Intimate relationships and olfaction

Body odors, adult attachment, and romance

Anna Blomkvist
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Abstract
Odors influence several aspects of life, such as thoughts, memories, decisions, and emotions. Numerous studies have shown that human behavior can be affected by odors in different contexts. One such context is social relationships, in which body odors play a role. For example, previous studies have shown that close family members can identify each other’s body odors and prefer these compared to the body odors of non-family members. However, further research is needed to establish how body odors and olfactory functioning affect interpersonal behaviors and intimate relationships. In this thesis, I have conducted three studies highlighting the interplay between intimate relationships and olfaction. The overall purpose of this thesis was to investigate if and how olfaction is related to behaviors in intimate relationships.

Study I tested if a romantic partner’s body odors have stress-altering effects and whether such effects differ depending on individual differences in romantic attachment security. As the practice of smelling a partner’s worn garment has been reported as a self-treatment against stress, my colleagues and I carried out an experiment to determine whether exposure to a partner’s body odor attenuates adult individuals’ subjective discomfort and psychophysiological responses. To induce discomfort and stress responses, participants were exposed to weak electric shocks while smelling their partner’s body odor (experimental condition) and three control odors (control conditions). The results showed that partner body odor had an attenuating effect on subjective discomfort during stress. Additionally, highly attachment-secure participants exhibited attenuated skin conductance specifically when exposed to their partner’s body odor. Thus, study I concluded that partner body odor is a scent of security, especially for relatively attachment-secure adults.

Next, to determine whether olfaction is linked to sexual outcomes in intimate relationships, study II explored associations between self-reported olfactory functioning, on the one hand, and infidelity and sexual well-being, on the other, using a survey design. Our exploratory analyses found that self-reported olfactory function predicted sexual well-being positively and infidelity negatively, while controlling for other relevant socio-demographic variables. These results are discussed from a relationship science perspective, in which one’s intimate partner signifies sexual bonding in addition to caregiving and attachment. Thus, study II suggests that a partner’s body odor might be a scent of monogamy.

Study III summarized the literature on populations with an impaired or total absence of a sense of smell. The interplay between olfaction and intimate relationship variables was examined by reviewing research reports and empirical studies concerning individuals with an impaired sense of smell. My colleague and I provided an overview of how olfactory impairment can impact three types of close social relationships: family relationships, friendships, and romantic relationships. For romantic relationships, which are the main focus of this thesis, three categories were defined in which olfactory impairment can impact close social relationships: eating, social support, and sexuality. Thus, study III concludes that olfactory ability is related to various romantic, intimate relationship behaviors.

In sum, all three studies reported findings highlighting that olfaction (body odors and olfactory functioning) is related to intimate relationships. The results from the three studies are discussed via theoretical frameworks concerning the sense of smell, romantic relationships, and attachment. The thesis concludes that olfactory functioning and the experience of body odors are meaningful for intimate relationships and, as such, also for various behaviors in these relationships.

Keywords: Intimate relationships, olfaction, body odor, attachment, sexual well-being, romantic relationships, infidelity, caregiving, intimacy, odors.

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Svensk sammanfattning (summary in Swedish)


För att undersöka hur lukt är relaterat till sexuella utfall i intima relationer undersökte studie II om och hur självrappertad luktfunktion är associerad med otrohet och sexuellt välbefinnande. Medan tidigare studier har visat att luktfunktion spelar en viktig roll för att knyta an i ett romantiskt förhållande, undersökte mina kollegor och jag det möjliga sambandet mellan självrappertad luktfunktion, sexuellt välbefinnande och otrohet genom en
enkätstudie. Våra analyser fann att självrapporterad luktfunktion predicerade sexuellt välbefinnande positivt och otrohet negativt, även då vi kontrollerade för andra variablers påverkan. Dessa resultat diskuteras i ett relationsvetenskapligt perspektiv, där den ena partnern i ett intimit förhållande signalerar mer än bara omsorg och anknytning, även sexuella funktioner. *Studie II* indikerar att en partners lukt kan vara en doft av monogami.


Alla tre studierna rapporterade resultat som visar på att lukt (kroppslukt och luktfunktion) är relaterat till intima relationer och en rad olika beteenden. Jag diskuterar forskningsresultaten från de tre studierna utifrån teoretiska ramverk om luktsinnet, romantiska relationer och anknytning. Sammanfattningsvis ger denna avhandling insikter om att luktfunktion och upplevelsen av kroppslukt är betydelsefulla för intima relationer.
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I am a middle child. I believe that Jeff Kluger has stated in his book that middle children often connect with others and create families outside the biological family. I am fortunate enough to be one of those middle children with several families besides my biological one. At a moment like this when I can acknowledge who has helped me reach my goal and complete this thesis, it seems reasonable to thank all of these family members. They have all been supportive, questioned my choices of research questions to everyday habits, and expanded my views in so many areas. I am very grateful to have all these people in my life.

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Selected additional scientific work not included in the thesis


This doctoral thesis is based on the following studies, which are referred to by their Roman numerals. The original papers are reprinted by permission from the publishers; Elsevier, Springer Nature and Oxford University Press.


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## Abbreviations

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<tr>
<td>ECR</td>
<td>Experiences in Close Relationship Scale</td>
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<td>IWM</td>
<td>Internal Working Model</td>
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<td>WAIC</td>
<td>Watanabe-Akaike Information Criterion</td>
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<td>SC</td>
<td>Skin Conductance</td>
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<td>TDDS</td>
<td>Three Domains of Disgust Scale</td>
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<td>BODS</td>
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<td>SOI-R</td>
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<td>AAI</td>
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<td>CSFQ</td>
<td>Changes in Sexual Functioning Questionnaire</td>
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<td>IIEF</td>
<td>International Index for Erectile Function</td>
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Introduction

Odors and the olfactory system

An odorant is a chemical molecule that elicits an olfactory response. A slightly different phenomenon is an odor, which is a sensation resulting from a stimulation of the olfactory organs. As odors are sensations, they can differ in how they are experienced, going from being pleasant to absolutely dreadful. Hence, odorants are an extraordinary stimulus to use in psychological research.

The development of the olfactory system starts at an early point in our life. The human olfactory system starts to develop in the uterus around week 12, and meaningful biological odors can be learned already by week 30. For instance, one study showed that babies whose mothers consumed anise during pregnancy had a clear preference for that smell, given their exposure to the odor in-utero, compared to aversive reactions to anise by babies who did not have this anise predisposition (Schaal et al., 2000). Hence, maternal odor promotes various adaptive emotional and social behaviors in children (Sullivan et al., 2011). After birth, in the early stages of life, we humans orient ourselves with the help of our olfactory system (Schaal et al., 2020) partly based on what we have learned in-utero but also based on newly formed associations. After the first few days living outside of the uterus, the infant finds olfactory cues deriving from the mother’s nipple area to be particularly action-evoking given the learned association between a feeding-based reward and the nipple area but also a probable innate attraction (Porter & Winberg, 1999). This orientation towards the nipple/areola region leads to successful nipple localization and breastfeeding (i.e., a necessity for survival). Another study showed that an infant will, within days, preferentially turn his or her
head towards the scent of breast milk (Makin & Porter 1989). A range of studies also showed that olfactory cues significantly impact many emotions and behaviors, such as sleeping and arousal at an early stage of life (for example, see Schaal et al., 2004). Also beneficial for survival, findings show that young infants react positively to their mother’s scent (Rattaz et al., 2005) and can discriminate their mother’s scent from that of other mothers very quickly even when a new artificial odor is paired with the mother’s scent (Delaunay-El Allam et al., 2006).

Just like small infants, adults also orient themselves by their sense of smell. In one experiment, for instance, a significant number of adult participants smelled their fingers without being instructed to do so after shaking the test leader’s hand (Frumin et al., 2015), presumably to get valuable information about the test leader. From an evolutionary perspective, this gathering of olfactory information is vital to humans. However, this behavior is often implicit in the individual. This implicit social information gathering behavior is linked to the fairly common argument that olfaction is the most implicit of our senses and thus untestable. The importance of a functioning sense of smell is evident in several regards (Stevenson, 2010). Hence, this implicit characteristic of olfaction preceding its reputation as an unimportant sense is unfair. This thesis argues that olfaction is not untestable nor does it play a less important role for developing close intimate relationships, although it is implicit and in some regards challenging to test.

Moreover, the ability to smell is necessary for survival across species, and olfaction is known to be the oldest and most primitive of the senses. For instance, animal literature has studied how rats use their sense of smell for bonding, survival, and orientation (e.g., Moriceau et al., 2006; Tabuchi et al., 1991; Upton & Sullivan, 2010). The olfactory system of mammals is described to consist of three subsystems; the trigeminal, vomeronasal, and the main olfactory system.

The latter system, the main olfactory system, consists of four key structures that are highly interconnected to other parts of the brain; the olfactory bulb, olfactory cortex, olfactory clefts and epithelium. A wide range of odors can be detected by the main olfactory system, even at a low intensity. This system is typically categorized into central structures within the brain, such as the olfactory bulb and the olfactory cortex (Doty & Kamath, 2014), and peripheral structures outside the brain, such as the olfactory epithelium. This main human olfactory system is the most relevant for this thesis (see Figure 1).
Neurological underpinnings of olfaction

Olfactory processing takes a specific route. The olfactory bulb is the first relay station of the peripheral olfactory neurons (Mori et al., 1999). To connect with other brain areas, a complex network of cortical regions interprets olfactory inputs, as the orbitofrontal cortex (for a review, see Gottfried & Zelano, 2011). Thus, olfactory impulses are then, partially directly transported to key regions of the brain, such as the limbic areas that deal with, among others, processing of emotions and memory. As odors are processed along this direct pathway with fewer synaptic connections than the other sensory information to cerebral areas important for emotional control and memory encoding, it is hypothesized that this is one of the factors as to why olfactory information is known to result in emotional reactivity (LeDoux, 2012; Walliczek-Dworschak & Hummel, 2017).

Perhaps these quick emotional responses to odors are a product of extensive and repeated learning. For example, negative associative pairing can change the absolute sensitivity to an odor by increasing the number of receptors in the olfactory bulb that detect that specific odor (Åhs et al., 2013). In addition,
within the spherical olfactory bulb glomeruli, there are receptor cell axons arranged in double or single layers. These defining features of the olfactory system decrease with age and are nearly absent in elderly individuals (Doty, 2009; Doty & Kamath, 2014). This points to olfactory ability to some degree being a process related to age and perhaps to learning mechanisms as well.

Certain odors seem to trigger particular parts of the brain. For example, the body odor from 2-day-old babies has in one study been shown to activate a brain region associated to reward processing, in both women who had not previously given birth and women who had recently given birth (Lundström et al., 2013). These types of neurological reward-activations by odor stimuli processes can also be found in other species, such as rats (Opendak et al., 2020).

Gorillas, chimpanzees, bonobos, and orangutans are our closest relatives and we all belong to the unique group of species with axillary (armpit) scent glands. The neurological and animal behaviorist evidence shows that the great apes are micro-osmic and have a relatively small olfactory bulb (for a review see, Schaal & Porter, 1991). However, we do differ in some ways; for instance, humans have been noticed to be the most scented ape of all as we differ in the size and number of apocrine and sebaceous glands (Stoddart, 1990). In comparison with dogs, which are famous for their smelling capacity, the human olfactory bulb only accounts for about 0.01% of our brain volume whereas the same ratio for dogs is 0.31% (Kavoi & Jameela, 2011). However, size is not all that matters and, as mentioned earlier, other brain areas being integrated with human olfactory bulbs have proven to be key in human decoding of olfactory messages (Keverne, 1983). In a comparison between mammals with regard to 138 odors, humans turned out to have higher sensitivity than most other species tested, including species supposedly possessing a highly developed olfactory system, such as mice, rats, and rabbits (for a review, see Laska, 2017). Another recent review also established that humans are actually more sensitive in terms of detecting a variety of odors than previously expected (McGann, 2017). Other scholars argue that humans detect up to a billion or even a trillion different odors. Furthermore, the consensus in comparative research is that the species-specific behavioral relevance of the stimuli used during testing constitutes the best predictor for olfactory performance (Laska, 2017).

For individuals with smell blindness (anosmia), which means that they are unable to detect smells, a range of consequences may be expected. For example, reductions in the olfactory bulb volume has been related to changes in the emotional regions of the brain linked to depression (Negoias et al., 2010). It is important to note that individuals born without an olfactory bulb, congenital anosmics, might have a different set of experiences and suffer different consequences from missing a sense of smell than those of a clinical
group that suffers from having injured the olfactory bulb or part of the olfactory system later in life (Peter et al., 2019: 2020). Perhaps this also highlights that olfactory stimuli and the ability to connect odors with behaviors, individuals, and emotions are neurologically learned throughout the lifespan, both unconsciously and consciously. In this thesis with its focus on intimate relationships, study III summarizes the current literature regarding olfactory impairments and romantic relationships.

