INNOVATIONS IN SOCIAL PSYCHOLOGY

Olfactory Cues From Romantic Partners and Strangers Influence Women's Responses to Stress

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The scent of another person can activate memories, trigger emotions, and spark romantic attraction; however, almost nothing is known about whether and how human scents influence responses to stress. In the current study, 96 women were randomly assigned to smell one of three scents (their romantic partner's, a stranger's, or a neutral scent) and exposed to an acute stressor (Trier Social Stress Test). Perceived stress and cortisol were measured continuously throughout the study (5 and 7 times, respectively). Perceived stress was reduced in women who were exposed to their partner's scent. This reduction was observed during stress anticipation and stress recovery. Cortisol levels were elevated in women who were exposed to a stranger's scent. This elevation was observed throughout stress anticipation, peak stress, and stress recovery. The current work speaks to the critical role of human olfactory cues in social communication and reveals that social scents can impact both psychological and physiological reactions to stress.

Keywords: olfaction, social communication, social support, nonverbal communication, health behaviors

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People regularly rely on social partners for support during stressful situations (DeLongis & Holtzman, 2005). Contact with social partners has a multitude of positive influences on mental and physical well-being (Uchino, Cacioppo, & Kiecolt-Glaser, 1996; Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007; Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Uchino & Garvey, 1997). Meta-analyses suggest that positive effects of social support on health are comparable to—or even larger than—positive effects of exercise, weight control, and not smoking (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015; Holt-Lunstad, Smith, & Layton, 2010).

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A romantic partner is often the first person we turn to in times of stress (Coyne & DeLongis, 1986), and research suggests that support from a romantic partner can buffer the negative effects of stress on well-being (Bodenmann, Meuwly, & Kayser, 2011; Dehle, Larsen, & Landers, 2001). For example, physical contact with a romantic partner—including holding hands and receiving a massage (Coan, Schaefer, & Davidson, 2006; Ditzen et al., 2007)—is an effective and reliable buffer of physiological and psychological responses to stress. Some of the benefits of a supportive other can be realized through activating a mental representation of that person. For example, after a painful experience, viewing a photograph of a romantic partner reduces emotional and self-reported pain (Selcuk, Zayas, Günaydin, Hazan, & Kross, 2012; Eisenberger et al., 2011; Younger, Aron, Parke, Chatterjee, & Mackey, 2010).

It is less clear whether, or under what specific conditions, strangers might have a similar stress buffering effect. One study reported that holding hands with a stranger during a stressful experience buffered threat responses (Coan et al., 2006). However, a follow up study with a larger and more representative sample did not find a similar stress-buffering effect of strangers (Coan et al., 2017). Two further studies exposing participants to painful stimuli also found no evidence for a stress buffering effect of strangers (Eisenberger et al., 2011; Master et al., 2009). One potential explanation for these divergent findings is that people's reactions

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to a stranger may depend heavily on the social context, traits (social anxiety, attachment styles), and socioeconomic status (SES). For example, low SES has been associated with higher levels of perceived threat to ambiguous social stimuli, suggesting that lower SES individuals might reap fewer benefits from interactions with strangers (Chen & Paterson, 2006).

Compared to what is known about visual (photos) and tactile (hand-holding) modalities, far less is known about the effects of scents on stress responses. Research shows that the scent of a loved one can be identified and is considered both pleasant and comforting (Porter & Moore, 1981; Hold & Schleidt, 1977; Shoup, Streeter, & McBurney, 2008). Indeed, one study reported that over 80% of women and 50% of men intentionally smell their partner's worn clothing (McBurney, Shoup, & Streeter, 2006). These actions led to feelings of comfort and relaxation (43% for women and 16% for men), and/or security and safety (10% both sexes), suggesting that exposure to a partner's scent may incur immediate psychological benefits.

The smell of a loved one may be more than just psychologically comforting; it may also have effects on physiological responses to stress. Cross-species research provides initial support for this possibility. For example, rats—like humans—exhibit a reduced cortisol response to stressors while in the presence of a familiar rat. However, olfactory cues are essential for this social stress-buffering effect in rats to appear: When a stressed rat is unable to smell a familiar other, the stress-buffering benefit on cortisol levels is lost (Kiyokawa, Takeuchi, Nishihara, & Mori, 2009). Studies on human infants have documented that newborns are calmed by the scent of their mother's milk, an effect that manifests itself in reduced movement and decreased cortisol levels of the infant (Nishitani et al., 2009; Rattaz, Goubet, & Bullinger, 2005). However, to our knowledge, there is no empirical research exploring whether and how olfactory cues of supportive others influence responses to stress in adult humans.

