cues from the eyes. *Neuropsychopharmacology*, *40*(2), 287. https://doi.org/10.1038/npp. 201 4.183

Keenan, J. P., Wheeler, M. A., Gallup Jr, G. G., & Pascual-Leone, A. (2000). Self-recognition and the right prefrontal cortex. *Trends in Cognitive Sciences*, *4*(9), 338-344. https://doi.org/10.1016/S1364-6613(00)01521-7

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *Journal of Cognitive Neuroscience*, *14*(5), 785-794.https://doi.org/10.1162/08989290260138672

Keverne, E. B., & Kendrick, K. M. (1992). Oxytocin Facilitation of Maternal Behavior in Sheep a. *Annals of the New York Academy of Sciences*, *652*(1), 83-101.https://doi.org/10.1111/j.1749-6632.1992.tb34348.x

Kirsch, P., Esslinger, C., Chen, Q., Mier, D., Lis, S., Siddhanti, S., ... & Meyer-Lindenberg, A. (2005). Oxytocin modulates neural circuitry for social cognition and fear in humans. *Journal of Neuroscience*, *25*(49), 11489-11493. doi: https://doi.org/10.1523/JNEUROSCI.3984-05.2005

Kolb, B. (1990). Recovery from occipital stroke: A self-report and an inquiry into visual processes. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *44*(2), 130. https://doi.org/10.1037/h0084246

Lane, A., Luminet, O., Nave, G., & Mikolajczak, M. (2016). Is there a Publication Bias in Behavioural Intranasal Oxytocin Research on Humans? Opening the File Drawer of One Laboratory. *Journal of Neuroendocrinology*, 28(4). doi:10.1111/jne.12384

Le Bon, G. (1895). The crowd: a study of the popular mind. London: 1920. *Psychologie des foules*.

Leng, G., & Ludwig, M. (2016). Intranasal oxytocin: myths and delusions. *Biological Psychiatry,* 79, 243–250. doi: 10.1016/j.biopsych.2015.05.003

Liu, Y., Sheng, F., Woodcock, K. A., & Han, S. (2013). Oxytocin effects on neural correlates of self-referential processing. *Biological Psychology*, *94*(2), 380-387.https://doi.org/10.1016/j.biopsycho.2013.08.003

Liu, Y., Wu, B., Wang, X., Li, W., Zhang, T., Wu, X., & Han, S. (2017). Oxytocin effects on self-referential processing: behavioral and neuroimaging evidence. *Social Cognitive and Affective Neuroscience*, *12*(12), 1845-1858. https://doi.org/10.1093/scan/nsx116

Luria, A. R. (1976). The working brain: An introduction to neuropsychology. USA: Basic Books.doi:http://thuvienso.thanglong.edu.vn/handle/DHTL_123456789/

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review*, *98*(2), 224.https://doi.org/10.1037/0033-295X.98.2.224

Ma, Y., Liu, Y., Rand, D. G., Heatherton, T. F., & Han, S. (2015). Opposing oxytocin effects on intergroup cooperative behavior in intuitive and reflective minds. *Neuropsychopharmacology*, *40*(10), 2379. doi:10.1038/npp.2015.87

Ma, Y., Shamay-Tsoory, S., Han, S., & Zink, C. F. (2016). Oxytocin and social adaptation: insights from neuroimaging studies of healthy and clinical populations. *Trends in Cognitive Sciences*, *20*(2), 133-145.https://doi.org/10.1016/j.tics.2015.10.009

Mead, G. H. (1934). *Mind, self and society* (Vol. 111). University of Chicago Press.: Chicago.

Meyer-Lindenberg, A., Domes, G., Kirsch, P., & Heinrichs, M. (2011). Oxytocin and vasopressin in the human brain: social neuropeptides for translational medicine. *Nature Reviews Neuroscience*, *12*(9), 524. doi:10.1038/nrn3044

Mitchell, J. P., Heatherton, T. F., & Macrae, C. N. (2002). Distinct neural systems subserve person and object knowledge. *Proceedings of the National Academy of Sciences*, *99*(23), 15238-15243.https://doi.org/10.1073/pnas.232395699

Mitchell, J. P., Macrae, C. N., & Banaji, M. R. (2004). Encoding-specific effects of social cognition on the neural correlates of subsequent memory. *Journal of Neuroscience*, *24*(21), 4912-4917. doi: https://doi.org/10.1523/JNEUROSCI.0481-04.2004

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, 11, 56–60. doi:10.1080/ 17470215908416289

Morin, A. (2002). The Split-brain debate revisited: on the importance of language and self-recognition for right hemispheric consciousness. *Homo Oeconomicus*, *18*, 523-534. doi: *RePEc:hom:homoec:v:18:y:2002:p:523-534*

Mu, Y., Guo, C., & Han, S. (2016). Oxytocin enhances inter-brain synchrony during social coordination in male adults. *Social Cognitive and Affective Neuroscience*, *11*(12), 1882-1893. https://doi.org/10.1093/scan/nsw106

Mu, Y., & Han, S. (2010). Neural oscillations involved in self-referential processing. *Neuroimage*, *53*(2), 757-768. https://doi.org/10.1016/j.neuroimage. 2010.07.008

Nave, G., Camerer, C., McCullough, M., 2015. Does oxytocin increase trust in humans? A critical review of research. *Perspectives on Psychological Science*. 10, 772–789. doi: 10.1177/1745691615600138

