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The interactive role of odor associations in friendship preferences

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Who we choose to befriend is highly personal, driven by idiosyncratic preferences about other individuals, including sensory cues. How does a person's unique sensory evaluation of others' body odor affect friendship formation? Female participants took part in a speed-friending event where they made judgments of friendship potential (FP) following a 4-minute live interaction. Prior to and following the speed-friending event, participants judged the FP of these women based solely on *diplomatic* odor (including daily perfume/hygiene products) presented on worn *t*-shirts. Participants also judged FP based on facial appearance (a 100-ms presentation of portrait photographs). Judgments based solely on diplomatic odor predicted FP judgments following in-person interactions, beyond the predictive ability of photograph-based judgments. Moreover, judgments based on the live interaction predicted changes in the second round of diplomatic odor judgments, suggesting that the quality of the live interaction modified olfactory perception. Results were driven more strongly by idiosyncratic preferences than by global perceiver or target effects. Findings highlight the dynamic role of ecologically relevant social olfactory cues in informing friendship judgments, as well as the involvement of odor-based associative learning during the early stages of friendship formation.

Keywords Friendship, First impressions, Social olfaction, Odor associations, Multimodal perception

Friendships are paramount to mental and physical wellbeing[1,2]. From an evolutionary perspective, friendships are adaptive, increasing survival and reproductive success[3]. In the present work, we examine how *diplomatic* olfactory cues (the way a person smells on a daily basis, including any fragrances, hygiene products, and dietary and lifestyle choices) forecast an inclination to befriend another person, and in turn, how these olfactory associations are modified by actual interactions.

Sensory cues are assumed to serve as "heuristics," allowing individuals to quickly assess whether a person is a potential friend or foe, to be trusted or not[4,5]. Much work focuses on how visual information, such as facial cues, shape interpersonal judgments[6,7]. Much less work has focused on the role of olfactory cues, although each person has a unique odor signature[8,9], and each in-person social interaction takes place in the olfactory context of the other person's body odor.

Olfactory preferences are rooted both in genetics[10,11] and experience[12], with strong, emotional odor associations forming after a minimal number of exposures[13]. Odor associations have been shown to modulate perception of other social cues[13,14]. Thus, olfactory associations with cosmetic and personal odors may influence social impressions such as evaluations of friendship potential.

Body odors themselves are susceptible to associative learning, in contexts from maternal bonding[15] to threat perception[16] to romantic partners[17]. As information is acquired about another person, olfactory associations may update to reflect the quality of social interactions with a given partner. As a friendship (or any relationship) develops, a person might learn to associate an individual's body odor with the emotional outcome of their interactions experienced over time, with the person's body odor increasing its rewarding value if the interaction was positive, and acquiring aversive value if the interaction was negative. Such associative learning between body odor and emotional states likely accounts for learned responses to body odors, such as smelling a partner's shirt for comfort during periods of separation[17]. Ultimately, associations with another person's body odor might help reinforce social dynamics, including motivations and decisions about continued investment in a relationship[14,18].

Historically, social olfactory research has focused on mate choice[19,20], but increasingly, work has shown that body odors shape person perception more broadly, including impressions of aggression[21], cooperativeness[22], and emotion[23]. Within this growing literature, the majority of work utilizes *natural* body odor (i.e., devoid of

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exogenous fragrances, deodorant, dietary influences, etc.), collected on *t*-shirts or pads, composed mostly of armpit, or *axillary*, sweat. In many cultures, however, individuals typically don't encounter another person's natural axillary odor. Instead, people encounter others' *diplomatic* scent, which includes fragrances, deodorant, and other hygiene products. Gaby and Zayas (2017) found that social judgments based on diplomatic scent and social judgments based on natural body odor were only weakly correlated, suggesting that the two convey different information. Specifically, judgments of interpersonal liking based on someone's diplomatic odor, which included aspects such as body odor pleasantness and perceived friendliness, were not predicted by the same judgments made about that person's natural odor. These findings are consistent with research showing that fragrance modifies judgments of body odor[24] and personality traits[25]. In general, individuals are judged more positively when wearing fragranced products than in their natural condition. It is currently unknown whether critical information, such as health status or emotional state, is impacted by the use of fragranced products, though one study does suggest that antiperspirant deodorant might block emotionally salient cues of stress[26]. Havlíček and Roberts (2013) suggest that the use of fragrance reflects an interaction between biological and cultural evolution, and that the unique percept of body odor in combination with fragrance is socially significant of its own accord[27]. These studies highlight the importance of assessing the role of diplomatic odor in social interactions.