It is also unknown whether and how olfactory cues of strangers influence responses to stress. One study found that exposure to a stranger's scent was consistently rated as more intense and less pleasant than a friend's scent, and that a stranger's scent activated cortical regions associated with viewing threatening stimuli (such as photos of people displaying fearful facial expressions; Lundström, Boyle, Zatorre, & Jones-Gotman, 2008). Thus, it is possible that detecting a stranger's scent may be a unique signal of physical proximity to a potentially dangerous individual, triggering increased perceived stress and/or mobilizing the body's physical resources for an uncertain event. This mobilization could activate the hypothalamic-pituitary-adrenal axis, resulting in elevated cortisol levels (Jacobson, 2005).

To examine these possibilities, the current study randomly assigned women to smell one of three shirts (their romantic partner's, a stranger's, or an unworn shirt), after which they underwent a stressful lab event (Trier Social Stress Test [TSST]; Kirschbaum, Pirke, & Hellhammer, 1993). Their stress responses (perceived stress and cortisol)[1] were monitored throughout the procedure. We predicted that the scent of a romantic partner would buffer stress reactions. We did not make a directional prediction regarding how reactions to the stranger's scent would compare to the unworn scent. Methods were preregistered through the Open Science Framework (https://osf.io/6anhd/).[2]

Materials and Methods

Participants

Ninety-six couples completed the study (mean female age = 21.5 years, *SD* = 4.06; mean male age = 22.8 years, *SD* = 5.29; relationship mean length = 2.4 years, *SD* = 2.2). Participants primarily identified as Asian (including Indian, 74%), or Caucasian (22%). The remaining 4% of participants identified as a variety of other ethnicities (e.g., Black, Arab).[3] Participants were eligible to complete the study if they were in heterosexual long-term romantic relationships (>3 months) and met basic health and screening criteria (e.g., no chronic medical disorders, had the ability to smell). Given the influence of sex hormones on cortisol reactivity and olfactory sensitivity (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Lundström, McClintock, & Olsson, 2006), women currently using hormonal birth control were ineligible to participate in the study. Methods were approved by the university's behavioral research ethics board. See Supplemental Table S2 in the online supplemental material for more detailed information about recruitment, eligibility, and exclusions.

Scent donors. Male partners acted as the scent donors for the women in the partner and stranger conditions (i.e., women exposed to a stranger's scent smelled a shirt previously worn by another woman's partner). The male partners of all women were asked to follow the same scent collection procedures (even though not all shirts were actually used). To capture natural body odor, we provided each male scent donor with a white T-shirt that he wore for 24 hours. Recent research indicates that body odors presented on worn t-shirts are perceived similarly to body odors in live interactions (Gaby & Zayas, 2017). Scent donors followed procedures consistent with standard data collection methods (Miller & Maner, 2010; Singh & Bronstad, 2001). Specifically, to reduce extraneous odors, scent donors were instructed to shower with unscented soap and shampoo (provided by us), refrain from using deodorant or scented body products, sleep alone, and avoid activities such as exercise, drinking, smoking, or eating odor-producing foods (e.g., garlic, onion, vinegar). They were also asked to use unscented laundry detergent (provided by us) to wash any bed linens and clothing that would come into contact with their shirt.

Men were given minimal information about the purpose of the experiment; specifically, upon arrival they were informed that the study was "looking at the role of smell" and that for the research

[1] Heart rate data was also collected using POLAR chest straps and watches worn by the participants during the procedure. However, because of equipment malfunction, over a fourth of our data were lost, and remaining data were unreliable. Analysis on the reduced dataset (available in the online supplemental material) resulted in no significant effects of condition.