**Body odors**

All humans have a unique individual body odor that appears to be relatively stable over time (Roberts et al., 2013). Odor-producing areas in humans are scalp/hair, mouth/breath, axillae/underarms, chest, genital/vaginal, and feet. Different parts of the human body produce different amounts and types of odors, much due to the eccrine and sebaceous glands being distributed differently throughout the body (Starkenmann, 2017). These glands are essential for skin protection and thermoregulation, among other functions. In general, most body odor formation is of bacterial origin, but in the genital/vaginal and scalp/hair areas, there is also yeast. Together, these materials constitute body odors (Starkenmann, 2017).

Moreover, our immune system is involved in the composition of our body odor. A set of genes called major histocompatibility complex (MHC) in the immune system exists to facilitate self- and non-self-recognition within the body in order to aid T-cells in their work to localize and fight foreign pathogens. This gene group of more than 50 genes is tightly tied to one chromosome. MHC genes are also the most variable across individuals, and every individual has a unique setup of MHC genes (Pause, 2017). In humans, the MHC genes are often referred to as HLA (human leukocyte antigen) since the molecules are bind to leukocytes, a type of white blood cells. This individual unique odor print becomes an exclusive body odor to the individual, much like a fingerprint (Herz, 2007).

Previous evidence (Lobmaier et al., 2018; Havlíček & Roberts, 2009) reported that olfactory attractiveness in humans promotes mating with people presenting a dissimilar MHC in order to obtain increased pathogen resistance in the progeny. However, recent studies question the extent to which these effects of mate choice and attraction are MHC-related. The small number of studies conducted have presented mixed results and sometimes go in opposite directions (for a review, see Havlíček et al., 2020). In addition to MHC genes, body odor quality is affected by many other factors, such as diet, developmental changes related to sex and age, and disorders or diseases related to metabolic functions (for a review, see Havlíček et al., 2017). Thus,
the genetic make-up of MHC genes is engaged in a complex interaction with metabolic and physiological environments.

Due to this rather intricate creation of body odors and the wide variety of body odors among the human population, it is not always easy to identify and link a specific body odor to a specific person. However, some key findings show that specific body odor group characteristics seem to be perceived in a particular culturally derived way. For example, more intense smells are thought to arise more often from males than females, regardless of the actual sex source in experiments (Doty et al., 1985). One study also showed that individuals unaware of the relationship between the body odor samples could match parents and their offspring based solely on body odor cues (Porter et al., 1985). Another example is that diseases and infections impact body odors (Olsson et al., 2014). More specifically, it has been found that the body odors of sick individuals are perceived and rated as less likable (Sarolidou et al., 2020).

Personal habits, disease, hygiene, and living conditions can alter overall body odor (Xu et al., 2007). Developmental changes can also impact body odors. The human apocrine glands develop during puberty, especially the axillary glands in the armpits (Starkenmann, 2017). The most noticeable changes happen during puberty when there is growth of armpit hair and an increased activity of the glands. Findings concerning androstenedione (a steroid that is excreted only during fertile age) can reveal these developmental differences. Before puberty, children can detect the odor of 5 alpha-androst-16-en-3-one (androstenone), but many men become anosmics with regard to androstenone after puberty (Dorries et al., 1989). Women, on the other hand, become more sensitive to androstenone as they get older and retain their ability to smell it.

Masking body odors is a multibillion-dollar industry. Across the world, body odor masking is linked to different cultural and societal norms and values connected to how, to what degree, and to which types of odorants are used. In Western societies, for instance, perfumes in the form of liquids with floral scents (first primarily created in secret in monasteries) have been popular since the beginning of the 14th century (Pickenhagen, 2017).

Measuring olfactory function and body odors

Recognizing an odor in general is not always easy and there seems to be a difference in this ability across sex, where women tend to be better in terms of recognizing a smell than men (Sorokowski et al., 2019). More specifically, a study of people having a normal sense of smell showed that the group explicitly rating their olfaction as being very important was young women,
defined to be under the age of 25 years (Murr et al., 2018). Across different studies, such sex differences in olfactory abilities have been detected. Furthermore, it is not always easy to even identify one’s own body odor among other body odors. For example, one study showed that only 5.6% of the male participants and over half (59.4%) of the female participants could identify their own odor (Platek et al., 2001). Some of this variability in the human odor perception literature have been described as a result of design differences or method of data analysis (for a review see Kaeppler & Mueller, 2013). Especially for body odor studies, designs may differ in sampling method of body odors (often a t-shirt worn by the subjects), the frequency of exposure and for how long the participant is able to smell the body odor samples.

Recognition of body odors also seems to be a process related to families or kinship. As previously mentioned, it has been shown that newborn babies can distinguish their own mother from other breastfeeding mothers based on body odors alone (Cernoch & Porter, 1985). Likewise, new mothers (who had been with their newborn baby for a maximum of 1 hour) could recognize their baby only by scent cues among the scents of other babies (Kaitz et al., 1987). Fathers also recognize their babies, though somewhat more poorly than mothers (Kaitz et al., 1987). The body odor of siblings can also be recognized by children in the age span of 3–8 (Porter et al., 1986). As adults, siblings can correctly recognize their sibling only by smell, even though they have not been in contact for up to 30 months. However, recognizing the body odor of family members is influenced by relationships. For instance, impairments in the mother-child relation are associated with lower success rates with regard to recognizing the child’s body odor (Croy et al., 2019). Although the directionality is unclear, body odors can presumably signal both familiarity and a range of other interpersonal qualities.

Pleasantness ratings of body odors are also a matter of families and kinship. Children smell lovely to their parents, who can both identify and prefer their own child’s body odor in comparison to other children’s body odors (Schäfer et al., 2020). Mothers also find other babies’ diapers to be more disgusting than their own baby’s diapers in blind experimental settings (Case et al., 2006). However, as older children reach puberty, this maternal preference for the own child’s body odor change (Schäfer et al., 2020). Perhaps this is convenient for several members of the family: the teen who wants independence and the parent who could ease up some of his or her responsibility.

Being able to recognize body odors within the family also highlights the importance of familiarity when it comes to body odors. Familiarity as a measure of odor perception is frequently used in olfaction research as both an outcome measure and a control measure. In experimental settings where the

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participant is to be exposed to various odors, it is important to assess familiarity to prevent any potential biases of earlier perceptions in order to measure the odors equally. For example, in a cultural context where garlic is a familiar odor used in various foods, this familiar odor presumably has a positive valence rating. In certain cultures, on the other hand, garlic might be used as a cure for a disease, purely for medical purposes, and could also result in a high familiarity rating but not a positive one. In other words, testing both familiarity of odors and pleasantness is crucial in experimental olfactory research.

The intensity of an odor can have, similar to pleasantness and familiarity, an influence in different experimental settings and practical effects in real life. For instance, if a variation of diluted odors is compared, the more diluted odor is often harder to recognize. The same is valid for body odors; a more diluted body odor might then lose a great deal of valuable social information. However, if a more intense (i.e., less diluted) body odor occurs, this would lead to a behavioral reaction, obviously depending on other essential variables such as the receiver individual’s sensitivity level to that particular body odor, evaluated pleasantness, and the general context. Thus, some odors may have meaning in a social context, relatively independent of that odor’s intensity (Haviland-Jones et al., 2016).

When measuring olfactory function and ability, it is quite common to use different methods: self-report measures or more objective behavioral testing, as well as physiological tests. A frequently used behavioral test is the Sniffin’ Sticks test (SST; Hummel et al., 1997). In this test, olfactory discrimination, threshold, and identification are assessed, and a combined score reflecting olfactory ability is created. Other assessments of testing human olfactory sensitivity through self-reported measures (e.g., questionnaires) correspondingly tend to tap into these olfactory abilities of sensitivity, discrimination, and identification. It is important to note here that self-reported olfactory function measures and more objective behavioral measurements are reported to be poorly correlated (Landis et al., 2003). Hence, both behavioral and physiological measurements (study I) and self-reported measurements (study II) are examined in this thesis to assess olfactory ability and different interpersonal psychological effects.

The communicative feature of body odors

As humans, we want and need to interact with other individuals in various ways, and this is a feature we share with other mammals. Monkeys (e.g., owl monkeys) use olfactory cues for mating choices (Wolovich & Evans, 2007). Similarly, natural human body odors serve as important markers for sexual
interest in both women and men (Herz & Inzlicht, 2002). Humans are mammals, and as such, body odors are likely essential means of communication. This ranges from the most crucial behavior of reduced crying or preparatory feeding responses (i.e., mouthing) in babies when exposed to maternal scent (Sullivan & Toubas, 1998) to subtler and more complex behaviors and communication, such as decision-making in social settings related to food (Laidre, 2009).

Body odors can also signal who is ill and who is healthy. Pathogens, or infectious organisms deriving from different sources, signify a threat to people’s vitality (Oaten et al., 2009). It has been posited that in support of our physiological immune system that protects us from pathogens and diseases, we humans have evolved a matching set of psychological mechanisms to detect, react to, and avoid pathogen threats, which has been named the behavioral immune system (BIS) (Schaller & Park, 2011). Pathogen disgust is thought to have evolved as the first line of defense in the behavioral immune system and serves to recognize substances likely to carry pathogens, such as rotting foods and bodily fluids (Tybur et al., 2009). In a way, humans’ sense of smell plays a role as a gatekeeper in detecting invisible pathogens (Olsson et al., 2014; Stevenson, 2010) before they come in contact with our bodies. Here, olfactory-induced disgust sensitivity might be crucial in the BIS (Liuzza et al., 2017). As an example of the importance of the sense of smell and the behavioral immune system, the ability to detect and avoid sick individuals has been noted to occur with regard to unique body odor cues (Olsson et al., 2014). Another recent large study showed that people are less averse to engage in infection-risky acts with friends and strangers who are agreeable in comparison to dishonest strangers (Tybur et al., 2020). Thus, behaviors to avoid pathogens are highly related to social contexts and behaviors within various relationships.

Body odors can also signal comfort. In animal models, findings show that maternal odors can protect against fear conditioning and reduce stress responses in small infants (Hostinar et al., 2014; Raineki et al., 2015). Additionally, young children with sleeping difficulties may be calmed by the axillary odors of their mothers (Schaal, 1988). This phenomenon of smelling a garment containing body odors from a specific person to gain relief and comfort is named comfort smelling. As a concept, comfort smelling has also been evident in studies on romantic adult partners (Hofer et al., 2020; McBurney et al., 2006; 2012; Shoup et al., 2008) in terms of gaining more comfort or lowering stress levels. Comfort smelling occurs for both adults and children, and previous survey and lab studies have shown that smelling a romantic partner’s garment can improve sleep and serve as a stress release (Hofer et al., 2018, Hofer & Chen, 2020). Missing from this comfort smelling literature is whether and how relationship variables, such as individual differences in attachment security, affect comfort smelling.
Another part of communication that could be signaled through body odors concerns different personality traits (for a review, see Havlíček et al., 2017). Among several Big Five personality dimensions such as extroversion and dominance, has been recognized by the opposite sex raters based solely on body odor (Sorokowska et al., 2012). Other personality traits such as neuroticism have also been shown to be detected by both children and adults in controlled body odor experiments (Sorokowska et al., 2012; Sorokowska, 2013), especially where body odors alone were assessed in comparison with the same body odors accompanied by fragrant cosmetics (Sorokowska et al., 2016). The level of individual social openness (the skill to initiate social contact) also seems to matter for the perception of body odors as social cues. In one study, individuals with a higher social openness rather than a low social openness exhibited greater activation in the inferior frontal gyrus and caudate nucleus (Lübke et al., 2014) when smelling body odors.

There also seems to be a link between mating behavior and body odors. For example, body odors can reveal who is single and who is not (Mahmut and Stevenson, 2019). Another study indicates that men rate women’s genital sweat as being the most sexually attractive during the follicular phase of their menstrual cycle (Doty et al., 1975). Further, Singh and Bronstad (2001) suggest that men can distinguish body odors from women in the ovulatory (late follicular) and non-ovulatory (luteal) phase. In another study, younger women (mean age of 21) who rated themselves as very passionately in love with their current partner were less likely to identify the body odor of an opposite-sex friend, a result presumably reflecting that these women did not have an interest in finding other potential partners (Lundström & Jones-Gotman, 2009). However, to the best of my knowledge, there is no recent research literature on body odors and romantic relationship formation from an attachment perspective that could help identify potential developmental mechanisms at play.