Pedersen, C. A., Ascher, J. A., Monroe, Y. L., & Prange, A. J. (1982). Oxytocin induces maternal behavior in virgin female rats. *Science*, *216*(4546), 648-650. DOI: 10.1126/science.7071605

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy**.** *Behavior Research Methods*, 10.3758/s13428-018-01193-y

Pfundmair, M., Rimpel, A., Duffy, K., & Zwarg, C. (2018). Oxytocin blurs the self-other distinction implicitly but not explicitly. *Hormones and Behavior*, *98*, 115-120.https://doi.org/10.1016/j.yhbeh.2017.12.016

Pfundmair, M., Zwarg, C., Paulus, M., & Rimpel, A., 2017. Oxytocin promotes attention to social cues regardless of group membership. *Hormones and Behavior*, 90, 136-140. doi: 10.1016/j.yhbeh.2017.03.006

Phan, K. L., Taylor, S. F., Welsh, R. C., Ho, S. H., Britton, J. C., & Liberzon, I. (2004). Neural correlates of individual ratings of emotional salience: a trial-related fMRI study. *Neuroimage*, *21*(2), 768-780. https://doi.org/10.1016/j. neuroimage.2003.09.072

Pincus, D., Kose, S., Arana, A., Johnson, K., Morgan, P., Borckardt, J., ... & Nahas, Z. (2010). Inverse effects of oxytocin on attributing mental activity to others in depressed and healthy subjects: a double-blind placebo controlled FMRI study. *Frontiers in Psychiatry*, *1*, 134. https://doi.org/10.3389/fpsyt.2010. 00134

Prentice-Dunn, S., & Rogers, R. W. (1980). Effects of deindividuating situational cues and aggressive models on subjective deindividuation and aggression. *Journal of Personality and Social Psychology, 39*, 104–113. doi:10.1037//0022-3514.39.1.104

Prentice-Dunn, S., & Rogers, R. W. (1982). Effects of public and private self-awareness on deindividuation and aggression. *Journal of Personality and Social Psychology*, *43*(3), 503. https://doi.org/10.1037/0022-3514.43.3.503

Radke, S., & de Bruijn, E.R. (2015). Does oxytocin affect mind-reading? A replication study. *Psychoneuroendocrinology*, 60, 75-81. doi:10.1016/j.psyneuen.2015.06. 006

Rilling, J. K., DeMarco, A. C., Hackett, P. D., Thompson, R., Ditzen, B., Patel, R., & Pagnoni, G. (2012). Effects of intranasal oxytocin and vasopressin on cooperative behavior and associated brain activity in men. *Psychoneuroendocrinology*, *37*(4), 447-461.https://doi.org/10.1016/j.psyneuen. 2011.07.013

Rimmele, U., Hediger, K., Heinrichs, M., & Klaver, P. (2009). Oxytocin makes a face in memory familiar. *Journal of Neuroscience*, *29*(1), 38-42. https://doi.org/10.1523/JNEUROSCI.4260-08.2009

Rogers, T. B., Kuiper, N. A., & Kirker, W. S. (1977). Self-reference and the encoding of personal information. *Journal of Personality and Social Psychology*, 35, 677–688. doi:10.1037/ 0022-3514.35.9.677

Ruissen, M. I., & de Bruijn, E. R. (2015). Is it me or is it you? Behavioral and electrophysiological effects of oxytocin administration on self-other integration during joint task performance. *Cortex*, *70*, 146-154. https://doi.org/10.1016/j.cortex.2015.04.017

Scheele, D., Kendrick, K. M., Khouri, C., Kretzer, E., Schläpfer, T. E., Stoffel-Wagner, B., ... & Hurlemann, R. (2014). An oxytocin-induced facilitation of neural and emotional responses to social touch correlates inversely with autism traits. *Neuropsychopharmacology*, *39*(9), 2078. doi:10.1038/npp.2014.78

Schmitz, T. W., Kawahara-Baccus, T. N., & Johnson, S. C. (2004). Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage*, *22*(2), 941-947. https://doi.org/10.1016/j.neuroimage.2004.02.018

Schulze, L., Lischke, A., Greif, J., Herpertz, S.C., Heinrichs, M., & Domes, G. (2011). Oxytocin increases recognition of masked emotional faces. *Psychoneuroendocrinology* 36(9), 1378-1382. doi: 10.1016/j.psyneuen.2011.03.011

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends in Cognitive Science*, 10(2), 70-76. doi:10.1016/j.tics.2005.12.009

Shalvi, S., & De Dreu, C. K. (2014). Oxytocin promotes group-serving dishonesty. *Proceedings of the National Academy of Sciences*, *111*(15), 5503-5507.https://doi.org/10.1073/pnas.1400724111

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The social salience hypothesis of oxytocin. *Biological Psychiatry*, *79*(3), 194-202. https://doi.org/10.1016/j.biopsych.2015.07.020

Shamay-Tsoory, S. G., Fischer, M., Dvash, J., Harari, H., Perach-Bloom, N., & Levkovitz, Y. (2009). Intranasal administration of oxytocin increases envy and schadenfreude (gloating). *Biological psychiatry*, *66*(9), 864-870.https://doi.org/10.1016/j.biopsych.2009.06.009