[2] Because of unexpected difficulty recruiting couples, a stopping rule was established to terminate recruitment after 30 months if the target sample of 150 couples was not reached. Data were not analyzed, and cortisol was not assayed, until the final sample was reached. The final sample included 96 couples. Because of the reduction in power associated with the reduced sample size, we were not able to examine individual differences in the effectiveness of the scent manipulation as originally planned.

[3] Differences across groups were not statistically tested due to sample size constraints; however, exploratory analyses suggested no obvious differences by ethnicity.

to obtain accurate results, it was important that they ensure that the t-shirts did not smell like anything other than themselves. After receiving compensation (course credit or $20 CAD), scent donors completed a compliance check. Shirts were only retained for men who completed protocols correctly or who reported only innocuous infractions to these stringent rules (e.g., consuming soup that contained small pieces of cooked onion).

Shirt preparation. Scent donors returned their worn shirts to the lab within 5 hours of removal. All shirts (including unworn) were turned inside out, folded, and placed in a sealed plastic freezer bag with the underarm section facing the opening. An identifying number was written on the freezer bag after participants left (ensuring that participants were not aware of the number associated with their shirt). They were stored in a −30°C freezer, in line with standard scent preservation methods (Lenochova, Roberts, & Havlicek, 2009). Couples were assigned to a condition when they signed up for the study; when women booked their final lab session, they were assigned a shirt number. Women in the partner condition were assigned their partner's worn shirt, women in the unworn condition were assigned an unworn shirt, and women in the stranger condition were assigned a shirt worn by the male partner of another woman in the experiment. To control for the amount of time that shirts were in the freezer, stranger shirts were selected by identifying the total freezer time of the most recent partner shirt, and choosing the available shirt that had been in the freezer for the most similar amount of time. All shirts were removed from the freezer one to two hours prior to use in order to ensure they were room temperature when smelled. Each shirt (including unworn) was smelled by only one woman.

Smellers. To control for differences in cortisol production across phase of menstrual cycle, female participants (smellers) completed the stress test during the luteal phase of their cycle, the phase when women have the most pronounced cortisol stress response (Kirschbaum et al., 1999). Smellers monitored their menstrual cycle using commercially available ovulation strips, which use urine to measure luteinizing hormone; positive results indicate impending ovulation (Guida et al., 1999). When women received a positive result, they were booked for a second lab visit (during their luteal phase, 4–11 days postpositive result). Eighteen women failed to obtain a clear indication of their ovulation status and were therefore not able to complete the study.

Trier Social Stress Test

Smellers participated in the TSST (Kirschbaum et al., 1993), a standardized laboratory-based psychosocial stressor involving a mock job interview and an unanticipated mental arithmetic task, which reliably induces physiological and psychological stress (Dickerson & Kemeny, 2004). They arrived to the lab between 3:30 to 6:00 PM for a 2-hr session (the restricted time window controlled for diurnal variation in cortisol; Kirschbaum et al., 1999). Using a double-blind procedure, smellers were randomly assigned to smell one of three objects: their partner's shirt, a stranger's shirt, or an unworn shirt. Smellers were given no information about the identity of the shirt they were smelling and were merely told they were smelling a shirt "which may be either worn or unworn, according to the condition you were randomly assigned to . . . there is a low probability that the shirt you smell has been worn by someone you know." Smellers first provided baseline measures of cortisol and perceived stress; thereafter, women smelled a shirt and completed stress measures throughout the study (see Figure 1).

Smellers then received information about an upcoming mock job interview and were given 5 min to prepare for the interview. They were then led into another room wherein two trained judges in white lab coats were seated at a table in front of a camera. The 10-min TSST stress procedure was conducted according to the original protocol (Kirschbaum et al., 1993). Judges were trained to appear neutral throughout the stress procedure and avoid smiling, nodding, and nonverbal feedback.