“Reading” the emotional states of others is crucial for improving social perceptiveness and communication with other people. Body odors are able to signal different emotional states and, similarly, different body odors can evoke different emotions. A key emotion that often gets paired with olfaction is disgust. For instance, disgust sensitivity to body odors is associated with a perceived vulnerability to disease and is even more strongly associated than traditional disgust sensitivity measures placing less emphasis on body odors (Liuzza et al., 2017). Another of our basic emotions (Ekman, 1964) that has also been linked to olfaction and particular body odors is fear (for examples, see de Groot et al., 2020; 2021). These emotions – disgust and fear – have been tested in relation to olfaction in various experimental designs in relation to olfaction. In terms of other emotional examples, participants have been able to detect emotions such as anger and happiness by smelling human body odor
samples in experiments (de Groot et al., 2015; Chen & Haviland-Jones, 2000). Additionally, a meta-analysis carried out by de Groot and Smeets (2017) examining the communication of fear, anxiety, and stress via body odor suggests that humans get affected by the scent of another person’s fear.

In conclusion, odors and, in particular, body odors can communicate a lot of information. For this thesis, this capacity to communicate by using olfactory information is key as the studies conducted include interpersonal communication of various sorts. Something investigated more closely in this thesis is the extent to which and what particular information in intimate relationships can be communicated via olfactory functioning and body odors.

**Memory and body odors**

The human sense of smell can also impact memory in various ways. Odor memories are described to include both memories that are connected to or associated with odors and memories evoked by odors. It has been suggested that odor memory is a system that is separate from visual-verbal memory (Herz & Engen, 1996). Odors have also been proposed as a strong elicitor for memories from childhood (Willander & Larsson, 2006), and the context of this exposure might be part of the explanation. Context-dependent memory has in several studies been shown to be associated with the sense of smell (for a review, see Larsson et al., 2017). For example, one study has shown that odors, in comparison with other sensory stimuli, are more emotionally recalled, even though all sensory modalities seem to elicit accurate recall (Herz, 1998). However, another pattern seems evident for long-term memories where odors outperform other sensory modalities in the information presented (Wilson & Stevenson, 2006).

As humans, we immediately evaluate an odor when we encounter it, assessing whether we should approach it or keep our distance. This makes research on the sense of smell and memory complicated. It is complicated because it can be difficult to disentangle the memory of sounds, emotions, and sights from smell (i.e., the context). For example, the scent of cinnamon and a fir tree, representing Christmas, can easily be linked to the feeling of love, the sound of a chorus, the sight of lit candles, and perhaps family members.. By using well-designed and controlled lab settings, this issue of separating olfactory cues from other stimuli could to some extent be overcome. This thesis includes a couple of such research attempts. In particular, *study I* attempted to disentangle the body odors of a partner by using strict experimental control settings in order to evoke a memory-like effect of attachment.
Attachment theory

Just as the sense of smell, the formation of interpersonal attachments is key for survival and reproduction in many species, including humans. Attachment theory initially focused on describing children’s attachment to their primary caregiver(s) (i.e., the attachment figure). Work in this field dates back to the mid-20th century and was carried out by John Bowlby. His theory has later been adjusted to emphasize the importance of a secure relationship between the child and the primary caregiver in childhood (Cassidy & Shaver, 2008). A secure relationship would typically be characterized by comfort in and reliance on the attachment figure for emotional support, whereas the lack of such support for comfort would typically be described as an insecure attachment relationship. So, in general, attachment behavior occurs within the child-caregiver relationship and could be described as responses to reciprocal signals (Bowlby, 1958). The importance of secure attachment is noted to help people regulate negative emotions and focus on re-establishing hope, enthusiasm, and optimism (Mikulincer & Shaver, 2016), to mention a few examples.

Attachment and regulating emotions are tightly intertwined (Mikulincer & Shaver, 2016), where humans have different emotion regulation responses, to some extent dependent on their attachment pattern of insecure or secure attachment. Such a complex emotion regulation system, according to Bowlby, is founded on seeking a stronger, wiser protective person who can provide safety, security, and guidance (Cassidy & Shaver, 2008). However, secure attachment is just one of the attachment patterns or styles identified. Variations of attachment (i.e., attachment patterns) have been defined through careful child-parent observation studies, including separations, such as the strange situation paradigm (Ainsworth et al., 1978). Ainsworth et al. (1978), later supplemented by Main and Solomon (1990), separate attachment patterns into three organized kinds (secure, insecure-avoidant, and insecure anxious) and one disorganized kind. These differences in attachment are crucial for further understanding behaviors in intimate relationships. For example, the original attachment theory presented by Bowlby (1969) includes the premise that individual differences in attachment are vital for understanding reactions to stressful events. Individuals presently scoring higher in attachment-related anxiety often experience attachment figures as
inconsistently available in the past and thus fear separation and learn that exaggerated expressions of need and vulnerability may be required to gain protection and support. Individuals scoring higher in the attachment anxiety dimension are often characterized by extreme worry regarding the attachment figure’s responsiveness and one’s value in the relationship. Individuals scoring higher in attachment avoidance are often characterized by independence and self-regulating their emotions, often by withdrawing from the attachment figures.

Studies on both adults and children have highlighted that the attachment figure often serves as a safe haven for the attached person. This safe haven function implies that the attachment figure can provide comfort during stress (Mikulincer et al., 2002). For example, children having been briefly inflicted with pain in a clinical situation showed less stress and pain reactions when presented with the body odor of their mother (Akcan & Polat 2016). The attachment figure could also serve as a secure base. In other words, by having an attachment relationship, the attached person gains a valuable platform of security for exploration and meeting challenges (Mikulincer et al., 2002). These functions of the attachment bonds – safe haven and secure base – involve concepts often found in child-caretaker attachment relationships, such as seeking proximity to an attachment figure and resisting separation from this attachment figure (Cassidy & Shaver, 2008).

Internal working models

Internal working models (IWMs) are cognitive-affective filters related to the self and others, and they yield expectations regarding the social world, in particular close interpersonal relationships. IWMs are tightly linked to accessing memories based on a (largely unconscious) processing of attachment-related information. This information is presumably based on experiences from the child’s behavioral approach to the parents and their responses to the child’s behaviors and intentions (Main et al., 1985). Since the experiences of attachment relationships serve as the primary foundation for IWMs, they include models of others and the self (Bowlby, 1973; Mikulincer & Shaver, 2016) and are used unconsciously to interpret novel situations. Bowlby (1969) pointed out that especially experiences concerning parental sensitivity during distress become internalized as IWMs. These gathered, early experiences from primary relationships with caregivers are internalized by the child as IWMs and become a guide for dealing with future attachment-related situations.

Main et al. (1985) extended the theory of IWMs from Bowlby’s original work to the level of adult cognitive representations and argued that IWMs reflect
memories of attachment-related experiences. Naturally, IWMs are different across individuals depending on the attachment experiences gained throughout life. As IWMs are represented by a single global affective and cognitive structure that influences reactions, IWMs are also reasonably stable across relationships (for a discussion, see Overall et al., 2003). Furthermore, Bowlby (1969) and Main et al. (1985) anticipated that intense interpersonal experiences could alter IWMs both during and after childhood.

Through emotional involvement and attachment-related experiences, IWMs are updated in interpersonal relationships throughout the individual’s lifespan (Cassidy & Shaver, 2008). IWMs are supposedly organized as generalized event representations (Main et al., 1985), based on earlier attachment-related experiences and stored in memory. As these representations guide interpersonal behavior and intimate relationships, new attachment-related experiences may influence the IWMs (Arriaga et al., 2018). However, IWMs also remain somewhat stable over time (Fraley et al., 2011).

Perception and internal working models

As the attachment system is a psychobiological system dependent on communication to and from caregivers, it is essential to get feedback from the different senses. For example, attachment behavior can be expressed by the small child by means of voice and touch, such as screaming, smiling or clinging behavior (Bowlby, 1958), both presupposing that the caregiver can detect these signals via his or her auditory and tactile senses. Thus, when a threat is near, the attachment behavioral system is automatically activated, and the needs of the individual are communicated. This activation manages physical proximity to the attachment figure in order to gain safety and comfort (Bowlby, 1969). Consequently, the attachment behavioral system is deactivated when the attachment figure is close to the individual, as the need to seek proximity during a threat is no longer necessary. Interestingly, following a zillion interaction episodes and concomitant cognitive maturation, a psychological sense of proximity to the attachment figure could also be achieved with imagination and activating internal working models (IWM).

In comparison to childhood attachment, adults are better able to regulate emotions on their own via their mental representation of their attachment figure (Mikulincer & Shaver, 2016). In other words, there is supposedly a lesser need for an adult to have their attachment figure physically present during a stressful event than for a small child. An example of this could be the extensive use of pictures of loved ones currently found in cell phones and previously in wallets. However, exactly which sensory stimulus is needed and sufficient for activating and representing such an emotionally regulating sense of presence remains to be determined. Where previous research on humans
has largely focused on the visual, tactile, and auditory senses, I suggest in this thesis that a smell could evoke, represent, or signal such a presence of an attachment figure.

Previous studies have used exposure to visual reminders (such as pictures) of one’s attachment figures to show activation of the safe haven function and facilitate emotional recovery (Selcuk et al., 2012). Picture stimuli have also been shown to lower pain ratings (Eisenberger et al., 2011). Another example of visual exposure is that people were generally more positively inclined toward an unfamiliar target after being exposed to an attachment-related visual stimulus than a neutral stimulus (Granqvist et al., 2012). Other sensory stimuli have also been used to evoke attachment representations. For instance, touch, such as holding a hand of the attachment figure without seeing them, has also proven to be a key factor for social support and emotion regulation, as reflected in both neurological (Coan et al., 2006) and behavioral findings (Brennan & Shaver, 1995). However, olfactory stimuli are missing from this literature, which is remedied in study I in this thesis.

Similar olfactory findings, without the attachment approach, highlight that a partner’s body odor can lower participants’ stress levels (cortisol level) in a social lab stress test compared to a stranger’s odor (Hofer et al., 2018). Another example of partner presence in the form of his/her body odor is that individuals reported smelling their partners’ clothing when they were apart to gain comfort and support (McBurney et al., 2006, 2012; Shoup et al., 2008). Taken together, all these reported studies concerning comfort smelling demonstrated that the presence of one’s partner, in the form of limited perceptual input restricted to the partner’s body odor, could lower stress responses and possibly have several additional positive physiological and psychological effects. In other words, these perceptual reminding stimuli could be explained in terms of triggering or activating the individual’s internal working models (IWMs).

Being able to imagine with limited sensory input (e.g., only having access to body odor) may not be an easy task for everyone. Multiple sensory inputs might facilitate imagining the presence of an attachment figure. Previous studies have shown that other interpersonal abilities and behaviors seem to be multimodal, such as attractiveness (Groyecka et al., 2017). With this line of thinking, multiple sensory inputs of the attachment figure can facilitate the imagination process in order to achieve comfort and appropriate emotion regulation. Another way of highlighting the importance of imagination and multimodal sensory importance is when a sense is impaired. In the absence of one sensory modality, perhaps other senses could compensate to signal partner presence and yield stress-altering effects. This idea is explored in this thesis in study III, where I discuss whether individuals with olfactory impairments might have other compensatory senses regarding interpersonal behaviors and
expressions in romantic relationships. Perhaps such compensatory sensory abilities could also extend to the ability to imagine the presence of the attachment figure, but this remains to be empirically tested.

Adult attachment

According to Weiss (1991), the features characterizing infant-caregiver bonds apply to most committed adult romantic relationships. More specifically, in such adult romantic relationships, a person wants to be with the partner, especially in stressful times, protests when the partner threatens to become unavailable, and derives security and comfort from his or her partner. In a way, this mimics child-caregiver attachment concepts of proximity seeking and separation resistance. Similarly, sexual pair bonds have been highlighted by Ainsworth (1989) as the prime example of adult attachments. Additionally, and of importance for this thesis, Bowlby (1969) emphasized the importance of considering attachment to be active throughout the entire lifespan, “from the cradle to the grave.”

Naturally, moments in need of a wiser and stronger caregiver occur more frequently when one is vulnerable and physically smaller (i.e., infant, toddler, and childhood years). Hence, the adult caregiver is naturally seen as wiser and stronger for a young child, thus playing a particular role in terms of safety and protection. Later, peers gain significant value in older childhood and adolescence, and a shift in the prominent attachment relationship often occurs – from caregiver attachment to peer attachment. The acquisition of autonomy and self-esteem becomes increasingly important. For instance, Zeifman and Hazan (2016) conducted interviews with children aged 6–17 to study components of development attachment. They asked the children and adolescents which person they would most like to turn to in different situations. Concerning proximity seeking, both children and adolescents stated that they preferred to spend time with peers. The perception of a safe haven varied between childhood and adolescence. During middle childhood, parents were still the most important “safe haven,” while younger and older teenagers often listed a peer as their most important. Examples of a fully developed attachment relationship to a peer were only found in the oldest teenagers, and of these, almost all interviewees stated that it was a girlfriend or boyfriend (i.e., a romantic relationship). Hence, one could argue that in late adolescence and early adulthood, peers are often the most important to the individual as a reference group and for key attachment relationships. Additionally, during this developmental period, it is also common that a romantic relationship plays a central role, where that special someone for the individual can offer comfort in stressful situations. In other words, adult...
attachment (i.e., romantic attachment) is beginning to form, where the safe haven and secure base functions are provided by a romantic partner.