In live, in-person interactions, individuals encounter not only diplomatic scent, but also a wealth of other information, including physical appearance, tone of voice, nonverbal behaviors, and the environmental context of the interaction. This information, especially the powerful influence of facial cues[28], may eliminate, dilute or modify the effects of olfactory cues. Understanding how body odor is utilized in naturalistic, multimodal settings is critical to elucidating the functional role of body odor outside of the lab[29]. Two studies examining the use of natural olfactory cues in multimodal interactions draw contrasting conclusions. Roth et al. (2021) examined the role of natural body odor in romantic attraction in multimodal settings and found that natural olfactory cues failed to predict actual attraction[30]. In contrast, Ravreby et al. (2022), using natural body odor in multimodal, non-romantic interactions, found that body odor similarity might be important in the formation of "click" friendships.

Few studies have focused explicitly on diplomatic odor. In one investigation of the role of diplomatic body odor in semi-naturalistic settings[31], blindfolded and earplugged perceivers judged the likeability of "target" individuals who briefly sat beside them for one minute. In the absence of visual or auditory information, perceivers made reliable judgments based solely on these odor cues. The findings demonstrate that diplomatic olfactory cues encountered on whole bodies and at typical social distances are perceptible and can be utilized to make social judgments. The study did not, however, utilize a multimodal context to examine if such cues are utilized when other information is present. Studies utilizing semi-diplomatic odors (application of a study-specific perfume) in multimodal settings suggest that body odors are important in informing social judgments[32–34].

To clarify the importance of diplomatic odors in non-romantic social judgments, the present work examined how perceivers use diplomatic olfactory cues in real, multimodal interactions to inform friendship preferences. Informed by past work showing modification of olfactory associations from learning, this work also investigated how the quality of live interactions might modify olfactory associations with an individual's diplomatic odor.

In a "speed-friending" paradigm, female participants had approximately ten four-minute interactions with other women; following each interaction, they judged the friendship potential (FP) of each partner. Prior to and following the speed-friending interaction, participants also made FP judgments based on diplomatic odor cues collected on *t*-shirts. Diplomatic olfactory cues may be related to judgments based on other single modality cues, such as facial cues[35,36], which have been shown to predict liking judgments in live, in-person interactions[6,30,37]. To examine the differential forecasting power of olfactory cues, participants also judged FP based on viewing a target's portrait photograph for 100-ms. This design allowed us to investigate two central questions: First, to what extent do FP judgments based on diplomatic olfactory cues alone uniquely forecast FP judgments formed during face-to-face, multimodal interactions, beyond judgments based on visual cues alone? Second, to what extent do experiences in the live interaction subsequently predict changes in FP judgments of the same person's diplomatic olfactory cues?

Method

Participants

The study was advertised around campus as "Speed Friending?" Forty women ages 18–30 (mean age 21.1 years), all with a normal sense of smell (see SOM), participated in the study. They were compensated $35 at the end of the speed friending session for participating in all 4 parts of the study, with an option to receive course credit instead of cash. Given the repeated nature of our design, and that each participant judged approximately 10 targets on four liking judgments, we had a high number of observations to obtain strong statistical power. The degrees of freedom for a repeated measures correlation are approximately $X \approx K - 1$ times greater than the degrees of freedom for the Pearson correlation, where K is the mean number of repeated pairs within individuals. In our study, K is approximately 40. Thus, a post hoc calculation of statistical power showed that our design allowed us to achieve at least 95% statistical power for our primary hypotheses to detect within-person associations of $r = .1$[38].

Procedure

The study consisted of four parts (see Fig. 1): (A) an in-person pre-event session, wherein participants had their portraits (headshot) taken and were given materials for the odor collection phase, (B) an online pre-event session wherein participants completed self-report measures and provided judgments of friendship potential (FP) based on visual cues alone (i.e., 100-ms exposure of targets' portraits), (C) a diplomatic odor collection phase, wherein participants wore the *t*-shirt given in part A for approximately 12 h as they went about their daily