At the end of the stress procedure, women were led back to the original testing room, where they completed several questionnaires (e.g., if they believed the scent was that of their partner) and demographic information (e.g., age, relationship length). At the

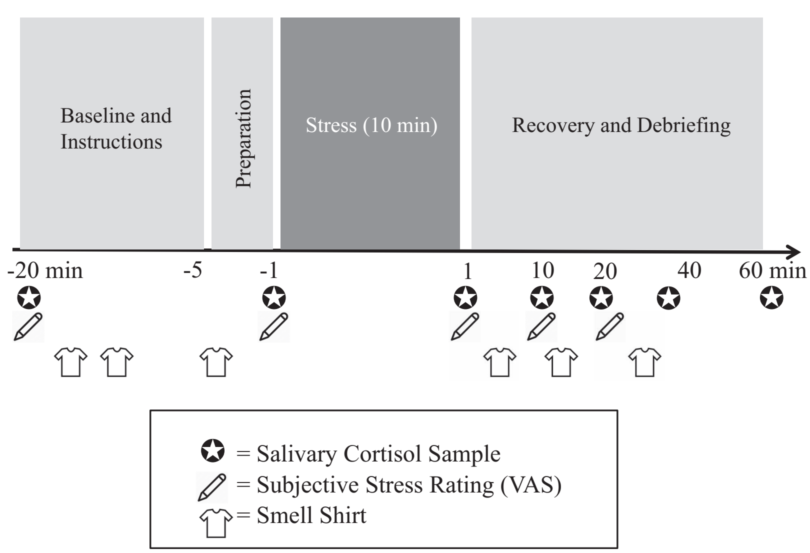

Figure 1. Timeline (in minutes) of in-lab component of experiment.

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end of the study, the judges joined the experimenter to debrief, thank, and compensate (with $40 CAD or course credit) the participant. Complete protocols, materials and data for all study sessions are available online (https://github.com/MarliseHofer/StressSmell).

Shirt smell. Women smelled the same shirt for 1 min on six occasions (at −13, −10, −4, +2, +12, and +24 min relative to TSST onset). Women were instructed to place their noses a few centimeters from the shirt and inhale deeply (this action was demonstrated by the experimenter prior to the first shirt-smelling occasion).

Perceived stress. A questionnaire was given five times during the experiment (at −20, −1, +1, +10, and +20 min relative to TSST). Women indicated anxiety, physical discomfort, desire to leave the situation, tension, and feelings of control on visual analog scales ranging from 0 (*not at all*) to 100 (*very*) (e.g., Berger, Heinrichs, von Dawans, Way, & Chen, 2016; Chen et al., 2011). Perceived stress was computed as the mean of the five items at each time point (feelings of control reverse-scored; Cronbach's alphas for the scale at the individual time points ranged from .70 to .86).

Cortisol. Saliva samples were collected seven times during the experiment (at −20, −1, +1, +10, +20, +40, and +60 min relative to TSST) using a standard sampling device (Salivette; Sarstedt, Germany). Women were instructed not to smoke (for 10 days) or eat or drink beverages containing caffeine or alcohol (for 2 hr) prior to the lab session. Samples were stored in a freezer at −30 °C after each experiment. For biochemical analyses, the samples were spun at 3,000 revolutions for 10 min to obtain 0.5–1.0 ml of clear saliva with low viscosity. Salivary cortisol concentrations were determined by a commercially available chemiluminescence immunoassay (CLIA; IBL, Hamburg, Germany). Interassay and intraassay coefficients of variation were below 8%, which indicates good precision (Schultheiss & Stanton, 2009).

Results

Data Analyses

Perceived stress and cortisol reactions from the 96 female participants were analyzed using two-way analyses of variance (ANOVAs) with repeated measures, Scent Exposure (partner, stranger, or unworn) × Time (repeated factor: 7 for cortisol, 5 for perceived stress).

Power Analysis

A power analysis was computed, using G Power, with an alpha level of 0.05 and 80% power. An effect size estimate was drawn from previous literature reporting stress reducing effects of partner physical contact (massage) compared to verbal support and no support conditions, which found an effect size of $\eta^2 = 0.05$ (condition by time interaction; Ditzen et al., 2007). The power analysis indicated that the required sample size to detect a Condition × Time interaction is 81 for perceived stress and 63 for cortisol. Our sample size of 96 exceeds these thresholds, indicating that the study was well powered to test our main hypotheses.