Adult attachment differs somewhat from early childhood attachment. First, adults are to a greater extent able to imagine. For instance, an adult can use internalized representations, such as memories of previous attachment persons, to achieve emotion regulation, comfort, and stress relief (Mikulincer & Shaver, 2016). Hence, external stimuli, such as a picture or an odor, could serve as a reminder of the attachment figure and aid in regulating emotions (e.g., attenuating stress responses). Second, the romantic attachment process is also dynamic and characterized by a symmetrical support system and reciprocal emotional regulation where both individuals give and receive support and help each other regulate emotions. In other words, ideally, both partners could take turns in perceiving the other as stronger and wiser.

Learning theory of attachment

The description of IWMs as a construct might be hard to grasp. Within the research field of attachment theory, the notion of IWMs is used rather broadly to describe various cognitive-affective, representational processes. To explain IWMs further and fill the gap between theoretical notions on IWMs and actual data concerning why certain variables, such as sensitive caregiving, can explain individual differences in attachment development (Verhage et al., 2016), Bosmans et al. (2020) recently presented a learning theory of attachment.

Using learning theories to explain the development of attachment is and has been debated to some extent. Bowlby was inspired by Lorenz (1966), who found imprinting behavior among other species; for example, that geese get “attached” to the first moving object they encounter after hatching. Thus, Bowlby (1969) highlighted that attachment is an evolutionarily primed behavioral system. Later, Ainsworth and Bell (1972) found that small children’s attachment behavior, such as an infant crying, decreased in response to quick parental responses (i.e., reinforcing a support effect). This, according to Ainsworth and Bell, highlighted the notion that attachment behavior was not learned through rewards.

Lately, with a new era of learning theories, it is becoming increasingly established that attachment relationships serve as a context for social learning and cultural transmission (Corriveau et al., 2009; Granqvist, 2021). Bosmans et al. (2020) more specifically propose that attachment develops via a safety conditioning learning process, which can be partially understood by using updated classical conditioning and operant conditioning models. An
attachment figure can become a safety cue, much like any other cue becoming a predictor in a learning process that an expected aversive event will not occur. According to earlier texts, Bowlby (1973) expressed similar ideas focusing on fear coping: seeking proximity to the attachment figure serves both to approach a person whose proximity is desired and to withdraw from frightening/distressing stimuli. Bowlby concluded that this is attachment behavior, while Bosmans et al. (2020) propose that this is learned behavior. These two perspectives are not to be viewed as conflicting but rather as highlighting two sides of the same coin.

Certain types of stimuli work better for fear conditioning than others. Biologically prepared stimuli often require fewer learning episodes and can still make humans act, both fast and persistently, on them. For example, snakes and spiders typically serve as genetically prepared stimuli to raise fear for humans, presumably with a survival value (Mineka & Öhman, 2002). Bosmans et al. (2020) extend this prepared fear conditioning to involve learned safety associations. They propose that attachment figures serve as the ultimate, biologically prepared, and learned safety cue. This preparedness idea corresponded with the imprinting view of attachment development presented by Bowlby (1969) and can also account for why not just any random object, person, or stimuli becomes a learned safety cue serving to lower distress. For example, their (Bosmans et al., 2020) proposal corresponds with several studies showing that small babies, even newborns, exhibit attentional preferences for their parents in comparison to others, possibly through their body odor or voice (e.g., Cecchini et al., 2011).

In this thesis, I mainly focus on classical conditioning. In order to integrate the learning theory idea with attachment theory, specific essential explanations are needed. Described in short, CS stands for the conditional stimulus that gets paired with the UCS, the unconditional stimulus. The UCS automatically elicits an unconditional response (UCR). The CS similarly evokes a conditional response (CR). After a child (an individual) is exposed to distress, each interaction with the parent (the attachment figure) could be considered a single learning event according to learning theory. In such a single learning event, if the attachment figure (CS) provides care and support (UCSsupport) after acknowledging the individual’s distress, this support results in a sense of comfort and relief (UCRpos). Similarly, the attachment figure can also elicit alleviated distress (UCRneg) and become associated with safety (CSsafety) as a follow-up by decreasing the UCRneg. If this occurs repeatedly over several learning trials, these associations become both quicker and more robust.

Suppose that well-established links frequently occur over learning events between the attachment figure (CS) and comforting behavior to the individual (UCSsupport). In such a case, the individual will have expectations (CR) that
the attachment figure will provide relief and comfort when distressed. Furthermore, this implies that if such a contingency in the CS-UCS support is high, this would be reflected in a secure attachment (i.e., positive IWMs). This can be viewed as a more dispositional (or trait-like) understanding of secure attachment expectations, which turns IWMs into a useful concept. On the other hand, insecure attachment (i.e., negative IWMs) will develop if the CS-UCS support contingency is low. This prompts a sense of disturbance due to the individual’s innate need for support (La Guardia et al., 2000) and leads to an insecure state of attachment (UCRneg). By being subjected to these repeated negative learning experiences and appraisals, more negative information regarding attachment will later translate into an insecure attachment disposition and associated IWMs.
Romantic relationships

Used as a term by Western societies after the 1800s, romantic love was defined as a distinct kind of love based on mutual feelings and attraction that bond partners as a couple. Additionally, romantic love is also defined as a requirement for starting an intimate relationship and building a family (Arosio, 2016). Romantic love has also been defined as “love characterized by romance and involving sexual attraction” (Collins Dictionary). There are nowadays numerous studied outcomes that have been shown to be linked to romantic involvement. For example, involvement in a romantic relationship is associated with different aspects of well-being (Robles et al. 2014). Similar findings point to that loneliness is negatively related to different forms of well-being and even mortality (Holt-Lundstad et al., 2015). Hence, romantic relationships and the need to belong have been and is important for humans in several regards.

Romantic relationships exist in various forms and, consequently, not all romantic relationships are filled with joy, happiness, and outcomes beneficial to health. For instance, abusive relationships are and have historically been reported across cultures and countries, and men’s violence against women in intimate relationships has recently been made a priority for the World Health Organization (2013). Some studies also report a relationship between attachment and non-functioning romantic relationships, where the trend is that previous attachment experiences characterized by neglect and abuse seem to be a marker for later troubles in romantic relationships (Raby et al., 2017; Labella et al., 2018). Although these topics are alarming and highly important, they are outside the scope of this thesis.

As described later in this chapter, romantic relationships are defined differently depending on which psychological perspective and framework are applied, which, in turn, also influences how studies are conducted and how different romantic relationships are explained to be formed. To mention a few, culture and norms can have a major impact on explaining variations of romantic relationship formation (e.g., arranged marriages), biology can and has also been used as a main explanatory variable to explain differences in romantic relationship formation and function (for a recent review, see Bode & Kushnick, 2021).
Psychological perspectives on romantic behaviors

There are multiple theories as to what constitutes a romantic relationship and what drives and motivates humans to engage in romantic relationships. One such theory derives from evolutionary psychology and another from theories in relationship science. Attachment theory, described earlier, is said to be linked to both theoretical traditions, as it is partly derived from an evolutionary framework (e.g., with the imprinting influences) and partly from a social psychological relationship science framework, such as early conceptualizations and measurements of romantic love and its dimensions (Rubin, 1970).

The focus of evolutionary psychology when explaining behaviors within and during the formation of romantic relationships is based on the assumption of selection driving and adapting the individual’s reproductive success (Buss, 2007). These ideas apply to several aspects of romantic relationships, such as romantic attraction, assortative mating, and mate selection, to mention a few (for a review, see Buss, 2007). Furthermore, theories of selection guide evolutionary psychologists to research questions with an underlying focus on strategies used by individuals. Such strategies are thought to enhance or protect their reproductive success in romantic relationships, sometimes even at the expense of their partners. One such research theme is that mating strategies are adaptable across both context and time, where either sex may be open towards or actively seek alternative partners when the cost of doing so is relatively low in relation to the benefits (Gangestad & Simpson, 2000).

The somewhat different focus in relationship science in describing how the formation of and behaviors within a romantic relationship occur is based on the premise that relationships to some extent are symmetrical and reciprocal. Contemporary relationship science seeks to understand the ontogenetic and proximate causal processes that govern interactions between partners across time (Rusbult & Van Lange, 2003). This perspective is based on a traditional focus of social psychology, where close relationships can have qualities that exceed the two individuals (Fitzsimons et al., 2015) and provide a context in which influential interactions take place. Further, it is assumed that people typically become interdependent with their close relationship partners over time. Due to this interdependence, it is possible to achieve important beneficial outcomes. These can include both personal outcomes, such as subjective well-being, and relational outcomes, such as sexual fulfillment and relationship satisfaction. In study II in this thesis, sexual well-being and infidelity are examined as relationship outcomes, and this is an example of a relationship science approach to a study design. Moreover, depending on one’s partner comes with the cost of vulnerability to be exploited (Murray et al., 2009) although commitment is key to several affective, cognitive, and
behavioral outcomes vital for maintaining a stable relationship. For example, people who are strongly (rather than weakly) committed to their romantic relationships more often forgive their partner’s transgressions (Finkel et al., 2002). They are also more inclined to perceive their relationship as better than those of others, an effect that is especially strong when their own relationship has been threatened by information suggesting that it may not endure (Rusbult et al., 2000).

A third psychological perspective on romantic relationships has been suggested by combining both the evolutionary psychology perspective and the relationship science perspective. This model is called the Conflict–Confluence Continuum Model and has been developed by Durante and colleagues (2016). In this model, ideas from evolutionary psychology that concern conflict-of-interest models and the relationship science confluence-of-interest models are integrated. In conflict-of-interest models, benefits achieved by one individual often come at the expense of the other partner; for example, to get sex an individual might lie about his or her level of commitment (Haselton et al., 2005). Typical theoretical perspectives for highlighting this notion of conflict-of-interest models include sexual conflict theory (Goetz & Shackelford, 2009). In contrast, by using confluence-of-interest models, an individual achieves a positive outcome by shifting the structure of a situation to create benefits for his or her partner, thus creating more corresponding interests (Finkel et al., 2013). An example of this could be when engaged in a conflict with the partner, the other person reappraises the conflict so that the outcome is not zero sum, but the conflict is rather solved together to mutual satisfaction. The theory of thriving through relationships (Feeney & Collins, 2014) is an example of a theoretical perspective associated with confluence-of-interest models.

These two broader families of models – conflict-of-interest and confluence-of-interest – are combined on one spectrum or continuum in the Conflict–Confluence Continuum Model (Durante et al., 2016). This latter model highlights how the two processes from each psychological perspective can co-exist simultaneously to varying degrees (for an illustration, see Figure 2). In other words, in order to create an equilibrium of the two, conflict and confluence, circumstances surrounding the relationships become important.
Figure 2. Conflict–Confluence Continuum Model.

Note. Own illustration of the Conflict–Confluence Continuum Model (Durante et al., 2016).
Intimacy and caregiving

At least three central behavioral systems can be invoked to conceptualize adult love: sexuality, caregiving (a mix of empathy and attractiveness), and attachment (Johnson, 2013; Hazan & Shaver, 1987, Mikulincer & Shaver, 2016). These three behavioral systems are all connected. For example, the degree of safety experienced with the partner and the level of ease with closeness translate into different kinds of sexual behaviors and may direct our sexual fantasies (Johnson, 2013). A recent study (Mark et al., 2018) explored how attachment is related to relationships, sexual satisfaction, and sexual desire. In their questionnaire study, which included a sexually diverse sample of 955 individuals, Mark et al. (2018) found that attachment style significantly predicted relationship, sexual satisfaction, and sexual desire. Furthermore, their study (Mark et al., 2018) shows that the satisfaction variables accounted for more of the variance than sexual desire, thus concluding that in their sample, attachment style seems to be a more critical factor for satisfaction than desire. This study is just one example of how the different behavioral systems might function together in intimate relationships (adult love). However, exactly how the caregiving behavioral system is combined with the intimacy (sexuality) behavioral system or attachment system might not be as clear.

Similar to attachment, intimacy has been described as a dynamic process by Reis and Shaver (1988), and it is formulated by their interpersonal process model of intimacy. This process begins when one person discloses personally sensitive information about the self to a partner. The partner’s responses then shape subsequent steps in the process. As with the learning theory of attachment, these steps lead to expectations of the partner’s reaction. For instance, a reply by the partner that is somewhat disapproving, distant, or even rejecting would interfere and discourage with intimacy and terminate the likelihood of an intimate relationship. On the contrary, an encouraging, supportive, and accepting reply facilitates expressing deeper personal concerns and needs, which gradually leads to an intimate relationship. Furthermore, this model underlines that an accepting and responsive partner generates certain positive feelings in the recipient partner, including a feeling of being validated (i.e., feeling that the partner respects and appreciates the speaker), understood (i.e., feeling that the partner accurately understands and perceives what is essential to the speaker), and cared for (i.e., sensing that the
partner is concerned about one’s wellbeing and is responsive to one’s needs). These feelings then strengthen the individual’s confidence in the partner’s good intentions and subsequently boost more intimate interactions (i.e., a positive feedback loop).