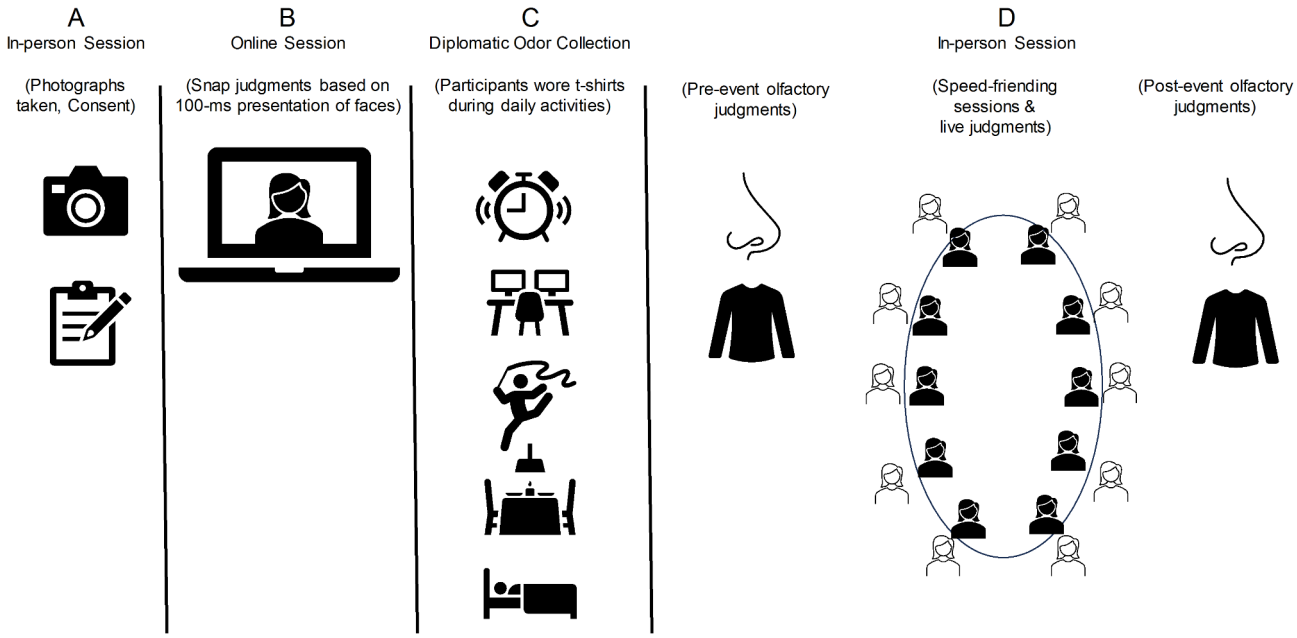

Fig. 1. Schematic Representation of Study Procedures and Key Measures. The study design consisted of four parts. (**A**) An in-person pre-interaction session wherein participants provided their informed consent, had their photographs taken, and were given materials for the odor collection phase, (**B**) an online pre-event session wherein participants completed self-report measures and a portrait judgment task (i.e., based on a 100-ms exposure to targets' portrait), (**C**) a diplomatic odor collection phase wherein participants wore a *t*-shirt as they took part in their daily activities, and (**D**) an in-person speed-friending session that included a pre-interaction rating of *t*-shirts worn by those in the session, the live speed-friending session, and post-interaction rating of the same *t*-shirts.

activities, and (D) an in-person session, wherein participants provided (pre-interaction) FP judgments based on olfactory cues alone (i.e., smelling *t*-shirts worn by those in the session), followed by the live speed-friending session wherein they had four-minute interactions with approximately ten partners, which was followed by a second round (post-interaction) of FP judgments based on olfactory cues alone (i.e., smelling the same *t*-shirts).

Judgments of friendship potential (FP)

Participants assessed the friendship potential (FP) of targets at four different times: based on visual cues (i.e., 100-ms exposure to targets' portraits), pre-interaction olfactory cues (i.e., diplomatic odor before the live interaction), live multimodal interaction (i.e., following the 4-minute interaction in the speed-friending session), and post-interaction olfactory cues (i.e., diplomatic odor following the live interaction). At each assessment, participants judged the extent to which the person "*… seems like a person whom…*": "*I would like to get to know*," "*I would like to share a social activity with*," "*I would like to be friends with*," or "*I would prefer NOT to hang out with*" (reverse-scored) using a Likert scale (1 = *strongly disagree* to 7 = *strongly agree*).

For the diplomatic olfactory judgments (both pre-interaction and post-interaction judgments) and live multimodal judgments, participants also judged pleasantness and intensity of body odor (1 = *not at all* to 7 = *extremely*). Additionally, participants also judged the target on the following: how attractive, likeable, competent, trustworthy, aggressive, and friendly the person was (1 = *not at all* to 7 = *extremely*). Participants also made a series of 5 personality judgments as reflected by the Big-5, rating the person in question on Likert scales anchored by the following five pairs of personality adjectives: reserved, quiet/extraverted, enthusiastic; critical, quarrelsome/sympathetic, warm; disorganized, careless/dependable, self-disciplined; anxious, easily upset/calm, emotionally stable, and conventional, uncreative/open to new experiences, complex. Lastly, for live judgments, participants were also asked a yes/no question, "*Would you like to exchange contact information with this participant?*" Participants were led to believe that if they chose to do so, their contact information would be shared with other participants (see figure S1 and OSF for a copy of the full instrument).

We analyzed intensity judgments to ensure that these did not moderate effects in the present work. However, we do not report the results of these other olfactory and live judgments in the present paper because we do not have comparable judgments in the portrait judgment task. We utilized only the four FP judgments in the snap judgment task as we were concerned that adding more trials would make the task too long (participants completed approximately 80 trials and an extensive demographic survey in the design we used). To keep analyses consistent, in the present manuscript we focus on the FP judgments that were assessed in a similar format across the different modalities.