Sheng, F., Liu, Y., Zhou, B., Zhou, W., & Han, S. (2013). Oxytocin modulates the racial bias in neural responses to others' suffering. *Biological Psychology*, *92*(2), 380-386. https://doi.org/10.1016/j.biopsycho.2012.11.018

Sripada, C. S., Phan, K. L., Labuschagne, I., Welsh, R., Nathan, P. J., & Wood, A. G. (2012). Oxytocin enhances resting-state connectivity between amygdala and medial frontal cortex. *International Journal of Neuropsychopharmacology*, *16*(2), 255-260.https://doi.org/10.1017/S1461145712000533

Stavropoulos, K. K., & Carver, L. J. (2013). Research review: social motivation and oxytocin in autism–implications for joint attention development and intervention. *Journal of Child Psychology and Psychiatry*, *54*(6), 603-618.https://doi.org/10.1111/jcpp.12061

Symons, C. S., & Johnson, B. T. (1997). The self-reference effect in memory: A meta-analysis. *Psychological Bulletin*, 121, 371– 394. doi:10.1037/0033-2909. 121. 3.371

Triandis, H. C. (1989). The self and social behavior in differing cultural contexts. *Psychological Review*, *96*(3), 506. https://doi.org/10.1037/0033-295X .96.3.506

Turk, D.J., Heatherton, T., Kelley, W.M., Funnell, M.G., Gazzaniga, M.S. & Macrae; C.N. (2002). Mike or Me? Self recognition in a split-brain patient. *Nature Neuroscience*, 5(9): 841-842.

Turk, D. J., Heatherton, T. F., Macrae, C. N., Kelley, W. M., & Gazzaniga, M. S. (2003). Out of contact, out of mind: the distributed nature of the self. *Annals of the New York Academy of Sciences*, *1001*(1), 65-78. doi:10.1196/annals.1279. 005

VanVoorhis, C. W., & Morgan, B.L. (2007). Understanding power and rules of thumb for determining sample sizes. *Tutorials in Quantitative Methods for Psychology*, 3(2), 43-50. doi: 10.20982/tqmp.03.2.p043

Walum, H., Waldman, I.D., & Young, L.J. (2016). Statistical and methodological considerations for the interpretation of intranasal oxytocin studies. *Biological Psychiatry*, 79, 251–257. doi: 10.1016/j.biopsych.2015.06.016

Webb, W. M., Marsh, K. L., Schneiderman, W., & Davis, B. (1989). Interaction between self-monitoring and manipulated states of self-awareness. *Journal of Personality and Social Psychology*, *56*(1), 70. https://doi.org/10.1037/0022-3514.56.1.70

Wicklund, R. A. (1975). Objective self-awareness. *Advances in Experimental Social Psychology, 8*, 233–275. doi:10.1016/S0065-2601(08)60252-X

Young, L. J., & Wang, Z. (2004). The neurobiology of pair bonding. *Nature Neuroscience*, *7*(10), 1048. doi:10.1038/nn1327

Zak, P. J., Stanton, A. A., & Ahmadi, S. (2007). Oxytocin increases generosity in humans. *PloS one*, *2*(11), e1128. https://doi.org/10.1371/journal.pone.0001128

Zhao, W., Luo, R., Sindermann, C., Li, J., Wei, Z., Zhang, Y., ... & Becker, B. (2020). Oxytocin modulation of self-referential processing is partly replicable and sensitive to oxytocin receptor genotype. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *96*, 109734. https://doi.org/10.1016/j.pnpbp.2019.109734

Zhao, W., Yao, S., Li, Q., Geng, Y., Ma, X., Luo, L., ... & Kendrick, K. M. (2016). Oxytocin blurs the self-other distinction during trait judgments and reduces medial prefrontal cortex responses. *Human Brain Mapping*, *37*(7), 2512-2527. https://doi.org/10.1002/hbm.23190

Zimbardo, P. G. (1969). The human choice: Individuation, reason, and order versus deindividuation, impulse, and chaos. In *Nebraska Symposium on Motivation*. University of Nebraska press.

5 Chapter 5

5.1 Overview

This chapter reviews the findings from all three studies reported in the previous chapters and provides a synthesis of results, consideration of their theoretical links and implications, and ideas for future research.

5.2 Recapitulation and synthesis

In the first study, a mirror increased public situational self-awareness. When placed in front of a mirror (vs. when not placed in front of a mirror) regardless of whether they had administered OT or not, participants were perceptually more aware of themselves. Higher scores on the public dimension of situational self-awareness are often associated with discomfort and, in consequence, lower self-esteem because people are more aware of features that are obvious to others, e.g. physical appearance (Bourgeois & Leary, 2001; Buss, 1980; Leary, Haupt, Strausser & Chokel, 1998). Indeed, in the placebo group, public self-awareness was negatively correlated to self-esteem. We observed this negative correlation independently of whether a mirror was present or not. However, as expected, the effect when confronted with the own reflection was stronger. Importantly, our results revealed that, after application of OT, self-awareness was not associated with fluctuations in self-esteem. Despite the presence of the mirror and the associated increase in self-awareness, there was no correlation between self-awareness and self-esteem to be observed in the OT group. Also, when testing OT's effects as moderator between self-awareness and self-esteem, a direct correlation between the variables could only be observed in the placebo condition.