Beyond the attachment behavioral system, people possess a caregiving behavioral system influenced by previous experiences of receiving care by caregivers’ at early developmental stages (Mikulincer & Shaver, 2016). As humans, we are born with the ability to develop care and empathy for others, especially when they are in need (Bowlby, 1969). From an evolutionary perspective, the caregiving behavioral system developed to increase human fitness (Hamilton, 1964) for survival and improve reproductive chances by responding to the needs of especially genetic kin, such as close family members. These days, the caregiving system is not thought of as a system exclusively of the smaller tribe or the family but rather is extended to any human being (or other animal) who suffers or is in need and activates the caregiving system. However, people still tend to care more quickly for genetically or psychologically close individuals (George & Solomon, 2008).

Batson (2010) refers to empathic concern as a vital component of the caregiving system’s primary strategy. This empathic concern for another individual’s suffering involves helping by adopting this person’s perspective and, as a result, aids in reducing suffering. Empathic concern or attitude includes two critical aspects, as mentioned in parental caregiving by Ainsworth et al. (1978); responsiveness and sensitivity (Collins et al., 2010). Responsiveness involves validating the troubled person’s feelings and needs, aiding the person to feel understood, loved, and cared for, and lastly, respecting the troubled person’s opinions, values, and attitudes (Reis, 2014). Additionally, sensitivity implies an accurate interpretation of another person’s signs of needs, worry, or distress, enabling an adequate caregiving response to the individual who is seeking support (George & Solomon, 2008).

So, when caregiving works ideally it benefits both the person being cared for and the support provider. The latter, the support provider, may experience an inner sense of what Erikson (1993) refers to as “generativity,” a feeling that one can contribute significantly to other people’s wellbeing and not only act as an isolated self. Other benefits for the support provider are that the conception of generativity often consists of positive feelings about oneself, such as of self-efficacy, having high moral standards and social skills, and feeling connected with others (Penner & Orom, 2010). Thus, the support provider can benefit a great deal from caregiving. The benefits for the recipient of care are needless to say also essential. Beyond protection and survival, receiving care benefits a sense of safety and security, and facilitates problem solving and coping abilities (Collins et al., 2010).
Missing pieces and general aims

To summarize, the previous literature has been limited in terms of exploring how olfaction is linked to intimacy, caregiving, and attachment in adult romantic relationships; in other words, how olfactory functioning and body odors affect behaviors in intimate relationships. Previous studies focused on romantic relationship formation and olfaction have horned in on mate selection processes (for a review, see Williams, 2021) but have lacked an attachment perspective. Other studies have focused on biological markers of attraction, including olfaction, but these have also neglected relationship quality variables such as intimacy, caregiving, and attachment (for a review, see Havlíček, 2020). In addition, meta-analyses have summarized well-being and satisfaction in romantic relationships from an attachment perspective (e.g., Li and Chan, 2012) but without giving any attention to sensory input or feedback in general, let alone olfaction in particular. A recent review has noted similar missing pieces in the literature concerning body odors and olfactory ability in different stages of romantic relationship formation and development (Mahmut & Croy, 2019).

So, with this thesis, I aim to address these missing pieces in the previous literature. The general goal of this thesis is to cross-fertilize these two fields of research, intimate relationships and olfaction. More specifically, this thesis aims to investigate and extend our knowledge of how olfaction is linked to interpersonal behavior and intimate relationships by means of its three studies. By using testing paradigms from adult attachment studies and theories regarding relationship psychology, the three individual studies report on different facets of how olfaction affects interpersonal behaviors and intimate relationships.

The aim of study I was to test whether the body odor of a romantic partner alters psychophysiological stress and subjective discomfort and whether such effects are moderated by adult attachment security. Study II aimed to explore whether self-reported olfactory function is related to sexual well-being and infidelity. Study III aimed to provide a narrative review of previous studies having addressed the role of olfaction in intimate relationships with a focus on individuals suffering from impaired olfaction. In conclusion, this thesis aims to investigate and establish how body odors and olfactory functioning affect interpersonal behaviors and intimate relationships.
Overview of studies

Study I – The scent of security


Aims and background

The presence of a romantic partner has an effect on stress regulation. Recent research by Hofer et al. (2018) shows that women’s stress responses in a social lab test were attenuated by olfactory cues from their partners. Other previous studies have shown that stress-regulating effects differ depending on individual differences in attachment security. For example, relatively secure individuals, as measured by heart rate and blood pressure, exhibit a lower level of physiological stress responses when their partner is present in comparison to insecure individuals (Carpenter & Kirkpatrick, 1996). Endocrinological and brain activation studies show similar stress regulating, attachment-dependent effects (Diamond & Fagundes, 2010).

*Study I* aimed to determine whether the body odor of one’s romantic relationship partner (i.e., adult attachment figure) – compared to control odors – results in a reduction in stress response to an aversive stimulus. The aim of this study was also to address whether this presumed stress regulating effect is manifested in both subjective measures of discomfort and in more objective measures of psychophysiological processes. Finally, we aimed to determine whether these presumed effects are moderated by attachment security, the idea being that relatively secure individuals benefit more from exposure to their partner’s odor during stress.
Method

The study took place in Sweden and included 34 young, non-smoking female participants (M = 23.31 years old, SD = 3.08). All participants were screened for any medical condition that would make the mild electrical shocks inappropriate. The participants were also screened for a number of conditions that could impair their sense of smell or known conditions that could compromise body odor composition. On the day of the experiment, the participants were tested for functional anosmia using a 5-item, four-response-alternative odor identification test, based on the clinical test Sniffin’ Sticks (Hummel et al., 1997), and they needed to identify 3 out of 5 correct odors. Another inclusion criterion to participate was to be involved in a current, heterosexual, and monogamous relationship for at least 4 months (M = 39.89 months, SD = 29.55 months).

Four different odor stimuli in the form of cotton t-shirts were used – partner, self, rose, and neutral. The neutral odor was a clean t-shirt washed in a non-scented laundry detergent. The rose odor consisted of three drops of a 40% solution of phenethyl alcohol in odorless propylene glycol that were added to a similar t-shirt having been washed in a non-scented laundry detergent. Each participant received written instructions on how to treat the t-shirt that would later in the experimental setting work as the partner and self scent conditions. The t-shirt was worn for three consecutive nights, and the participants were instructed not to use deodorant, antiperspirant, or any new scented hygiene products. Participants also slept in different beds or on different sides of the bed, avoided physical contact with their partners, and used beddings as usual. During daytime, they kept the t-shirt under their pillow, and on the day of the lab experiment, the t-shirt was transported to the lab in sealable plastic odorless bags. The participants also refrained from eating spicy food known to alter body odors. On the test day, the participants did not consume caffeinated drinks or any food within 2 hours prior to their lab visits.

To assess individual differences in attachment security, the 36-item Experiences in Close Relationship Scale (Brennan et al., 1998) was utilized. A one-dimensional insecurity scale was created with an overall high internal consistency (α = 0.93). The participants completed the ECR through an online survey platform before their scheduled lab visit.

As a stress stimulus, mild electrical shocks were delivered by stimulating the phalanx of the index finger of the participants’ dominant hand using two Ag/Ag electrodes connected to a stimulus isolator (PowerLab Stimulus Isolator, ADInstrument, Colorado). The shock level was adjusted individually to correspond to “uncomfortable but not painful” (5) on a visual analog scale, ranging from “no discomfort” (1) to “extremely painful” (10). Starting at 0 mA, the intensity was increased by increments of 0.1 mA until the individual
discomfort threshold was reached. Shock levels rated as a 5 among the participants ranged from 0.3 to 4.1 mA (M = 1.2, SD = 0.77). Skin conductance (SC) was measured continuously through Ag/Ag electrodes. The mean high-pass filtered (0.05 Hz) SC in microsiemens (µS) of the 20 seconds preceding each odor condition was used as a baseline, and a mean baseline-corrected SC was subsequently calculated for each 20-second interval within each odor condition. The subjective discomfort ratings were reported 6 times using a 10-point scale ranging from relaxed (1) to extremely uncomfortable (10). All participants reported this verbally to the experimenter. The discomfort ratings were highly internally consistent across odor conditions (range of αs = 0.93–0.94).

A mixed factorial design was used. First, the odor condition was a within-subject, experimentally manipulated independent variable. This variable had four levels: attachment figure’s/partner’s odor, self odor, neutral odor, and rose odor. Second, adult attachment insecurity was a between-subjects, individual difference predictor variable. The dependent variables were subjective discomfort and skin conductance responses to the electric shocks. A linear multilevel model (LMM; Bates et al., 2014) using a Bayesian approach through the package brms (Bürkner, 2016) was used together with the statistical software R (R Core Team, 2013). All continuous variables were standardized prior to the data analysis. The prior distributions for the coefficients were set as normal distributions centered on zero, with standard deviations of 0.5, so that 95% of prior beliefs are placed on coefficients ranging between −1 and +1. Model selection was performed using the differences in the Watanabe-Akaike Information Criterion (ΔWAIC, Watanabe, 2010) across models. 10,000 samples were generated from a normal distribution with the ΔWAIC as a mean and its standard error as sigma and checked if > 5% of the generated sample was in the opposite direction, as recommended by McElreath (2016). This simulated false positive rate serves as a threshold criterion when two models have a similar WAIC. When false positive error rates exceeded 5%, a more parsimonious model was chosen. The model started with a full model comparison with the maximum fixed effect structure and the maximum random effect structure implied by the design, as suggested by Barr (2013). The full fixed effects model consisted of the triple interaction between individual scores in insecurity, odor condition, and time window (shock vs. relaxation) along with the respective lower-order (2-way) interactions and main effects. The maximum random structure consisted of: 1) random intercepts for participants, 2) intercepts of odor condition nested within participants, 3) random slopes for the time window effect in each participant, 4) random slopes for the time odor condition effect in each participant, and 5) random slopes for the interaction between time window and odor condition in each participant.
Results and discussion

The WAIC model comparison used to investigate if the odor of a romantic partner worked in terms of reducing subjective discomfort during stress and if such effects were moderated by attachment insecurity identified a model that only included the effect of odor condition. Hence, there was no main effect or moderation by attachment security-insecurity. There was strong evidence that the partner odor condition differed from the self odor ($BF_{10} = 55$). There was no evidence that the partner odor differed from the neutral odor or the rose odor. In sum, the results showed that body odor from one’s partner reduces subjective discomfort during a stressful event in comparison with the odor of oneself.

Regarding physiological stress responses, a WAIC-based model suggested that the interaction between insecurity and odor condition played a key role in explaining participants’ SC responses (Figure 3). More specifically, insecurity and SC were positively related, specifically in the partner odor condition. Highly secure participants exhibited attenuated SC during stress when smelling their partner’s odor in comparison to highly insecure participants. The relationship between insecurity and SC was reversed but non-significant in the other three conditions. Furthermore, the slope for the partner odor condition differed from the slopes of all other conditions averaged together ($BF_{10} = 4.89$). The partner odor condition vs. each of the single slopes provided anecdotal evidence ($BF$s ranging from 1.19 to 2.64). Moreover, anecdotal evidence was also found that the slopes of the other conditions did not differ from each other ($BF_{01} > 2.55$).
Figure 3. Effects of odors during a mildly stressful event.

Note. Across the four odor conditions, individual baseline-corrected skin conductance (SC) responses correlated with insecurity values. The black bars at the lower end of each graph indicate individual data points contributing to the regression line. Blue lines indicate the regression lines and shaded blue areas indicate 95% credibility intervals.

From an attachment learning perspective, these results consisting of physiological responses go well with attachment-related responses being learned, meaning that relatively secure individuals expect relief and comfort from the presence of the attachment figure. As shown in this study, the attachment figure’s presence can occur in its simplest form and just contain his or her body odor. These results are not only in line with olfactory findings in human babies showing the comforting scent of maternal odor but also with findings on adults indicating that a romantic partner psychologically serves as a caregiver and target of attachment. More specifically, the partner’s body odor functions as a calming signal for the attachment behavioral system (as moderated by IWMs) presumably because the partner’s role as a caregiver is associated with proximity seeking and stress relief.

Lastly, high attachment-related insecurity, presumably avoidance in particular, could also imply that the scent of oneself, the self odor condition, could function as the soothing scent and lower one’s stress responses. This
might relate to evolved learned insecure attachment strategies for coping with stress and regulating emotions based on withdrawal and self-soothing rather than proximity-seeking behaviors aimed at the attachment figure.