In-person pre-event session

Approximately two weeks before the speed-friending session, participants attended an in-person pre-event session where written informed consent was obtained from all participants. They were also given materials and instructions for the diplomatic odor collection phase (i.e., a clean cotton *t*-shirt in a Ziplock bag; see Diplomatic Odor Collection section below).

Participants were also asked to pose for a photograph to be used in the face judgment task. Photographs were taken using autofocus against a plain white wall with participants looking straight at the camera. Although we did not document specifics about the focal length and distance of the camera from our subjects, these factors were standardized for all participants and as described next, the photos were further standardized with editing software, so their influence would be consistent for all individuals. Smiling photographs (with glasses, if participants wore glasses) were used for the face judgment task, as these were assumed to better capture how individuals would appear when meeting someone for the first time. Photographs were cropped so that the participant's face was centered in the photo, with minimal space at the top of the head. Bottom margins were aligned just below the collarbone and side margins were aligned approximately with the AC joint, where shoulders begin to slope downwards. Photos were standardized to 336 pixels in height, with slight variations in width to accommodate for differences in shoulder-to head ratios between individuals. Photos were displayed at 96dpi with 24 bit depth (see Fig. 2 for an example).

Online pre-event session: portrait judgment task and self-report measures

Following the in-person pre-event session and at least two days before the live speed-friending session, participants completed the snap judgment task and self-report surveys including a demographic questionnaire online.

Fig. 2. Sample stimulus used in the snap judgment task.

During the face judgment task, participants judged friendship potential (FP) based on a 100-ms exposure of portrait photos of the other participants in the study. Participants judged approximately 20–24 unique target faces, approximately half of which they would interact with in the speed-friending event (see SOM for details). The specific FP questions were randomly presented throughout the task. At the end of the task, we asked participants if they had viewed photographs of anyone they knew. If the person was more than a passing acquaintance (e.g., "*This person is in my history class but I don't know their name*"), we ensured that participants ($n = 11$) were moved to separate days or placed into non-interacting roles (i.e., both as targets or both as raters) so they would not evaluate each other in the speed-friending session.

Diplomatic odor collection

Between one and three days before the speed-friending event, we followed protocols for collecting diplomatic odor[31] and asked participants to wear their cotton *t*-shirt for approximately 12 h, as they went about their daily activities (actual wear times ranged from 7.75 to 16.75 h; M = 12.3 h, SD = 1.58 h). Because we were interested in capturing daily diplomatic odors, participants were asked not to make any modifications to their daily hygiene or habitual routines. They were asked, however, to avoid smoking or drinking alcohol in order to avoid strong smells that might obscure their normal daily odor. If participants wore perfume or other fragranced products during odor collection, they were asked to wear the same products to the speed-friending session. If they engaged in exercise at the gym or showering, participants were instructed to remove their shirts and then put them back on afterwards. Participants also reported if this happened and, if so, for how many hours they removed their shirts; only one participant reported removing their shirt to go to the gym for an hour. At the end of the collection period, participants placed their *t*-shirt in the freezer in the provided Ziploc bag, then brought the shirt with them to the speed-friending session. Participants were also asked to fill out an activity log for the day of odor collection (see OSF materials). Most participants reported donning their *t*-shirts between 7 and 10 am and removing them between 7 pm and 12 am. One participant each reported spray painting an art project, sexual activity, exercising, and spilling a small amount of black beans on their shirt. Two each reported cooking/frying food and being in a smelly restaurant, and three reported holding a pet. Five participants reported taking an exam while wearing their shirts.

In-person speed-friending event

Prior to the speed-friending event, we randomly assigned participants to one of two groups; those in the stationary group were to remain seated throughout the speed-friending session, and those in the traveling group moved from one stationary participant to another. On the day of the speed-friending event, participants were asked to arrive in one of two locations to avoid meeting participants from the other group (who they would eventually interact with) before the speed-friending session.

Participants completed a brief "day of" questionnaire about their health, mental state, and menstrual cycle (see OSF materials). They also turned in bags containing their *t*-shirts to the experimenters, who labeled them with a randomly-generated unique number. The *t*-shirts from each group were exchanged so that the stationary group smelled the *t*-shirts of the traveling group and vice versa.

Pre-interaction diplomatic odor judgments Prior to the actual speed-friending event, participants (still in separate groups) were provided with gloves, a packet of rating sheets, a pen, and a randomized list of *t*-shirt numbers to ensure that *t*-shirts were smelled in a random order for each individual. *T*-shirts (in their bags) were placed individually on tables throughout the room. Participants were instructed to circulate to each *t*-shirt, while not talking with one another. For each *t*-shirt, participants were instructed to open the bag, take a single deep sniff, and close the bag before making FP judgments, using the same four questions used in the face judgment task as well as intensity and other judgments (see Figure S1).