Perceived Stress

Perceived stress changed over the course of the experiment as expected (significant main effect of time, $F(2.68, 249.44)$[4] = 123.06, $p < .001$, $\eta^2 = 0.57$), indicating that the stress test influenced participant's stress reactions. There was a nonsignificant main effect of scent exposure, $F(2, 93) = 1.15$, $p = .32$, $\eta^2 = 0.02$, which—of most relevance for our hypothesis—was qualified by a significant interaction between time and scent exposure, $F(5.36, 249.44) = 2.26$, $p = .04$, $\eta^2 = 0.05$. A visual inspection of the data indicates that, compared to women who smelled a stranger's or an unworn shirt, women who smelled a partner's shirt felt less stressed during both anticipation and recovery from the stress task (see Figure 2).

To follow up on the significant interaction between time and scent exposure, we conducted three regression analyses comparing scent exposure at three phases of stress (anticipatory, peak, and recovery). These phases of stress were tested separately because prior research has shown that social support can be beneficial during both stress reactivity and stress recovery phases (Ditzen et al., 2007; Heinrichs et al., 2003; Meuwly et al., 2012). Two dummy coded variables were created. In the first, partner/unworn were coded as 0, and stranger as 1. In the second, partner/stranger were coded as 0, and unworn as 1. Coding the partner group as 0 for both variables allowed us to directly compare stranger and unworn scents to partner scents (Alkharusi, 2012; Cohen & Cohen, 1983). These two condition variables, along with baseline perceived stress, were used in a linear regression to predict three phases of stress: anticipatory (1 min prestress induction), peak (1 min poststress induction), and recovery (mean of 10- and 20-min poststress induction).

Results revealed that during the anticipatory stress phase, women exposed to their partner's scent reported significantly less perceived stress than those exposed to a stranger's scent (M = 32.81, SD = 18.07 vs. M = 42.25, SD = 18.63; perceived stress ratings range from 0 [*low*] to 100 [*high*]; $p = .017$, Table 1). During peak stress, scent condition did not predict perceived stress ($ps > .39$, Table 1). During stress recovery, women exposed to their partner's scent reported significantly lower perceived stress than both those exposed to a stranger's or an unworn scent (M = 20.25, SD = 14.96 vs. M = 27.14, SD = 16.67 and M = 29.01, SD = 14.19; p = .038 and .015, respectively, Table 1). Taken together, these results suggest that women experience a psychological stress-buffering response from exposure to the scent of their partner during both anticipatory stress and stress recovery.

Cortisol

Cortisol levels changed over the course of the experiment as expected— significant main effect of time, $F(1.42, 131.76) = 36.32$, $p < .001$, $\eta^2 = 0.28$—indicating that the stress test influenced participant's cortisol responses. There was a nonsignificant main effect of scent exposure, $F(2, 93) = 0.83$, $p = .44$, $\eta^2 = 0.02$, which—of most relevance for our hypotheses—was qualified by a significant interaction between time and scent exposure, F(2.83,

[4] Throughout the article, Mauchley's test was used to determine if sphericity was violated, and when necessary the Greenhouse-Geisser correction was used (indicated by degrees of freedom with decimal values).

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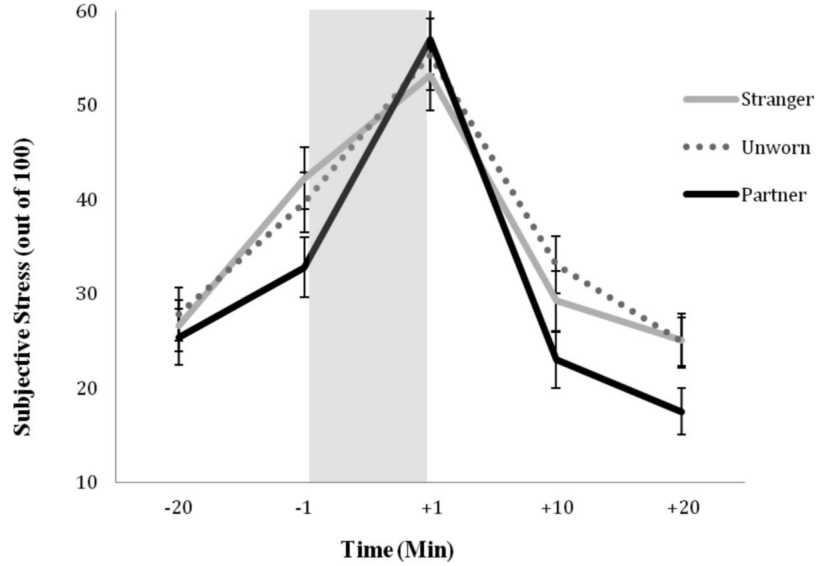

Figure 2. Perceived stress by time separated by scent exposure. Shaded section indicates stress induction (TSST). Error bars represent ±1 SEM.