**Conclusion**

This study demonstrates that as a sensory modality, olfaction is related to the attachment system’s sensory processing. Furthermore, this study concludes and expands upon previous child-caregiver studies that the body odor of the attachment figure (i.e., romantic partner) represents an effective scent of security also in adulthood, and especially so for relatively secure adults.
Study II – The scent of monogamy


Aims and background

*Study I* concluded that the body odor of a romantic partner could affect subjective experiences and physiology, in particular for relatively attachment-secure individuals. Additionally, a recent study has reported that sexual communication is moderated by olfactory cues (Lübke & Pause, 2015). This is highlighted in studies on populations with a compromised sense of smell. For example, people with a weaker sense of smell report fewer social interactions (Boesveldt et al., 2017a), lower sexual satisfaction (Ottaviano et al., 2013), and a decrease in sexual desire after olfactory loss (Schäfer et al., 2019). Thus, both olfactory ability and specific body odors relate to intimate relationships and sexual behaviors.

However, something missing in the literature is studies exploring how olfactory functioning might be related to sexual well-being and infidelity. Mahmut and Croy (2019) highlight this gap in the literature in their recent review summarizing the literature on romantic relationships and body odors. Consequently, there is a call for research exploring if and how olfaction relates to infidelity.

Here, in *study II*, individual differences in olfactory functioning were investigated in relation to various relationship outcomes. More specifically, *study II* exploratively investigates how olfaction and sexual behaviors are related. Various measurements of disgust sensitivity were also collected. Of particular interest for this thesis was to explore whether olfactory functioning could predict sexual well-being and infidelity.

Method

The study took place in Italy, where participants completed a self-paced survey. Using a cross-sectional design, this study included various questions asked to a large adult sample mainly living in southern Italy. The participants (N = 1,107, female = 646) voluntarily completed the online survey, which was written in Italian. Of particular interest for later analysis, the majority of the sample reported to be in a relationship (n = 786, 71%), and of those, many reported not to be cheating (n = 684, 90%). The study design and procedure took the form of a typical survey design; first, the participants answered
various demographic variables, such as age and gender, followed by questions concerning olfactory function, sexual well-being, and infidelity.

To assess self-reported olfactory function, the following question was used: “How do you rate your olfactory capacities?” where the participants needed to answer by choosing one of the five alternatives ranging from “Absent” to “Excellent.”

General sexual pleasure, arousal, and desire (frequency/interest) were measured using selected questions retrieved from the Changes in Sexual Functioning Questionnaire short form (CSFQ-14; Keller et al., 2006). For sexual function, four items were used from the International Index for Erectile Function (IIEF-15; Rosen et al., 1997) questionnaire regarding intercourse frequency. In addition, the sexual desire and pleasure items from the Female Sexual Functioning Index (FSFI; Rosen et al., 2000) were utilized. Both the IIEF and FSFI items were rephrased to be gender-neutral. The revised Sociosexual Orientation Inventory (SOI-R; Penke et al., 2008) was used to measure individual differences in the tendency to engage in casual sexual relationships. Also, SOI-R (a 9-item self-report test) was used to assess three facets of sociosexual orientation: behavior, attitude, and desire (Izzo et al., 2020). Finally, one question was included regarding infidelity: “Are you having affairs/extramarital affairs?” The response alternatives were “Yes, I am having affairs/extramarital affairs,” “No, I am not having affairs/extramarital affairs,” or “I do not have any relationship.” It is important to note that this question involves all relationships, not exclusively marriage, and includes all types of affairs.

For the disgust items, the Body Odor Disgust Scale (BODS) (Liuzza et al., 2017) and Three Domains of Disgust (TDDS) (Tybur et al., 2009) were used. For both these tests, higher scores denote higher levels of disgust sensitivity.

A factor analysis was used for data reduction purposes. This factorial analysis was conducted with the maximum likelihood estimation method and the principal axis method with oblimin rotation. The final analysis suggested a 4-factor solution, which produces a parsimonious solution and supports theoretical expectations. The four factors were pathogen disgust sensitivity, comprising the items of the pathogen subscale of the TDDS and the items from BODS. Sociosexuality was another factor that negatively comprised the items in the sexual subscale of the TDDS and positively comprised SOI items. Sexual well-being was the third factor and comprised items related to sexual well-being in the last four weeks. Lastly, the fourth factor was moral disgust sensitivity, which comprised the moral subscale items of the TDDS. The subsequent analyses were conducted with these four factorial scores. This factor analysis solution explained 38% of the variance.
Results and discussion

In general, participants reported having an average good sense of smell ($M = 3.89$, $SD = 0.97$, $Min = 0$, $Max = 5$). There was a significant difference in self-reported olfactory function between the individuals in a committed relationship ($M = 3.93$, $SD = 0.97$) and singles ($M = 3.76$, $SD = 0.95$), $t(606) = -2.67$, $p = .008$, $d = -18$). This effect remained significant even when controlling for all the sociodemographic factors that could affect smell ($p = .001$). There was no significant difference in olfactory function between women ($M = 3.91$, $SD = 0.96$) and men ($M = 3.83$, $SD = 0.99$), $t(971) = 1.7$, $p = .09$, $d = -0.1$. This latter result contrasts with earlier findings showing that women outperform men in olfactory function tests (especially sensitivity) and, consequently, exhibit higher disgust levels (Sorokowski et al., 2019). In addition, previous findings have shown that compared with men, women are more sensitive to odors in the context of sexual responses (Alves-Oliveira et al., 2018).

The effect of self-reported olfactory function on sexual well-being was significant even when controlling for other potentially confounding demographic factors ($B = 0.07$, $SE = 0.03$, $t(968) = 2.22$, $p = .02$). In addition, five different explanation models were created to evaluate how robustly the different factors accounted for sexual well-being. These five models included (1) the main effect of olfaction, (2) the main effect of moral disgust sensitivity, (3) the effect of moral disgust sensitivity + olfaction, (4) the effect of moral disgust sensitivity + pathogen disgust sensitivity, and, lastly, (5) the main effect of olfaction + moral disgust sensitivity + pathogen disgust sensitivity, all included demographic variables (age, gender, education level, and living area). The prediction accuracy of the different models could be estimated using the Akaike Information Criterion (AIC, Akaike, 1974). The best fit model includes all parameters: (5) olfaction + moral disgust sensitivity + pathogen disgust sensitivity and the sociodemographic variables.

The analysis of the infidelity variable was only conducted with participants reporting that they were currently in a relationship. The results indicated that self-reported good olfactory function significantly reduces the likelihood of having an extramarital affair ($OR: 0.78$, $z = -2.12$, $p = .03$). The likelihood of having an extramarital relationship significantly increased as a function of sociosexuality ($OR: 2.71$, $z = 5.26$, $p < .001$). However, sociosexuality was not significantly predicted by self-reported olfactory function when controlling for sociodemographic variables ($B = -0.02$, $SE = 0.03$, $p = .49$). Due to these results, self-reported olfactory function and infidelity could not be hypothesized to be mediated by sociosexuality.

Self-reported olfactory functioning significantly predicted sexual well-being. Combining these results with the attachment findings from study I, the
partner’s odor may not just be a security scent but also a monogamy scent – a scent of the one and only romantic partner. Thus, the partner’s scent, which individuals with good olfactory functioning should be able to detect and distinguish, could perhaps be a cue for the entire relationship for people in a secure and stable relationship. In other words, the partner’s scent could become stored as part of the individual’s internal working models (IWMs) relating to all sorts of expectations and behavioral systems, including caregiving, attachment, and, as this study shows, the sexual behavioral system. However, this study examined self-reported olfactory functioning, the general ability to smell, related to sexual well-being, which means that the interpretation of the partner’s body odor playing a specific and key role remains inferential.

The results concerning infidelity showed that a self-reported good olfactory function significantly decreases the likelihood of cheating. A similar recent finding concerning infidelity showed that higher levels of self-reported relationship sanctification (i.e., the concept that the relationship itself is sacred) were associated with a lower likelihood of emotional and physical cheating (McAllister et al., 2020). Altogether, this suggests that the way of living, behaving, and treating others, especially in close interpersonal relationships, is linked to personal constructs, expectations, and cognition (i.e., IWMs).

**Conclusion**

This study was exploratory, which is why the observed results cannot support any particular a priori hypothesis. However, the findings can be related to at least one claim: that olfaction function is related to our behaviors in intimate relationships, such as infidelity and sexual well-being. Just as the review by Mahmut and Croy (2019) concludes – that body odors are important for sexual satisfaction and interpersonal well-being – this study concludes that self-reported olfactory functioning is important for intimate interpersonal behaviors.
Study III – Olfactory impairments and romantic relationships


Aims and background

Previous relevant reviews in the field of olfactory functioning summarize olfaction across development (Schaal et al., 2020), examine social olfactory communication of emotion (de Groot & Smeets, 2017; Lübke & Pause, 2015), review causes and consequences of olfactory dysfunction (Schäfer et al., 2021), discuss functions of the human olfactory system (Stevenson, 2010; Hofer et al., 2020), evaluate clinical implication of anosmia (Boesveldt et al., 2017b), and explore the role of scent in romantic relationships (Mahmut & Croy, 2019). However, to the best of my knowledge, there is no recent literature review focusing on the question of how olfactory impairment impacts close social relationships. This latter question was the topic and aim of this review.

Method

As a narrative literature review, this study highlights the importance of olfaction in close social relationships. By dividing the findings from the literature searches into sections and themes as well as by relationship types, the review yields separate sections for family relationships, friendships, and romantic relationships. The research articles included were found by using search terms such as: “olfactory impairment,” “friendships,” “romantic,” “family,” “smell disorders,” “anosmia,” “social relationships,” “relationships,” and “olfaction.” These terms were searched in various combinations using the search engines Google Scholar and Web of Science. Under each section (i.e., family, friendship, romantic relationship), subheadings were used to facilitate readability and answer the overall research question of how olfactory impairment impacts close social relationships.

Results and discussion

The findings indicate that olfactory impairments affect romantic relationships. More specifically, olfactory impairments are hypothesized to affect individuals in a romantic relationship via two main routes. The first route is a direct link and concerns a disruption in one’s own willingness to interact with
others. The second route is more indirect and involves worrying about other people’s interest to interact. Via these two routes, this study highlights several impacted areas, such as eating behavior, sexual behavior (both initiation of sexual relationships and in more established romantic relationships), and social functioning/support.

To mention a few examples, in a Swedish adult sample of patients with anosmia or hyposmia, over half of the sample reported that they asked their spouse or other family members to taste food that they suspected to be spoiled (Nordin et al., 2011). This could be considered a direct effect of the olfactory impairment: not enjoying food or being insecure regarding tastes and nutrition values based on flavor and odors. Additionally, this example indicates an indirect effect of the need for support. It is suggested in the review that the caregiving system of the partner may be involved, which could later be beneficial in forming a solid romantic relationship with intimacy and openness to needs.

Another example from the theme of sexual behaviors was a German study that found that participants scoring higher on an olfactory threshold test, thus having a higher olfactory sensitivity, reported a higher level of pleasure from sexual activities (Bendas et al., 2018). This reported relationship between pleasure from sexual activities and olfactory sensitivity highlights that olfaction matters for sexual behaviors. In more depth, the study also found specific sex effects, where women reporting high olfactory sensitivity also reported a higher frequency of orgasms during intercourse (Bendas et al., 2018). Direct effects in this example would be less pleasure from sexual activities following an olfactory impairment. A possible indirect effect could be the reported frequency of orgasms, which could reflect the interplay between partners. This example could also be understood based on the Conflict–Confluence Continuum Model (Durante et al., 2016), explained earlier in this thesis, offering room for other circumstances to explain behaviors in romantic relationships, such as one’s perception of partner communication however implicit the olfactory cues of the communication might appear.

Lastly, in the social functioning/support section, one reported study found that women with anosmia experience reduced partnership security (Croy et al., 2013). This insecurity effect due to olfactory impairment is presumably a direct effect illustrating that olfactory impairment might undermine women’s confidence in their long-term romantic partnerships. An indirect effect of this reported finding may be unstable intimate relationships where caregiving, attachment, and intimacy functions may suffer due to detection errors vis-à-vis the partner’s body odor cues and other perceptual information or the perceived feeling of missing such important forms of communication. As suggested in several different models and frameworks within romantic
relationships, such as the caregiving behavioral system and the interpersonal process model of intimacy (Reis & Shaver 1988), both partners must communicate and disclose needs in order to achieve a mutually satisfying pair bond in which both partners feel validated and understood. Such disclosure might partly be missing due to an impaired sense of smell and lead to a less stable, more insecure intimate romantic relationship.

The review ends with several essential aspects for understanding the reported findings both theoretically and practically. First, many compensatory mechanisms are seemingly at play here, thus implying that olfaction is an important part of romantic relationships but hopefully not everything. For instance, intimate moments with a romantic partner are a combination of several senses. Second, and related to the compensatory senses, being aware of one’s olfactory ability seems to be crucial for these effects. This implies that if an individual with an impaired sense of smell is unaware of his or her olfactory impairment, the ensuing effects on close romantic relationships may be less noticeable.