Speed-friending event The entire speed friending event took place in the graduate student union on Cornell University's campus, a large, refurbished barn with a number of café tables spread throughout the first floor and an open mezzanine level. After providing their *pre-interaction diplomatic odor judgments*, stationary participants were led to chairs at one of the tables ("*meeting stations*") throughout the main speed-friending room so that there was at least one empty table between each participant, distributed on both the first and second floor of the building. Once all stationary participants were seated, traveling participants were brought to the speed-friending location. Each traveling participant was randomly assigned to one of the *meeting stations* around the room for their first meeting, then proceeded from station to station in a clockwise rotation.

In preparation for the speed friending session, all participants put on a name tag with their first name only and received rating sheets including the questions to assess friendship potential. Both travelling and stationary participants were given identical information about meetings: each meeting would last four minutes, during which participants were to try to get to know the person seated opposite them. Following the meeting, traveling participants were to move to the next meeting station before both parties made their ratings, so that participants could not observe the ratings being made about their most recent meeting. After the four-minute live interaction, participants provided their FP judgments using the same instrument as the t-shirt judgments, which contained the four questions used in the face judgment task and diplomatic odor judgments. Participants had two minutes between meetings before the experimenter made an announcement for them to move to the next station (if traveling) and to make their ratings.

Post-interaction diplomatic odor judgments At the end of the speed-friending event, participants returned to their original meeting places to complete the second round of diplomatic odor judgments. Participants were presented with the same *t*-shirts with the same numeric codes, but this time in a new randomized order, and again completed the same questions to assess friendship potential.

Debriefing. At the end of the session, participants were asked to fill out a brief survey asking them whether they thought they knew what the study was about, and, if so, to write down their guess as to the purpose of the

study (see OSF materials). Participants were then debriefed, allowed to ask any questions, and provided with their compensation.

Data analytic strategy

Our primary questions focused on the extent to which judgments based on pre-interaction diplomatic olfactory cues forecasted judgments based on the live multimodal speed-friending session, and the extent to which the nature of the live interaction forecasted changes in judgments based on post-interaction olfactory cues. Given the nested nature of our data, we tested our hypotheses using multilevel models (MLMs) with a restricted maximum likelihood estimation[39].

For descriptive purposes, we ran multilevel models, one for each modality, to estimate variance attributable to perceiver, target, and perceiver × target effects. Crucially, because each rater judged each target's FP four times, we were able to disentangle idiosyncratic preferences from the residual (i.e., noise). In all MLMs, we treated perceiver, target, and perceiver × target as random factors. MLM analyses were run using lme4[40] and for descriptive purposes, zero-order within-person correlations were run using rmcorr[38] in R version 6.0.

To test our first hypothesis, we treated diplomatic olfactory judgments as a fixed predictor. To isolate the unique predictive ability of diplomatic olfactory judgments on live friendship potential (FP) judgments, we also included visual judgments (i.e., based on the 100-ms exposure to targets' portrait) as a covariate, entering it into the model as a fixed predictor. Work using the speed-dating paradigm to examine romantic interest has shown that traveling (vs. staying stationary) leads to greater romantic interest[41]. Thus, in our MLMs, we included whether participants had been randomly assigned to the traveling or the stationary group (traveling = 1; stationary = 0) as a fixed predictor. Traveling in the speed-friending event was not a statistically significant predictor of FP judgments or the likelihood of exchanging contact information, and therefore, not included in the MLMs.

To test our second hypothesis regarding how olfactory associations may update following the quality of live multimodal interactions, we ran an MLM predicting post-interaction olfactory judgments from live judgments, and statistically controlled for pre-interaction olfactory judgments and portrait (visual) judgments, all entered as fixed predictors.

Results

Preliminary analyses

Following recommendations for reporting MLM results[42], descriptive statistics and zero-order correlations for all key variables are reported in Table 1. As exploratory analyses, dyadic correlations for all modalities are reported in Table S1. As shown, the within-person correlations revealed that judgments of friendship potential (FP) across modalities were correlated ($ps < 0.05$). Raters who judged targets as having high FP based on pre-interaction diplomatic olfactory cues alone were also more likely to judge the same targets as having high friendship potential based on portrait (visual) cues alone. Moreover, FP judgments based on single modalities were all correlated with friendship potential based on the live multimodal interaction.

Additionally, for each modality, we assessed the extent to which FP judgments reflected perceiver effects (e.g., do some perceivers judge others as generally having higher (or lower) FP?), target effects (e.g., are some targets consensually judged by perceivers as having higher (or lower) FP?), and perceiver × target combinations (e.g., do perceivers make idiosyncratic judgments of which targets have higher (or lower) FP?). Variance estimates for each modality are reported in Fig. 3 (see Tables S2-S5 for full results of MLMs). We find that FP judgments reflect some target effects and some perceiver effects, but that the majority of the variability reflects idiosyncratic preferences. This pattern was highly similar across modalities, but the idiosyncratic component in olfactory and live judgments was almost double the variance observed for visual judgments.