131.76) = 3.05, p = .03, η^2 = 0.06. A visual inspection of the data indicates that cortisol levels after the stress test were elevated for women who smelled a stranger's shirt (see Figure 3).

To explore the interaction between time and scent exposure, a series of linear regression models were used. As in the perceived stress analysis, two dummy coded variables were created. In the first, partner/unworn were coded as 0, and stranger as 1. In the second, partner/stranger were coded as 0, and unworn as 1. The two scent exposure variables and baseline cortisol were used in a linear regression to predict cortisol during three phases: anticipatory stress (1 min prestress induction), peak stress (mean of 10- and 20-min after the end of the stressor), and stress recovery (mean of 40 and 60 min after the end of the stressor). The mean of 10 and 20 min after the end of the stressor was used to represent peak stress because salivary cortisol levels are time-lagged relative to the occurrence of an acute stressor by approximately 15 to 30 min (de Kloet, Joels, & Holsboer, 2005).

Results revealed that cortisol levels were significantly higher in women exposed to a stranger's scent at each stress phase (compared to partner's scent; anticipatory, peak, and recovery, ps < .025, Table 2). Cortisol levels did not differ between women exposed to their partner's scent and an unworn scent at any stress phase (p's > .66, Table 2).

Table 1
Perceived Stress Predicted from Scent Exposure

Stress phase	*B*	β	*t*	*p*
Anticipatory				
Partner versus stranger	8.57	.22	2.43	**.017**
Partner versus unworn	5.14	.13	1.46	.149
Peak				
Partner versus stranger	−4.36	−.10	−.059	.607
Partner versus unworn	−2.62	−.06	−.098	.392
Recovery				
Partner versus stranger	6.13	.19	2.10	**.038**
Partner versus unworn	7.25	.22	2.48	**.015**

Note. Anticipatory = −1; Peak = +1; Recovery = mean of +10 and +20. Scent exposure dummy coded (partner = 0; other scent exposures = 1). Degrees of freedom = 92. Bold items indicate $p < .05$.

Discussion

This study provides evidence that the mere scent of another person can impact psychological and physiological reactions to stress. Women exposed to a stranger's scent displayed elevated cortisol levels throughout a stressful experience, and women exposed to their partner's scent reported less perceived stress both before and after a stressful experience.

With respect to cortisol, a "stranger danger" effect was observed. From infancy onward, humans are inclined to fear strangers—particularly strange males—a tendency that is theorized to have motivated adaptive responses to the widespread stranger violence in our ancestral past (Hahn-Holbrook, Holbrook, & Bering, 2010; Hrdy, 1999; Feinman, 1980). Indeed, when adults view faces of outgroup males, fear responses endure longer (Navarrete et al., 2009; Olsson, Ebert, Banaji, & Phelps, 2005). Interestingly, the "stranger danger" effect that we observed was limited to cortisol; we found no evidence that strangers' scents increased perceived stress. This suggests that cortisol reactions may represent energy mobilization within the metabolic system in preparation for a potential threat (the "fight or flight" response), and that this cortisol reaction may not be accessible to the subjective experience of stress.

With respect to perceived stress, a "partner comfort" effect was observed. Dissociations between cortisol reactions and perceived stress are often noted in the literature (Campbell & Ehlert, 2012; Kirschbaum, Klauer, Filipp, & Hellhammer, 1995; Ditzen et al., 2007; Frisch, Häusser, vanDick, & Mojzisch, 2014). However, exploratory analyses (available in the online supplemental materials) indicate that, when comparing the partner and stranger conditions, perceived stress levels during the anticipatory stress phase