We conclude that OT seems to act as a protective shield to stabilize the individual's self-esteem even in situations of increased self-awareness. We assume that even though perceptual salience of the self was enhanced in front of the mirror, our participants were able to focus rather on the external world and worry less about themselves in relation to others after application of OT. This can be defined as increased de-individuation. Importantly, we did not find a direct effect of OT on self-esteem. Only when the baseline level of self-related processing was high (in our case, experimentally increased via the own reflection in the mirror), OT's effect on stabilizing self-esteem scores became apparent. We chose to artificially induce higher levels of self-related processing to control for varying degrees of baseline self-awareness. However, as this manipulation was necessary to observe a buffering effect of OT on self-esteem, we conclude that the effect might not be easily observable but rather subtle.

The second study revealed that OT administration inhibited interoceptive accuracy: Accuracy of heartbeat perception increased among participants who administered a placebo and faced their mirror image compared to a condition without a mirror. This is in line with previous findings (Ainley et al., 2012; Ainley et al., 2013). With OT, however, there was no significant difference in accuracy of heartbeat perception between the mirror and no mirror condition. OT is proposed to direct attentional resources away from internal interoceptive towards external social salient cues (Abu-Akel et al., 2015; Shamay-Tsoory & Abu-Akel, 2016; Brodmann, Gruber & Goya-Maldonado, 2017). Our findings are in line with findings that attribute the role of OT in decreasing self-orientated behavior (internal) and increasing other-oriented (external) responses (Abu-Akel et al, 2015; Bartz et al, 2015; Zhao et al, 2016). We propose two lines of interpretation: A) OT might function as a shield to protect individuals from social anxiety that roots in enhanced perception of bodily signals in front of a mirror, and/or B) while reducing self-awareness and promoting de-individuation, OT allocates attentional resources towards social cues which, ultimately, results in enhanced social cognition and prosocial behavior. These two interpretations might both be true and interact in their manifestation of OT's social effects.

The first interpretation suggests that OT reduces bodily awareness due to anxiety reduction. Interoceptive awareness classically refers to the representation of afferent bodily physiological sensations (Craig, 2008; Critchley et al., 2004). High interoceptive sensitivity has been associated with emotional disorders (Ehlers & Breuer, 1996; Dunn et al, 2010). Yao et al. (2018) provided evidence that activation of the amygdala is negatively correlated with interoceptive accuracy, suggesting that increased emotional encoding in the amygdala leads to reduced interoceptive awareness. This might be the case under OT. Consistently, studies show that OT is associated with increased amygdala activation (Striepens et al, 2011; Gao et al, 2016).

A shift towards de-individuation, even when a mirror (that usually enhances self-awareness) is present, may be a second possible interpretation for reduced accuracy in interoception. This interpretation is consistent with the predictive coding framework. In this framework, attention to interoceptive or exteroceptive cues is mediated by the precision of ascending prediction errors encoded by the gain of postsynaptic responses. The neuromodulator OT potentially directs attention to external cues by increasing the precision of prediction errors in brain regions high in the hierarchy (e.g., in the AI) and decreasing the precision at lower, sensory, levels (such as the PI). The AI seems to be particularly involved in cognitive and emotional processing, whereas the PI seems to specifically process primary sensory components of interoceptive signals (Critchley et al., 2004; Pollatos et al., 2007; Kurth et al., 2010; Chang et al., 2012; Zaki et al., 2012; Uddin et al., 2014). This attentional shift may also facilitate associative learning between internal and external cues, a process fundamental to social cognition (Quattrocki and Friston, 2014). Thus, because OT might increase the gain of neuronal populations higher in hierarchy, the hormone and neurotransmitter might increase attention towards awareness of others more than the self and, ultimately, lead to enhanced social cognition and behaviors. In other words, OT might switch attention away from interoceptive cues towards external ones to promote social interactions.

The third and main study of the project revealed that OT reduces situational self-awareness - participants were less aware of themselves -, specifically, when previously instructed to introspect. This effect was observed on the public dimension of situational self-awareness, not the private one. Higher scores on the public dimension of situational self-awareness are often associated with discomfort because people are more aware of features that are obvious to others, e.g. physical appearance (Buss, 1980). Higher scores on the private dimension, on the other hand, imply intensified internal moral standards, values and moods (Webb et al., 1989). Thus, OT seemed to make our participants to focus rather on the external world and less to worry about themselves in relation to others. This can be defined as increased de-individuation. Importantly, we did not find a decrease in self-awareness independent of conditions. Only when the baseline level of self-related cognition was high (in our case, experimentally increased via the introspection task), OT's effect on reducing public self-awareness became apparent. We chose to artificially induce higher levels of self-related cognition to control for varying degrees of baseline self-awareness. However, as this manipulation was necessary to observe a diminishing effect of OT on self-related cognition, we conclude that the effect might not be easily observable but rather subtle.