Do pre-interaction olfactory judgments predict live multimodal judgments?

We examined the extent to which friendship judgments based solely on pre-interaction diplomatic olfactory cues forecasted FP judgments following the actual four-minute live, multimodal interaction in the speed-friending session. Results of MLM are reported in Table 2. Pre-interaction diplomatic olfactory judgments uniquely forecasted live judgments ($b = 0.16$, $p < .001$, 95% CI [0.11, 0.21]), even after statistically controlling

			Portrait (Visual)	Pre-interaction Olfactory	Live Multimodal	Post-interaction Olfactory
	Mean	*SD*				
Portrait (Visual)	4.57	0.71	-	0.14***	0.16***	0.06*
Pre-interaction Olfactory	4.31	0.69	0.37*	-	0.08**	0.41***
Live Multimodal	5.21	0.58	0.41**	0.50***	-	0.06*
Post-interaction Olfactory	4.31	0.77	0.35*	0.82***	0.45**	-

Table 1. Descriptive statistics and Zero-order correlations (Between- and Within-person) among portrait (Visual), live, and olfactory friendship potential (FP) judgments. Between-person Pearson correlations are reported in the lower diagonal; Within-person correlations in the upper diagonal ($df = 106$). Friendship potential judgments for all modalities were made on 7-point scales, with higher numbers reflecting greater friendship potential. *$p < .05$. **$p < .01$. *** $p < .001$.

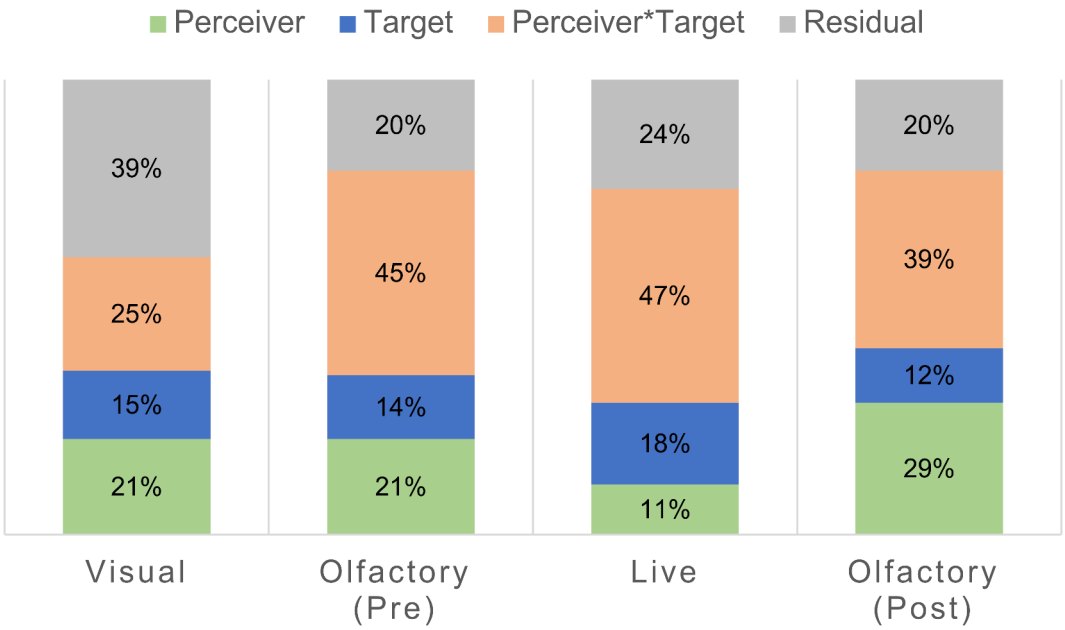

Fig. 3. Multilevel estimates of variance components reflecting perceiver effects, target effects, perceiver x target (idiosyncratic), and error (residual) for friendship potential judgments in each modality.

	Live Multimodal Judgments		
Predictors	*Estimates*	*95% CI*	*p*
(Intercept)	4.16	3.80–4.51	**< 0.001**
Portrait (Visual)	0.08	0.04–0.12	**< 0.001**
Pre-interaction Olfactory Judgments	0.16	0.11–0.21	**< 0.001**
Random Effects			
σ^2	0.39		
Perceiver: Target	0.82		
Perceiver	0.09		
Target	0.30		
ICC	0.76		
$N_{Perceiver}$	40		
N_{Target}	36		
Observations	1398		
Marginal R^2 / Conditional R^2	0.039 / 0.765		

Table 2. Multilevel model (MLM) estimates of Pre-interaction diplomatic olfactory judgments and portrait (Visual) judgments predicting live multimodal judgments in the Speed-Friending session.

for the predictive ability of portrait (visual) cues, which also forecasted FP judgments in the live interaction ($b = 0.08$, $p < .001$, 95% CI [0.04, 0.12]).