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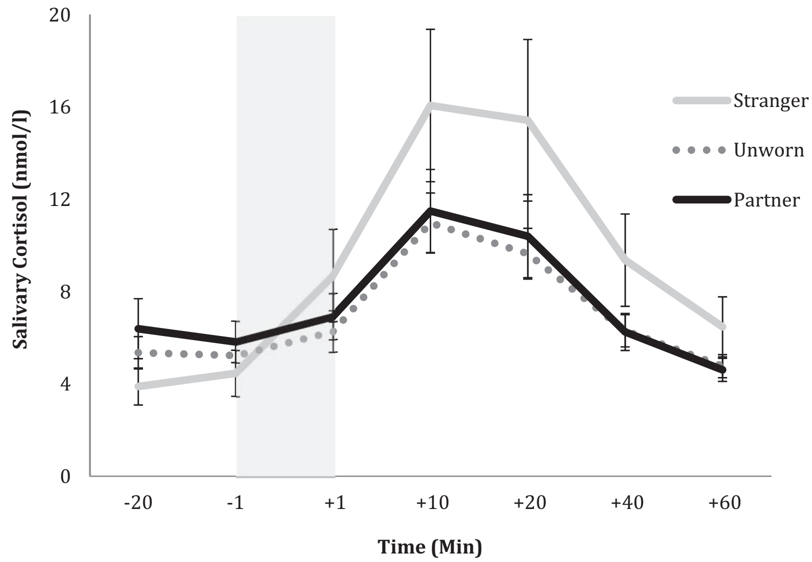

Figure 3. Cortisol separated by scent exposure. Shaded section indicates stress induction (TSST). Error bars represent ±1 SEM.

mediate the relationship between condition and cortisol production. Thus, although main effects of perceived stress and cortisol reactions were dissociated, some relationship may exist between the two outcomes.

Why was a "partner comfort" effect not observed in cortisol reactions (compared to neutral scents)? It is possible that the result reported in Figure 3 underestimates the stress-buffering effect of partner's scent because some women misidentified their partner's scent as that of a stranger, or vice versa. Indeed, only 63% of women exposed to their partner's scent believed they were smelling their partner's scent. Outside the context of a lab experiment, participants are likely to have knowledge about the origin of the scents they encounter (e.g., stranger scents are generally encountered in new social settings; partner scents are encountered when wearing a partner's clothing). Thus, examining only those women who correctly identified the scent to which they were exposed arguably provides additional external validity. Initial evidence indicates that, in the subset of women for whom actual scent exposure and belief about scent exposure match, women exposed to their partner's scent did produce less cortisol. The reduced cortisol in the partner condition (see Figure 4) was not statistically different from unworn when analyzed using ANOVA, but the difference was significant in an HLM analysis (see the online supplemental materials). Belief about scent exposure may play a crucial role in cortisol reactions to stress, and the physiological stress-buffering effects of a partner's scent may be most apparent when the origin of the scent is known.

Given that belief appears to impact cortisol reactions, we also explored the unique effects of scent exposure and belief about scent exposure on stress reduction. Initial evidence indicates that merely being exposed to a partner's scent (in the absence of belief) leads to reduced perceived stress, and merely believing that one has smelled a partner's shirt leads to reduced cortisol levels (analyses available in supplementary materials). Future research on a larger sample or involving systematic manipulation of belief will be necessary to fully disentangle the respective roles of scent exposure and belief about scent exposure.

Based on our power analysis, the current study was well powered to examine main effects of scent exposure on all participants. As this was the first test of social support effects using olfactory cues, strict rules were set (e.g., inclusion criteria, menstrual cycle stage, scent collection procedures) with the goal of reducing measurement error and further enhancing power. These detailed procedures and criteria meant that smellers were all women in the luteal phase of their cycle and in committed heterosexual romantic relationships. The decision to use women as smellers was not based on predicted sex differences, but rather on logistical considerations (e.g., prior research showing that women have a more sensitive sense of smell; Brand & Millot, 2001). Thus, future research will be necessary to determine whether these effects generalize to women in different menstrual phases, to men, and to different social relationships (e.g., homosexual, polygamous, platonic, parental).

Table 2
Cortisol Predicted from Scent Exposure

Stress phase	*B*	β	*t*	*p*
Anticipatory				
Partner versus stranger	4.10	.25	2.68	**.009**
Partner versus unworn	.32	.02	.21	.832
Peak				
Partner versus stranger	7.05	.25	2.28	**.025**
Partner versus unworn	.30	.01	.01	.923
Recovery				
Partner versus stranger	3.71	.28	2.59	**.011**
Partner versus unworn	.61	.05	.43	.668

Note. Anticipatory = −1; Peak = mean of +10 and +20; recovery = mean of +40 and +60. Scent exposure dummy coded (partner = 0; other scent exposures = 1). Degrees of freedom = 92. Bold items indicate $p < .05$.