On the other hand, subtler processes – for instance, physiological processes, such as social support through olfactory cues – may be missing regardless of whether or not the individual is aware of his/her olfactory impairment. However, whether that missing cue of caregiving or attachment is of value to the individual suffering from the olfactory impairment remains somewhat unclear. For instance, a recent study examined a group of participants, all of whom believed they had no olfactory impairment, even though some of them did (Oleszkiewicz et al., 2020). Furthermore, when compared to a group with no impairment, differences in well-being outcome measures were not evident (Oleszkiewicz et al., 2020). This study suggests that some of the deficits experienced by people with olfactory loss may be psychological. Lastly, this review highlights new ways of conducting olfactory research with inspiration from social psychology testing paradigms and approaches.

**Conclusion**

In conclusion, this literature review indicated that human olfactory impairments could interfere with close social relationship functioning. As explained in the results section, two main routes of how olfactory impairments affect romantic relationship functioning were found: a direct route concerning one’s own willingness to interact with others and an indirect route including worrying about other people’s interest to interact. The study concludes that olfactory impairments do impact close social relationships.
General discussion

The first study investigated how and to what degree body odors of a significant other can change both subjective discomfort and objective physiological responses of relief and comfort. It confirmed the effect of comfort smelling (McBurney, 2006; Shoup et al., 2008) and added that especially for more attachment-secure individuals, this comforting effect of partner body odors holds for both the subjective (or explicit) and objective (or implicit) measures. The second study shifted the focus to explore how olfactory functioning could be related to interpersonal aspects of intimate relationships, sexual well-being measures, and infidelity. The findings indicated that higher olfactory functioning was related to less infidelity and more sexual well-being. The third and last study, a literature review, aimed to answer how the sense of smell impacts intimate romantic relationships. By summarizing research literature on clinical groups with an impaired or absent sense of smell, the findings revealed that olfaction ability is related to various behaviors in intimate relationships.

Below, the findings presented in this dissertation are discussed vis-a-vis previous findings in the literature. This is followed by a discussion on methodological considerations and limitations. Finally, I propose ideas and directions for future research.

The importance of body odors

This thesis suggests that behavioral associations with the body odors of attachment figures exist (study I). Recent studies have similarly indicated calming or relief effects of a partner’s body odor (Hofer et al., 2018; McBurney et al., 2006; 2012; Shoup et al., 2008). Such relief effects (cf. safe haven in the attachment literature) from sniffing the partner’s body odor or garments containing the body odor are presumably based on an individual’s prior emotional experiences, discussed in the attachment literature as the foundation for the individual’s internal working model (IWM). Similar ideas regarding the importance of the individual’s prior experiences to gain particular body odor effects have been formulated by others albeit not with an applied attachment perspective or learning theory of attachment in mind.
In more detail, the body odor of the attachment figure could be viewed as an extension of the attachment figure (CS). It could accordingly provide comfort and support (UCSsupport) and result in a sense of relief (UCRpos). This suggests that the body odor of an attachment figure, an intimate partner, could also imply a sense of relief (CR) when a person is distressed (see Figure 4 panel B for details). Presumably, such an effect is seen in study I of this thesis, where participants on average experienced an attenuation in self-reported stress in the partner body odor condition. Also, in study I, we saw an attenuated physiological stress reaction from smelling the partner’s body odor, specifically among individuals scoring higher on attachment security. The learning theory of attachment (Bosmans et al., 2020) can be applied to illustrate why such a physiological effect may differ depending on attachment security and associated individual differences in IWMs.

**Figure 4.** Learning theory of attachment.

![Learning theory of attachment diagram](image)

*Note. In panel A, the learning theory of attachment is illustrated with regard to the classical conditioning paradigm. In panel B, the learning theory of attachment (Bosmans et al., 2020) is applied to this thesis and the hypothesis that the body odor of the attachment figure could serve as a CS.*

As highlighted by the learning theory of attachment, the body odor from the attachment figure results in expectations of safety responses such as a sense of comfort and relief, as well as perhaps a sense of belonging or being cared for. However, these expectations and effects depend on the frequency of exposure and the number of training trials. As an example, the small infant who has experienced body odor cues within the mother’s uterus (i.e., exposed to several learning trials) might then have developed a preparedness towards the same body odor from the mother once outside the womb. In other words, the small infant has learned that the body odor of the mother is a safe haven or cue for safety. Furthermore, in relation to the growing evidence of the importance of maternal odor with regard to the perception of faces in...
newborns (Leleu et al., 2020; Rekow et al., 2020), this thesis also highlights that it is the particular attachment figure’s body odor, such as the intimate partner, that can impact behaviors and indirectly the entire intimate relationship. As previous studies emphasize, individuals learn all sorts of information about their near family members, such as partners, parents, and friends, by using body odors (Hofer et al., 2020; Olsson et al., 2006; Mallet & Schaal, 1998; Cecchetto et al., 2020). However, this gathering of information should be viewed as part of a larger learning process, which would then entail that the effect of the attachment figure’s body odor as calming would depend on the number of learning trials.

Corresponding to the learning theory of attachment and associative learning, body odors are proposed to be especially powerful learning stimuli in intimate relationships. It could be because odors generally have a more or less direct pathway into the emotional brain, or it may be related to a cognitive memory component, similar to IWMs, that helps in making body odors special. Either way, as shown in this thesis, body odors are related to behaviors in intimate relationships.

Cultural aspects of olfactory perception

The development of the olfactory system has been suggested to be influenced by both cultural and biological inputs (Olofsson & Wilson, 2018). Different odors play a significant role in everyday life depending on the ecological and cultural spots in which they are placed. Typically, people have a slight discernible body odor in Western societies due to frequent bathing and showering. This focus on hygiene is argued to be a result of the moralization of cleanliness in Western society (Soo & Stevenson, 2007). Meanwhile, bathing and showering occur less frequently in other societies, often resulting in less masking of body odors or in even more masking with soaps, perfumes, and other products. This will have effects on olfactory perception in general and in particular when it comes to body odor perception. For example, studies with English speakers show that only a few words exist for odors, and naming odors is difficult (Majid, 2021). More specifically, one study comparing speakers of Jahai on the Malay Peninsula with an English-speaking group revealed that for the former, naming odors as colors was relatively easy (Majid & Burenhult, 2014). A similar study with Jahai and Dutch speakers showed that although the two different groups used different linguistic categorizations, Jahai speakers used a more abstract vocabulary. However, the facial expressions and initial emotional reactions to the odors were similar (Majid et al., 2018). So, culture does play a part in the possible role of odors in everyday life, perhaps through language; however, people’s emotional reactions to odors may nonetheless be applied across cultures.
In this thesis, the effects of the broader cultural context, as in cross-cultural studies, were not considered in any of the three studies. Therefore, the role of culture for the findings obtained remains unknown. An interesting approach that has yet to be adopted is a more phenomenological approach to how body odors of attachment figures are sensed in different ecological and cultural contexts. Such a study could provide an exciting extension of the findings of study I by addressing what a partner’s body odor subjectively signals and represents in terms of interpersonal functioning and values in combination with the influence of norms and culture.

Processing of olfactory information

In study I, two different measures were collected. The two measures, subjective discomfort ratings and the amount of sweat measured by skin conductance (SC), might not tap into the same process. The effects of a partner’s body odor differed somewhat with regard to the two measures. Finding these types of discrepancies between SC and self-report is rather common in the conditioning learning literature (for example, see Landkroon et al., 2019). The physiological measure of SC is naturally more implicit and self-reported subjective discomfort ratings are more explicit. Again, partner body odor had a key effect in terms of attenuating subjective discomfort (explicit processing) but an interactive effect together with attachment security in terms of attenuating SC (implicit processing). I interpret these results that the implicit physiological measure of SC is trickier, if not impossible, to fake. Hence, this measure should yield higher validity in some important ways; for example, by being more objective and getting “under the skin” of participants. Meanwhile, the subjective discomfort measures might not have been particularly well-hidden in our design, thus making the participants more conscious and subjectively influenced by the different odor conditions. This could have been tested by asking the participants if they knew what they were smelling after the experiment. However, such tests were not performed. Thus, the question remains whether the olfactory information was processed consciously with regard to source, which cannot be answered by study I.

The findings of study II relate to the issue of the receiver’s conscious processing of the olfactory messages. Specifically, a higher self-reported olfactory function was related to increased sexual well-being and less cheating. Thus, conscious processes are integral to self-reported olfactory functioning. The Conflict–Confluence Continuum Model (Durante et al., 2016) highlights how the two kinds of processes suggested in evolutionary and relationship science can, to varying degrees, co-exist simultaneously. In
other words, the circumstances of the relationships become essential for creating an equilibrium of the two: conflict and confluence. These circumstances can presumably be consciously or unconsciously processed by the individual. I suggest that circumstances contributing to the equilibrium include, perceptual abilities such as olfactory functioning. Figure 5 illustrates the Conflict–Confluence Continuum Model (panel A) and how it may apply to the infidelity and sexual well-being measures used in study II (panel B) in this thesis.

**Figure 5.** Conflict–Confluence Continuum Model illustrated with results of study II.

A)

- Relationship stability irrelevant to fitness.
- Relative frequent dissolution as outcomes.

B)

- Relationship stability strongly promotes fitness.
- Normative relationship quality outcomes.

Note. Illustration of the Conflict–Confluence Continuum Model (Durante et al., 2016) in panel A. In panel B, the specific results with the association between olfactory functioning and infidelity/sexual well-being in study II are mapped next to the Conflict–Confluence Continuum Model. This illustrates that as a result of this co-existence of two selection pressures or drives, other relationship circumstances can play a crucial role for behaviors in romantic relationships and create an equilibrium.

Additionally, scholars within the fascinating research field of chemosensory communication, where various information such as emotional states are thought to be communicated through olfactory cues, might interpret these results differently. For instance, the meta-analysis carried out by de Groot and Smeets (2017) shows that human body odor of fear affects others. I suggest that when scent cues are subtler and emotions more refined and perhaps mixed (e.g., in the case of shame when cheating), olfactory functioning may be more important than first assumed. Perhaps it is these more refined and mixed emotions that are more ecologically solid, as humans interact with each other using a variety of emotions, that entail communication within intimate relationships. For example, the relationship science framework stresses that
one partner must notice the other partner’s needs to act appropriately with regard to caregiving and intimacy. Accordingly, the sensitivity and responsiveness part of empathic attitudes in a caregiving relationship (Collins et al., 2010) concerns precisely that sort of response and act of being conscious of a partner’s needs. I propose that the same could be evident for olfactory communication. Thus, noticing various emotions and needs of the partner, in whatever mixed form, includes a whole range of perceptual functions, including olfaction. Although this is not supported in the results of this thesis per se, it would be interesting to explore this idea in future experiments, expanding the knowledge of chemosensory communication through olfaction in intimate relationships. This could also contribute to answering the lingering question of unconsciously vs conscious processing of olfactory information.

Social buffer, safe haven, or morality checker?

As IWMs develop through emotional involvement in attachment-related events (Cassidy & Shaver, 2008), it is not far-fetched to think that such emotional involvement could be triggered by the body odor of one’s partner. As previous olfactory findings point out, studies have shown that odor priming in general can activate various emotional arousals, and evoke specific memories (Smeets & Dijksterhuis, 2014), and that specific body odors can signal comfort (McBurney et al., 2006; Shoup et al., 2008). The questions explored in this thesis naturally lead to the question of which limits exist in terms of what body odors can signal.

To maintain a healthy intimate relationship bond, the interpersonal process model of intimacy suggests that feelings of being understood, validated, and cared for are key (Reis & Shaver, 1988). In this thesis, different ways of boosting these three feelings have been suggested, related to olfactory abilities and body odors of the romantic partner. In study I, the body odor of the partner was found to signal the safe function of attachment, altering the individual’s stress levels. What remains uncertain is whether the body odor of the partner can also serve as a social buffer for upcoming, known stressors, which thus makes it a question of storing the presumed stress-altering effect. In the animal literature, those types of social buffering effects are reported, both behaviorally and neurologically, with mother-offspring populations (Opendak et al., 2020). Furthermore, in study III, certain reviewed studies suggested that social buffering effects could indirectly occur in humans as well. Another suggestion, gained through a learning theory of attachment, is that through conditioned, extensively repeated exposure to the odor of the partner paired with safety responses, not only will safe haven and stress altering in direct
moments of stress occur, but this can also build a buffer of social responses to various forms of future and unknown threats.

Moreover, an inference from the results of study II in this thesis is that the body odor of the intimate partner might have ramifications for relationship attributes, such as morality and monogamy. This is admittedly a speculative inference from the results that self-reported olfactory function correlated with infidelity measures. The partner’s body odor, for those able to detect it, could signal a stable intimate relationship, with ensuing feelings of being validated and with an expectancy of monogamy and relationship security. An individual who is less able to detect the partner’s body odor, on the other hand, might have fewer such feelings and expectations.
Methodological considerations

In this thesis, I explore the relationship between olfaction and intimate relations by using various methods. The three studies included in this thesis are based on existing testing paradigms used in previous research, and they combine qualitative and quantitative methods. No study is perfect, and choices have been made, ending up with the designs in the three studies. In this section, I highlight some of these choices and discuss different alternative design approaches.