We conducted additional analyses to assess the robustness of these findings. First, we examined whether the results may be due to some targets having worn their t-shirts for longer than others. Although time worn was positively related to pre-interaction intensity judgments, it was not statistically significant ($b = 0.016$, $p = .068$) (see Supplemental Materials). Nonetheless, we reran our primary analyses with hours worn as a fixed predictor. All findings remain highly similar even when statistically controlling for hours worn (see Table S6).

Likewise, we examined whether the results might be due to the intensity of targets' smell. We reran our primary analyses with pre-interaction and live intensity ratings entered as fixed covariates. Again, the findings remain highly similar even when statistically controlling for intensity ratings (see Table S7). Interestingly, the intensity in the live interaction was positively related to FP in the live interaction ($b = 0.08$, $p = .031$).

Lastly, could these results be driven by universally opinionated perceivers (i.e., perceiver effects)? Although including rater as a random factor in our MLM models should take into account global perceiver effects. However, in mixed models with repeated measurements, effects may reflect a combination of within-person and between-person effects[43]. Thus, as an additional way for estimating the role of pre-interaction olfactory judgments on live interaction, we conducted a hybrid model. We computed each rater's mean of pre-interaction

	Post-interaction Olfactory Judgments		
Predictors	*Estimates*	*95% CI*	*p*
(Intercept)	2.33	1.95–2.71	**<0.001**
Portrait (Visual)	0.03	-0.01–0.07	0.094
Pre-interaction Olfactory Judgments	0.29	0.24–0.34	**<0.001**
Live Multimodal Judgments	0.12	0.07–0.16	**<0.001**
Random Effects			
σ^2	0.32		
Perceiver: Target	0.70		
Perceiver	0.24		
Target	0.10		
ICC	0.76		
$N_{Perceiver}$	40		
N_{Target}	36		
Observations	1394		
Marginal R^2 / Conditional R^2	0.130 / 0.795		

Table 3. Estimates of live interpersonal judgments predicting Post-interaction olfactory judgments, statistically controlling for Pre-interaction olfactory judgments and portrait (Visual) judgments.

olfactory judgments and the deviation of each rater's pre-interaction olfactory judgments from the rater's mean. We then entered these predictors into the MLM; the former estimates the between-person effect and the latter the within-person effects. The findings from the hybrid model corroborate our conclusions; the within-person estimate for the pre-interaction diplomatic olfactory judgments forecasted live judgments ($b = 0.15$, $p < .001$, 95% CI [0.09, 0.20]) (see Table S8).

How do live multimodal interactions forecast shifts in olfactory judgments?

We reasoned that the quality of the live interaction, as reflected in FP judgments, would predict updating olfactory associations, as reflected in post-interaction olfactory judgments. Results of the MLM revealed that live multimodal judgments predicted post-interaction olfactory judgments ($b = 0.12$, $p < .001$, 95% CI [0.07, 0.16]) (see Table 3), above and beyond pre-interaction olfactory judgments. We included portrait (visual) judgments as a predictor in the MLM with post-interaction olfactory judgments as the outcome to keep the MLMs equivalent. Nonetheless, when we reran the MLM without portrait (visual) judgments as a covariate, FP judgments based on the live multimodal interaction remained a statistically significant predictor of FP judgments based on post-interaction olfactory cues ($b = 0.11$, $p < .001$, 95% CI [0.07, 0.16]).

Again, we performed a hybrid model to examine the extent to which the results could be driven by perceiver effects. We entered each perceiver's mean live judgments and the deviation of their live judgments from the perceiver's mean into the MLM; the former estimates the between-person effect and the latter the within-person effects. The findings from the hybrid model corroborate our conclusions; the within-person estimate for the live judgments forecasted FP judgments based on post-interaction olfactory cues ($b = 0.11$, $p < .001$, 95% CI [0.06, 0.16]) (see Table S9).

Discussion

In our daily lives, evaluating other people is critical to navigating the social environment. Given the paramount importance of friendship to health and wellbeing, decisions regarding whom to befriend can have long-lasting impacts on emotional well-being, social status, and professional success. The present research highlights the understudied role of olfactory information in initial friendship preferences and the early stages of friendship development. In this study, we assessed the ability of olfactory cues to forecast social judgments in live, multimodal interactions, and the potential for the quality of those live interactions to modify olfactory preferences.

As hypothesized, we found that judgments of friendship potential immediately following a four-minute live, multimodal interaction were uniquely predicted by both diplomatic olfactory and portrait (visual) judgments. Further, we found that judgments in the live interactions predicted judgments in the post-interaction *t*-shirt judgments, above and beyond the initial relationship between olfactory cues and live judgments, suggesting that olfactory associations are modified by learning during the live interaction. This iterative modification of odor perception following live interactions could underlie learned responses to familiar body odors, supporting the idea that olfactory cues may reinforce emotional connections as a friendship develops.