Our results are in line with the previously discussed idea of OT increasing attention to social information (Andari et al., 2010; Guastella, Mitchell & Dadds, 2008;

Pfundmair et al., 2017) and reducing processing of self-related representations (Liu et al., 2013; Liu et al., 2017; Zhao et al., 2016; Zhao et al., 2020). However, they do not exclusively support our reasoning but leave room for two lines of interpretation. Our first interpretation suggests that OT might function as a shield to protect individuals from social anxiety based on discomforting thoughts about themselves in the light of self-related cognition that would hinder them in their social interaction. If social anxiety arises from the discomfort of being self-aware in the public dimension, OT allows socially anxious people to attend to the social cues they might otherwise avoid. Another line of interpretation suggests that by reducing self-awareness and promoting de-individuation, OT increases the salience of social cues and facilitates affiliative motivation. This, in turn, leads to enhanced social cognition and prosocial behavior. Enhanced sensory perception of the outside world in the form of de-individuation might help to establish "perceptual common ground" (Clark, 1996; Clark & Krych, 2004). This promotes the ability to understand others' intentions and allows humans to adequately and successfully interact with others (Sebanz, Bekkering & Knoblich, 2006). Consistently, previous research has shown that OT facilitates correct predictions about someone's future behavior. This is only possible if the social environment provides enough information to eliminate ambiguity and to promote socially adequate effects (Burgstaller, Paulus & Pfundmair, 2019).

In summary, all our studies point to the direction of OT promoting de-individuation in self-related processing and cognition. The first study explored self-related processing, i.e. the implicit processing of the own reflection inducing increased self-awareness, while the second study was designed to tie together aspects of implicit self-related processing (in front of a mirror) and a more explicit form of self-related cognition when counting the own heartbeat. The third study was designed to explore the most sophisticated level of self-related cognition and focused on OT's effect when instructed to introspect. The two manipulations (the presence of a mirror and the instruction to introspect) intended to promote a sense of dualism in participants. By increasing self-awareness these manipulations might enforce the perceived boundary between self and other. OT, on the other hand, served as manipulation in the opposite direction. The results of our studies consistently support the idea that OT promotes de-individuation, a state in which the boundary between self and other vanishes. This effect on the self might be the underlying mechanism and serves as potential explanation of OT's prosocial effects.

5.3 Implications and opportunities for future research

5.3.1 Theoretical implications

Due to its effects on several aspects in the social domain there is high interest in OT research. However, and as proposed in chapter 1, studies of OT's effects should consider changes not only in one's perception of others but also in the processing of self-related information (Colonnello et al., 2013; Colonnello & Heinrichs, 2014). Because of brain activity changes observed in subcortical-cortical midline structures as a consequence of OT treatment, it seems plausible that the neuromodulator affects self-related processing (Northoff and Panksepp, 2008). Moreover, because it has been shown that OT also modulates brain network activity involved in higher cognitive functions, i.e. the shared neural representations of others and self, it is likely that OT also influences self- and other-related cognition (Lombardo et al., 2010). To this end, future studies should attempt to establish a clear neurobiological distinction (in both; structure and function) of brain networks involved in self-related processing or cognition, respectively. However, it seems likely that such clear separation does not exist on the biological level, since bottom-up information processing and top-down cognition necessarily need to merge, in order to give rise to a highly conscious and functioning human organism. Future research would be crucial to support our findings of OT's role in self-other distinction and the ability to shift from self-oriented to other-person-oriented perspectives. Especially because of the close link between interoception and empathy and because self-related processing and cognition are among the mechanisms implicated in empathy (Ernst et al., 2013), such more detailed investigations lay the ground to understand OT's prosocial effects.

5.3.2 Practical implications

Practically, our results could be applied in contexts of health and disease, when the boundary between self and others plays a role in individual's well-being. In the light of empathy in healthy individuals, practical implications go both ways, since high levels of empathy might not always be beneficial for the individual. For example, when being in love and in a state of increased levels of OT that blur the distinction between the self and the loved-one, one might want to be cautious about protecting own values. In such settings people might find themselves trapped in unhealthy relationships and experience a loss of control as if the own self is merged into the other. Understanding the underlying mechanism of self- and other-related processing and cognition might help to be more cautious and aware and act accordingly with enhanced self-interest. On the other side, enhanced empathy might trigger prosocial behaviors such as helping people in danger and could thus be utilized to shape a more compassionate world. It remains to be elucidated how OT could be made applicable. Besides employing a nasal spray, natural interventions to increase OT levels seem fruitful, but further research in this field is crucial to reveal how, in everyday life, people can tackle their OT levels and benefit from it.

In future studies, it would be a valuable addition to investigate the advantage of OT as treatment option in disease. An important field of application could be that of therapy settings: It has been shown that OT levels are decreased in patients suffering from depression (Ozsoy, Esel, & Kula, 2009). Combining the current treatment options (e.g. cognitive-behavioral therapy) with application of OT might help to train individuals to develop a buffer against the negative consequences of enhanced self-related processing and cognition on self-esteem levels. Because in depression, patients suffer from rumination and destructive thoughts centred around the self (Cooney, Joormann, Eugène, Dennis, & Gotlib, 2010), increased awareness of the consequences such thoughts trigger unconsciously, might help to identify such patterns of thinking faster and react accordingly. *For loneliness itself only exists in dualism.*

Evaluations of these application possibilities would be an important next step to investigate our results within a practical context.

5.4 Conclusion

In conclusion, the empirical results and new theoretical framework suggest that OT's effect on social cognition and prosocial behavior might be a consequence of reduced self-related representations in brain activation and, thus, increased de-individuation. The current work provides a valuable contribution to the existing literature and might have implications to understand OT's function in brain activation associated with self-related processing and cognition. Together, the insights gained from the studies presented in this thesis serve as common ground explanation for the neuromodulator's paradoxical and context dependent effects and advance our understanding of the hormone's role in human's social behavior.