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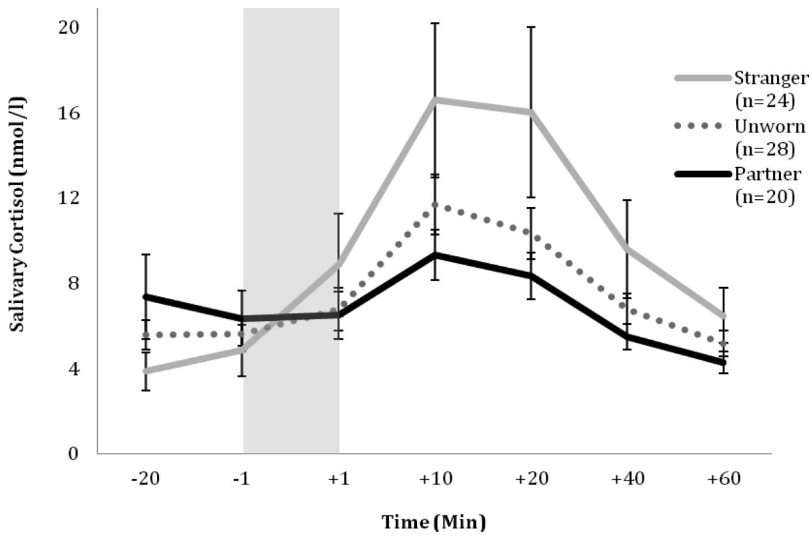

Figure 4. Cortisol separated by scent exposure in the subset of 72 participants who correctly guessed whether or not they had been exposed to their partner's scent. Shaded section indicates stress induction (TSST). Error bars represent ±1 SEM.

Scent collection procedures in this study (and the majority of existing scent research studies) strictly regulate foods and activities of scent donors with the goal of ensuring that natural body odor is not overpowered by external smells. However, consistent scent alterations (e.g., cologne; scented body lotion) may contribute to how a person is generally perceived. Indeed, recent research has demonstrated that perceptions of a person change when smelling a stranger's "altered" body odor versus their "natural" body odor (Gaby & Zayas, 2017). Future research on the benefits of partner odor could profitably compare the stress-buffering effects of natural and altered body odor. This may be especially relevant in cases where a person alters his or her body odor in the same way each day (e.g., daily use of cologne).

This research could be extended to encompass other health-relevant processes. Several positive health behaviors have been linked to social support, such as improved sleep, smoking cessation, and healthy eating (Friedman et al., 2005; May & West, 2000; Nastaskin & Fiocco, 2015; Wing & Jeffery, 1999). The current study indicates that some of the positive effects of social support on stress can be communicated via scent alone. Therefore, future work could examine whether exposure to supportive scents are associated with a broader range of health outcomes.

With globalization, both short-term and long-term separation from social support networks is becoming increasingly common. U.S. residents alone took over 2 billion trips in 2016 (U.S. Travel Association, 2016), and a 2013 Gallup survey reported that 24% of Americans have moved to a new city in the past 5 years (with similar numbers reported in other Western cultures; Esipova, Pugliese, & Ray, 2013). Individuals separated from loved ones may particularly benefit from a behavioral strategy to reduce stress. From a practical perspective, these findings could be used to develop everyday strategies (which may be as simple as traveling with an article of clothing from a loved one) to promote healthy stress coping during times when people are physically separated from supportive others.

The current work ties together two lines of research, one suggesting that the scent of a close other is pleasant and comforting (Hold & Schleidt, 1977; Shoup et al., 2008; McBurney et al., 2006), and the second indicating that social support reduces stress reactions (Ditzen et al., 2007; Meuwly et al., 2012; Heinrichs et al., 2003). The finding that olfactory cues influence psychological and physiological reactions to stress builds upon this existing knowledge and highlights the critical role of olfaction on communication, social support, and health.

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