Using several different methods is always recommended and regarded as a “strong” design in several areas of psychology when it comes to investigating complex mechanisms. However, the pros and cons of different approaches or methods used for gathering information concerning one particular phenomenon are debatable. Study I, comprising an experimental design and a smaller sample size, highlighted certain aspects of how olfaction impacts intimate relationships. Using a cross-sectional design with correlational results and a larger sample, study II addressed how olfaction is linked to intimate relationship attributes. Nevertheless, it might be study III in this thesis, comprising a narrative review of studies addressing olfactory loss, that most expands the general understanding of how olfaction impacts intimate relationships. While each different method and analytical approach has some real advantages, they all, unfortunately, come with some costs as well.

As an example, the choice in study I to conduct the analyses within a Bayesian linear mixed model was motivated by the sensitivity it allows in terms of providing evidence for the absence of an effect (i.e., for the null hypothesis) and also by its insensitivity to prior sampling plans. This is because it is based on continuously updating knowledge without a sampling plan or stopping rule. Meanwhile, in study II, a frequentist approach to the statistical analyses was chosen due to the large sample size and exploratory nature of the study. Nevertheless, the correlational design employed in study II results in non-causality and the practical implications being ambiguous. Such practical implications can be gained through other types of study designs, such as intervention studies, strict lab or field experiments, or longitudinal studies using both physiological and self-reported diary methods. In study III, a variety of studies were gathered and reviewed using different analytical and methodological approaches. Here, a pattern of three major themes was
crystallized to capture how olfactory impairments impact close social relationships, such as intimate relationships.

Self-report and cross-sectional design

Social desirability is the tendency that some participants filling out any type of self-report might misrepresent themselves for the better due to their beliefs of a favorable or “correct” answer in line with social expectations, attitudes, and norms. It is important to be aware of this when conducting any research assuming the validity of self-reports, and this is a notable limitation in study I and study II. This is particularly noted as a limitation for study II, as previous reports have found that self-reported olfactory function measures and objective olfaction measures are often poorly correlated (Landis et al., 2003). On the other hand, in order to gain a large sample size, self-reported olfactory function is still better than no measurements. It is also the current research practice for conducting studies with larger samples. For study I, predicting relevant interpersonal aspects and behavior, self-reports (e.g., regarding attachment) like the questionnaire used have proven to offer a decent estimate (Mikulincer & Shaver, 2016).

Causality is not the same as a correlation. First, in this thesis, the main direction of the associations is that olfaction impacts intimate relationships. However, the opposite direction may be correct as well. As explained in the introduction, interpersonal behaviors are often learned through repeated and frequent learning trials. One could assume, with evidence from studies on smell training improvements after Covid-19 (Kattar et al., 2021; Le Bon et al., 2021), that overall olfactory ability could be trained and improved with the help of a partner or by exposure to more intimate moments (learning events) with the partner. Hence, more diverse experiences when in an intimate relationship could also entail a more diverse exposure to odors. This, in turn, would imply that intimate relationships could impact olfaction in some instances. Second, as causality is not the same as correlation, the results of study I and, in particular, study II should be regarded as potential associations that need further investigations. Under the heading “Future directions,” I describe these further investigations for expanding the findings in this thesis.

Study II used a complete cross-sectional design where the participants completed the questionnaire on a single occasion. The strength of this type of design is the feasibility for participants to be a part of the study, as indicated by the relatively large sample in study II. Furthermore, by having a large sample size, this study gains sufficient power and a more accurate representation of the population (i.e., generalizability). Nevertheless, this limits the study in terms of explaining any association that could imply
causality, where other designs could have offered more insight in terms of uncovering cause-and-effect associations.

*Study I* is designed quite differently from *study II* with an experimental setup comparing different conditions (i.e., odors and body odors). However, the key finding that attachment security matters, in interaction with odor condition, for psychophysiological stress regulation is still correlational, and thus prevents strong causal conclusions.

**Stimulus control**

In olfactory research, as in much other perception research, one has to be aware of the potential costs and benefits of using a particular stimulus. For example, the four different odors included in *study I* were actively chosen. First, the partner odor was clearly important as it was the key experimental condition; all three other odors were chosen as control odors. However, we lacked a familiar person’s body odor as a control condition. This was a necessary omission to succeed with the recruitment to the study. Instead of a familiar person’s odor, we chose the odor of the self as a form of proxy for a social, familiar smell. In hindsight, we could have used a sex-matched stranger’s odor like other studies have done (for example, see Hofer et al., 2018 or McBurney et al., 2012) or used the body odor of a family member who is not an attachment figure (e.g., a younger sibling or similar). However, with the attachment perspective in mind, the strategy often used by certain insecurely attached individuals is to self-soothe in various ways when stressed, thus presenting a good rationale for actually using the odor of the self as a control odor. The third odor was the rose odor as it is known to be an odor with a calming, stress-reducing effect (Fukui et al., 2007). Furthermore, it was also chosen as a control since it is processed differently due to being a monomolecular odor rather than an odor mixture (like body odors) (Boyle et al., 2009). Finally, the neutral odor condition with no scent serves as a good control to make sure that the other t-shirts actually had a smell that was perceived differently than just a clean, neutral t-shirt. However, in hindsight and for future studies, even more control could be performed to make sure that the odor stimuli are comparable. For instance, the procedure of weighing the odor material before and after sweat collection to ascertain the amount of body odor could constitute a more controlled approach. Still, this does not control for either the intensity or the concentration of the body odor stimuli, that is known to vary in the population (Havlíček et al., 2017). Another idea is to use a familiar odor of relationship value, such as a parent’s body odor as a control. By using a “former” or currently less central attachment figure as a comparison, the effects of the romantic partner’s body odor (typically the principal attachment figure in adulthood) could be examined in more detail.
Another concern regarding stimulus control is the point in time chosen to present a certain stimulus. The data collection for study II occurred during the Covid-19 pandemic and as highlighted in the published study, this is a limitation where effects of both self-reported olfactory function and close relationships could be impacted by a third unknown variable of the rather chaotic time of a pandemic crisis in Italy, the location of the data collection. In hindsight, this could have been prevented had the study design been different, with follow-up studies a year or so later. Due to obvious practical reasons, this was not possible for this study. However, the issue of timing does not take away the value of the correlations found, and as certain questions in study II reflected the last four years, this could be a minor consideration. Additionally, the effect sizes are small in study II, but at the same time the larger sample size warrants optimism regarding replicability. Conversely, study I presented greater effects, but the modest sample makes replication critical.

It is important to note that a strength of both study I and study II was the use of well-validated methods, such as established questionnaires that have previously been used to study similar topics. In addition, study I used experimental methodology and an objective measure of skin conductance, acknowledged as a valid marker of psychophysiological emotional reactions in many previous studies (for example, see Christopoulos et al., 2019). Perhaps the most exciting part of this thesis is the combination of experimental, cross-sectional, and narrative review designs used to explore different facets of a complex phenomenon: the relation between olfaction and intimate relationships.
Future directions

Many studies within the olfactory research field address sex differences. In their meta-analysis, Sorokowski et al. (2019) stress that women outperform men in some olfactory measures, like recognizing a smell. In a recent study investigating self-reported olfactory functioning, my colleagues and I (Shell et al., 2021) found similar sex differences. We found that attachment insecurity (both anxiety and avoidance) were linked to a decrease in self-reported olfactory functioning in women (Shell et al., 2021). This type of exploratory gender research may be helpful in increasing understanding of how intimate relationships and olfaction are linked. Future research should investigate sex differences further and explore other potential group differences relating to olfactory abilities and attachment.

While not as quick and feasible, interview studies could be one alternative for future studies in order to expand our knowledge regarding the role of olfaction in intimate relationships. For instance, the well-established Adult Attachment Interview (George et al., 1996) could be a useful alternative, where attachment relationships experienced in the past are explored and measured through a linguistic analysis of coherence by using a semi-structured interview format. As a novel addition to this type of interview technique, olfactory information might work as means for communicating previous caregiving, intimacy, or attachment experiences. By employing such a phenomenological approach, studies could further explore how olfaction and intimate relationships are interrelated.

I also call for longitudinal studies with follow-ups every week (during a year or so) to examine how olfactory perception changes, perhaps due to a disease like Covid-19, and impacts intimate relationships over time. This design could be done if body odor samples are preserved in a freezer as frozen body odor samples have been shown to have no effect on perceived odor hedonicity, even after several months (Lenochova et al., 2008). This longitudinal study design might reveal how olfaction impacts intimate relationships more precisely, which could then better inform intervention study designs and target practical help for individuals suffering from olfactory impairments, including their partners.
As highlighted in this thesis by study III, when the sense of smell and taste is limited due to an illness, temporarily or permanently, the effects might be noticeable in different behaviors and emotional expressions. For example, a relatively new qualitative study (2018) focusing on the experiences of lung cancer patients showed that many of the challenging adjustments they faced in daily life were related to their impaired sense of smell and taste (Belqaid et al., 2018). Furthermore, patients rarely received help from their primary care facility regarding issues related to olfaction but rather tended to enlist the help of close family members to make these adjustments (Belqaid et al., 2018). Once again, the importance of a stable romantic relationship and olfaction is noted. A possible future route for an applied study design to improve life for various patients could be interventions for relatives. In detail, they could be informed and taught to administer olfactory tests and perhaps learn skills to validate and understand the condition of their family member. With the main effect of partner body odor attenuating stress found in study I in mind, another health-related direction could be to design an intervention study on a form of care facility where patients experience stress. Here, the experimental condition could be to add a piece of clothing from their partner as a comforting smell during these stressful events. If the effects of study I were to be replicated in such applied settings (i.e., decreased subjective discomfort), this would be a relatively low-cost application for different health institutions.

Furthermore, study III was a narrative literature review. Thus, the selected research articles and empirical work cited were chosen to highlight a specific topic and research question. It would be beneficial for the research field and highly interesting for a future study to conduct a stricter meta-analysis on olfactory impairment and social relationships. Through this form of analysis, future paths of interest could be more clearly marked for research relating to intimate relationships and olfaction.

Another set of studies that would be of interest as follow-ups of this thesis concerns broadening and examining other interpersonal phenomena that the partner’s body odors could have the capacity to signal and evoke. For instance, and as a corollary of the secure base phenomenon, do individuals become more daring or exploratory when smelling the body odors of their intimate partner? By continuing to use established research frameworks presented in this thesis, such as attachment theory (Bowlby, 1969) or, more specifically, the learning theory of attachment (Bosmans et al., 2020), it is possible to evaluate other functions of the attachment figure besides the safe haven function studied in study I. Perhaps the effect of partner body odor could also be extended to signal a secure base where a valuable platform of security for exploration and meeting challenges is gained (Mikulincer et al., 2002).

Finally, the olfactory system has been proposed to develop partly by cultural settings (Olofsson & Wilson, 2018). Therefore, studies exploring and perhaps
comparing extreme subject groups in the olfactory domain might be interesting for future studies. For instance, professional perfumers vs. a clinical group suffering from anosmia would be a future design to highlight the larger, presumable contrast effects of interpersonal behaviors and the role of olfaction in those behaviors. Additionally, intimate relationship formation could also be studied from an olfactory perspective. For example, does the scent of a partner change from having a more arousing effect to gaining an increasing calming effect as the relationship matures from its initial passionate phase to the establishment of an attachment bond? Cross-cultural differences could also be of interest here as intimate relationship formation and development may differ across cultures, depending on whether or not monogamy reigns. Where it does, olfaction may be tied up in caregiving and attachment functions, in addition to sex. Where it does not, olfaction may be more exclusively linked to sexual arousal. Hence, it would be valuable to explore the main findings of this thesis in more diverse populations, preferably even across cultures, than the Western, educated, industrialized, rich, and democratic (WEIRD) samples studied here. Such studies might reveal how olfaction is tied up in intimate relationships in more depth.
Concluding remarks

All three studies in this thesis contribute to the main research question of how olfaction and intimate relationships are linked. Based on the main findings and interpretations from the three studies, I conclude that the body odor of a romantic partner can be both a scent of security (study I) and of monogamy (study II), and also that olfactory ability is related to various romantic, intimate relationship behaviors (study III).

In addition, I have argued that body odors are particular signals that can carry various messages in intimate relationships. Therefore, the olfactory function and ability of the receiver of these olfactory body odor messages do matter. This olfactory back-and-forth information between individuals in intimate relationships has been highlighted in this thesis, based on relationship science and attachment theory considerations.

In conclusion, I have shown that olfaction is closely tied to intimate relationships.


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