5.5 References

Abu-Akel, A., Palgi, S., Klein, E., Decety, J., & Shamay-Tsoory, S. (2015). Oxytocin increases empathy to pain when adopting the other-but not the self-perspective. *SocialNeuroscience*, *10*(1), 7-15. https:// doi.org/10.1080/ 17470919. 2014. 948637

Ainley, V., Tajadura-Jiménez, A., Fotopoulou, A., & Tsakiris, M. (2012). Looking into myself: Changes in interoceptive sensitivity during mirror self-observation. *Psychophysiology*, *49*(11), 1672-1676. https://doi.org/10.1111/ j.1469-8986.2012.01468.x

Ainley, V., Maister, L., Brokfeld, J., Farmer, H., & Tsakiris, M. (2013). More of myself: Manipulating interoceptive awareness by heightened attention to bodily and narrative aspects of the self. *Consciousness and Cognition*, *22*(4), 1231-1238. https://doi.org/10.1016/j.concog.2013.08.004

Andari, E., Duhamel, J. R., Zalla, T., Herbrecht, E., Leboyer, M., & Sirigu, A. (2010). Promoting social behavior with oxytocin in high-functioning autism spectrum disorders. *Proceedings of the National Academy of Sciences, 107*(9), 4389-4394. doi.org/10.1073/pnas.0910249107

Bartz, J. A., Lydon, J. E., Kolevzon, A., Zaki, J., Hollander, E., Ludwig, N., & Bolger, N. (2015). Differential effects of oxytocin on agency and communion for anxiously and avoidantly attached individuals. *Psychological Science*, *26*(8), 1177-1186. https://doi.org/10.1177/0956797615580279

Brodmann, K., Gruber, O., & Goya-Maldonado, R. (2017). Intranasal oxytocin selectively modulates large-scale brain networks in humans. *Brain connectivity*, *7*(7), 454-463. https://doi.org/10.1089/brain.2017.0528

Bourgeois, K. S., & Leary, M. R. (2001). Coping with rejection: Derogating those who choose us last. *Motivation and Emotion*, *25*(2), 101-111.

Burgstaller, J., Paulus, M., & Pfundmair, M. (2019). Oxytocin promotes action prediction. *Hormones and Behavior*, *107*, 46-48. https://doi.org/10.1016/j.yhbeh.2018.09.004

Buss, A. H. (1980). *Self-consciousness and social anxiety*. Freeman.

Chang, L. J., Yarkoni, T., Khaw, M. W., & Sanfey, A. G. (2012). Decoding the role of the insula in human cognition: functional parcellation and large-scale reverse inference. *Cerebral Cortex*, *23*(3), 739-749. https://doi.org/10.1093/cercor/bhs065

Clark, H. H. (1996). Using language. Cambridge, England: Cambridge University Press.

Clark, H. H., & Krych, M. A. (2004). Speaking while monitoring addressees for understanding. *Journal of Memory and Language,* 50, 62–81. doi.org/10.1016/j.jml.2003.08.004

Colonnello, V., Chen, F. S., Panksepp, J., & Heinrichs, M. (2013). Oxytocin sharpens self-other perceptual boundary. *Psychoneuroendocrinology,* 38, 2996–3002. doi: 10.1016/j.psyneuen.2013.08.010

Colonnello, V., & Heinrichs, M. (2014). Intranasal oxytocin enhances positive self-attribution in healthy men. *Journal of Psychosomatic Research,* 77, 415–419. doi: 10.1016/j.jpsychores.2014.06.016

Cooney, R. E., Joormann, J., Eugène, F., Dennis, E. L., & Gotlib, I. H. (2010). Neural correlates of rumination in depression. *Cognitive, Affective, & Behavioral Neuroscience*, *10*(4), 470-478.

Craig, A. D. (2008). Interoception and emotion: a neuroanatomical perspective. *Handbook of emotions*, *3*(602), 272-88.

Critchley, H. D., Wiens, S., Rotshtein, P., Öhman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience*, *7*(2), 189.doi:10.1038/nn1176

Dunn, B. D., Stefanovitch, I., Evans, D., Oliver, C., Hawkins, A., & Dalgleish, T. (2010). Can you feel the beat? Interoceptive awareness is an interactive function of anxiety-and depression-specific symptom dimensions. *Behaviour Research and Therapy*, *48*(11), 1133-1138.https://doi.org/10.1016/j.brat.2010. 07.006

Ehlers, A., & Breuer, P. (1996). How good are patients with panic disorder at perceiving their heartbeats?. *Biological psychology*, *42*(1-2), 165-182.https://doi.org/10.1016/0301-0511(95)05153-8

Ernst, J., Northoff, G., Böker, H., Seifritz, E., & Grimm, S. (2013). Interoceptive awareness enhances neural activity during empathy. *Human Brain Mapping,* 34, 1615–1624. doi: 10.1002/hbm.22014

Gao, S., Becker, B., Luo, L., Geng, Y., Zhao, W., Yin, Y., ... & Yao, D. (2016). Oxytocin, the peptide that bonds the sexes also divides them. *Proceedings of the*

National Academy of Sciences, *113*(27), 7650-7654. https://doi.org/10.1073/pnas.1602620113

Guastella, A.J., Mitchell, P.B., & Dadds, M.R. (2008). Oxytocin increases gaze to the eye region of human faces. *Biological Psychiatry* 63(1), 3-5. doi:10.1016/j.biopsych.2007.06.026

Kurth, F., Zilles, K., Fox, P. T., Laird, A. R., & Eickhoff, S. B. (2010). A link between the systems: functional differentiation and integration within the human insula revealed by meta-analysis. *Brain Structure and Function*, *214*(5-6), 519-534.https://doi.org/10.1007/s00429-010-0255-z

Leary, M. R., Haupt, A. L., Strausser, K. S., & Chokel, J. T. (1998). Calibrating the sociometer: The relationship between interpersonal appraisals and the state self-esteem. Journal of Personality and Social Psychology, 74(5), 1290–1299. https://doi.org/10.1037/0022-3514.74.5.1290

Liu, Y., Sheng, F., Woodcock, K. A., & Han, S. (2013). Oxytocin effects on neural correlates of self-referential processing. *Biological Psychology*, *94*(2), 380-387.https://doi.org/10.1016/j.biopsycho.2013.08.003

Liu, Y., Wu, B., Wang, X., Li, W., Zhang, T., Wu, X., & Han, S. (2017). Oxytocin effects on self-referential processing: behavioral and neuroimaging evidence. *Social Cognitive and Affective Neuroscience*, *12*(12), 1845-1858. https://doi.org/10.1093/scan/nsx116

Lombardo, M. V., Chakrabarti, B., Bullmore, E. T., Wheelwright, S. J., Sadek, S. A., Suckling, J., et al. (2010). Shared neural circuits for mentalizing about the self and others. *Journal of Cognitive Neuroscience,* 22, 1623–1635. doi: 10.1162/jocn.2009. 21287

Northoff, G., & Panksepp, J. (2008). The trans-species concept of self and the subcortical–cortical midline system. *Trends in Cognitive Science,* 12, 259–264. doi: 10.1016/j.tics.2008.04.007

Ozsoy, S., Esel, E., & Kula, M. (2009). Serum oxytocin levels in patients with depression and the effects of gender and antidepressant treatment. *Psychiatry Research*, *169*(3), 249-252.

Pfundmair, M., Zwarg, C., Paulus, M., & Rimpel, A., 2017. Oxytocin promotes attention to social cues regardless of group membership. *Hormones and Behavior*, 90, 136-140. doi: 10.1016/j.yhbeh.2017.03.006

Pollatos, O., Schandry, R., Auer, D. P., & Kaufmann, C. (2007). Brain structures mediating cardiovascular arousal and interoceptive awareness. *Brain Research*, *1141*, 178-187.https://doi.org/10.1016/j.brainres.2007.01.026

Quattrocki, E., & Friston, K. (2014). Autism, oxytocin and intero-ception. *Neuroscience & Biobehavioral Reviews*, *47*, 410-430. https://doi.org/ 10.1016/j.neubiorev.2014.09.012

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends in Cognitive Science*, 10(2), 70-76. doi:10.1016/ j.tics.2005.12.009

Shamay-Tsoory, S. G., & Abu-Akel, A. (2016). The social salience hypothesis of oxytocin. *Biological Psychiatry*, *79*(3), 194-202. https://doi.org/10.1016/j.biopsych.2015.07.020

Striepens, N., Kendrick, K. M., Maier, W., & Hurlemann, R. (2011). Prosocial effects of oxytocin and clinical evidence for its therapeutic potential. *Frontiers in Neuroendocrinology*, *32*(4), 426-450. https://doi.org/10.1016/j.yfrne.2011.07.001

Uddin, L. Q., Kinnison, J., Pessoa, L., & Anderson, M. L. (2014). Beyond the tripartite cognition–emotion–interoception model of the human insular cortex. *Journal of cognitive neuroscience*, *26*(1), 16-27. https://doi.org/10.1162/jocn_a_00462

Webb, W. M., Marsh, K. L., Schneiderman, W., & Davis, B. (1989). Interaction between self-monitoring and manipulated states of self-awareness. *Journal of Personality and Social Psychology*, *56*(1), 70. https://doi.org/10.1037/0022-3514.56.1.70

Yao, S., Becker, B., Zhao, W., Zhao, Z., Kou, J., Ma, X., ... & Kendrick, K. M. (2018). Oxytocin modulates attention switching between interoceptive signals and external social cues. *Neuropsychopharmacology*, *43*(2), 294. doi:10.1038/npp.2017.189

Zaki, J., Davis, J. I., & Ochsner, K. N. (2012). Overlapping activity in anterior insula during interoception and emotional experience. *Neuroimage*, *62*(1), 493-499. https://doi.org/10.1016/j.neuroimage.2012.05.012

Zhao, W., Luo, R., Sindermann, C., Li, J., Wei, Z., Zhang, Y., ... & Becker, B. (2020). Oxytocin modulation of self-referential processing is partly replicable and sensitive to oxytocin receptor genotype. *Progress in Neuro-Psycho-*

pharmacology and Biological Psychiatry, *96*, 109734. https://doi.org/10.1016/j.pnpbp.2019.109734

Zhao, W., Yao, S., Li, Q., Geng, Y., Ma, X., Luo, L., ... & Kendrick, K. M. (2016). Oxytocin blurs the self-other distinction during trait judgments and reduces medial prefrontal cortex responses. *Human Brain Mapping*, *37*(7), 2512-2527. https://doi.org/10.1002/hbm.23190

6 APPENDIX

Acknowledgements

First of all, I thank Michaela for being the first supervisor of my thesis, for her inspiring broad knowledge and the freedom she gave me, to follow my curiosity and to work on a project that I am deeply passionate about. Thanks for your guidance and for constantly challenging and motivating me. Further, I express my appreciation to Prof. Dieter Frey for his scientific advice and constructive supervision during my project.

I am very grateful for all my friends who always support me: Ibi, Lisa, Julia, Conny, Miri, Anja, Tine...to name just a few. There would be no thesis without you always reminding me of what is really important in life. #liebeundbier

I very much thank my brother Domi for being someone I can always look up to. Lisa, thank you so much for your support during highs and lows in the final phase of my thesis and for clearing my mind, helping me to stay focused and motivated. Thanks for the warmhearted home and the beautiful life that we share. My deepest gratitude belongs to Isabel. Thank you for your sincere friendship. You are my best companion, you mean the world to me and I don’t know what I’d do without you in my life.

Mam, without you, I wouldn't be who I am or where I am today. You inspire me. Thank you for your endless love, support and your everlasting belief and trust in me. I hope that one day I can be as good of a mom as you are.

Curriculum vitae

Jessica Burgstaller, born in Munich, Germany

EDUCATION

10/2015 – 08/2020	Doctoral Student (Social Psychology) at the Ludwig-Maximilians University (LMU), Munich, Germany Supervisor: Prof. Dr. Michaela Pfundmair, Prof. Dr. Dieter Frey Examination committee: Prof. Dr. Michaela Pfundmair, Prof. Dr. Dieter Frey, Prof. Dr. Thomas Bonk
10/2013 – 12/2019	Fast-Track PhD program at the Graduate School of Systemic Neurosciences (GSN), Munich, Germany Supervisor: Prof. Dr. Herwig Baier Examination committee: Prof. Dr. Herwig Baier, Dr. Jason Rihel, Dr. Virginia Flanagin, Dr. Mathias Schmidt
10/2013 – 08/2015	Master of Science in Clinical Psychology and Cognitive Neuroscience (LMU); grade: 1.15
10/2010 – 08/2013	Bachelor of Science in Psychology (LMU); grade: 1.28
10/2008 – 08/2011	Bachelor of Pharmaceutical Sciences (LMU); grade: 1.53
09/1999 – 06/2008	Oskar-Maria-Graf Gymnasium, Neufahrn Graduation Certificate: Allgemeines Abitur; grade: 1.3

RESEARCH EXPERIENCE

10/2015 – 10/2018	Ludwig-Maximilians University, Munich Doctoral Student in the department: Social Psychology Lecturer for Social Neurosciences, preparation of seminars and workshops about communication, conflict management and social psychology
10/2014 – 10/2019	Max-Planck-Institute for Neurobiology, Martinsried PhD Student in the department: Genes-Circuits-Behavior Evaluation of the use of a zebrafish model with mutation in the glucocorticoid receptor for research into the pathogenesis of depression

_______________________ _______________________

(Datum) (Unterschrift)

List of publications

McIlwrick, S., Rechenberg, A., Matthes, M., **Burgstaller, J.**, Schwarzbauer, T., Chen, A., & Touma, C. (2016). Genetic predisposition for high stress reactivity amplifies effects of early-life adversity. *Psychoneuroendocrinology*, *70*, 85-97.

Barber, D. M., Schönberger, M., **Burgstaller, J.**, Levitz, J., Weaver, C. D., Isacoff, E. Y., ... & Trauner, D. (2016). Optical control of neuronal activity using a light-operated GIRK channel opener (LOGO). *Chemical science*, *7*(3), 2347-2352.

Trads, J. B., **Burgstaller, J.**, Laprell, L., Konrad, D. B., Weaver, C. D., Baier, H., ... & Barber, D. M. (2017). Optical control of GIRK channels using visible light. *Organic & biomolecular chemistry*, *15*(1), 76-81.

Burgstaller, J., Paulus, M., & Pfundmair, M. (2019). Oxytocin promotes action prediction. *Hormones and behavior*, *107*, 46-48.

Pfundmair, M., Schindler, S., & **Burgstaller, J.** (2019). The role of oxytocin in terror management processes. *Psychoneuroendocrinology*.

Burgstaller, J. (2019). *Neuroactive drug discovery in the larval zebrafish* (Doctoral dissertation, lmu).

Burgstaller, J., Hindinger, E., Gesierich, B., & Baier, H. (2019). Light-sheet imaging and graph-theoretical analysis of antidepressant action in the larval zebrafish brain network. *BioRxiv*, 618843.

Affidavit

Eidesstattliche Versicherung

Hiermit versichere ich an Eides statt, dass ich die vorliegende Dissertation “The effects of oxytocin on self-related processing and cognition” selbstständig angefertigt habe, mich außer der angegebenen keiner weiteren Hilfsmittel bedient und alle Erkenntnisse, die aus dem Schrifttum ganz oder annähernd übernommen sind, als solche kenntlich gemacht und nach ihrer Herkunft unter Bezeichnung der Fundstelle einzeln nachgewiesen habe.

I hereby confirm that the dissertation “The effects of oxytocin on self-related processing and cognition” is the result of my own work and that I have only used sources or materials listed and specified in the dissertation.

München, den 02.09.2020

Jessica Burgstaller