Our study focused on how olfactory cues as encountered in everyday life may shape social judgments in platonic contexts. As platonic interactions make up the majority of social interactions on a daily basis for many individuals, this study sheds light on the influence of sensory cues in everyday life. It provides empirical evidence that these cues can be perceived in olfactorily "messy" environments and at social distances in multimodal interactions. Further, our use of diplomatic odor—and live interactions—is a rare approach[29] and provides support for the idea that olfactory cues are operating in ecologically relevant contexts, not just in laboratory settings.

To the best of our knowledge, only two other studies have examined olfactory and visual modalities in tandem with a live interaction[30,44]. In a mating context, Roth et al. (2021) found that judgments based on photographs (presented for longer than in our study) predicted liking in a live speed dating setting[37], but importantly, judgments based on natural odor did not. They suggested that perhaps diplomatic odor would be a better predictor of liking, and indeed that is what we find here. Ravreby et al. (2022) found that similarity of visual cues (face and torso) predicted how well women would get al.ong with a female partner in a platonic social interaction, and so did similarity of natural olfactory cues as rated by an e-nose. However, they did not directly test whether a person's *liking judgments* based solely on olfactory cues of a specific individual predicted the quality of an actual interaction with that person, nor did they examine diplomatic odor. Interestingly, human raters did not demonstrate an ability to predict the potential for perceived friendliness when evaluating body odors, though the e-nose did. Again, it is possible that this discrepancy is due to the use of natural rather than diplomatic body odor. The present research highlights the importance of using diplomatic odor to maximize ecological relevance.

Our data also allowed us to decompose whether friendship potential (FP) judgments reflect something about the person being judged, the person doing the judging, idiosyncratic effects, or unexplained sources. The results show that similar to other judgments like attractiveness[45], judgments of friendship potential across the different modalities are highly idiosyncratic. Indeed, close to half of the variance of FP appears to reflect unique preferences. The remainder of the variance reflects target effects (i.e., shared agreement about who has FP or not) and perceiver effects (i.e., perceivers' general tendencies to judge others as having more or less FP). This is consistent with other work examining the correspondence of judgments across modalities[46].

Importantly, idiosyncratic preferences showed consistency across modalities. For example, visual and olfactory judgments were related within-person (see Table 1), providing support for the notion that olfactory signals provide complimentary, rather than redundant, information in social interactions. In a recent meta-analysis of research using more traditional methodology and focused on mate selection, the authors found weak but statistically significant cross-modal associations between body odor and visual attractiveness[47]. Another recent study found weak but significant associations among olfactory, visual, and vocal cues specifically for women being judged by men, again using traditional methods and a mate-selection approach[46]. Our study focused on platonic interactions and using diplomatic odor also found small but statistically significant within-person correlations, but that olfactory and visual information each uniquely predicted judgments made in live interactions. Further, a comparison of the coefficients provides suggestive evidence that olfactory information may play a greater role than even visual information in predicting judgments in multimodal contexts. But we caution against overinterpreting these results; although we aimed to keep judgments in single modalities as comparable as possible, they still differed. Visual judgments were assessed online the day or two prior to the live in-person setting, whereas olfactory judgments were assessed in person immediately prior to the live in person interaction. Moreover, raters were limited in the visual information by presenting photographs for 100 ms, whereas raters had more time to inhale the scent from the *t*-shirt. Relatedly, the focal length and distance of the camera from our subjects were standardized, both of which could have influenced the general attractiveness of the photographs[48]. Nonetheless, our results support the idea that olfactory and visual information contribute different types of social information in the realm of first impressions and assessments of friendship potential.

There are some important constraints on generality to consider for this work. This study examined the responses of heterosexual females at an American university in a fairly narrow age range. College-age women are an appropriate population of interest given the importance of peer relations in this developmental period. Yet, it is possible that there might be some differences in how these cues function for older or younger women, or women in more mixed age groups, as well as how they might be utilized among men. Use of deodorant and fragranced products is common among American women[49], with online perfume, cosmetic, and fragrance sales driving $48.1 billion in revenue in 2024[50]. Future studies might consider a wider age range, investigate individuals at different stages of development, focus on how these cues function in male-male platonic interactions, or examine how scent in daily interactions shapes friendship judgments in other cultures.

Our findings are consistent with the proposition that olfactory cues shape the inferences we make about other individuals, as well as our own behaviors towards others. If you find someone's odor pleasant, even if you aren't consciously registering it, that odor may help to set your expectations about their behaviors. Additional interactions with this individual may help to strengthen (or weaken) the valence of associations with their body odor, functioning as a reinforcing cue in future interactions. This study demonstrates the complex, multimodal nature of platonic interpersonal interactions, and highlights the importance of diplomatic olfactory information in real life impression formation.

Data availability

Materials, data, and analysis scripts are available at https://osf.io/4k7mg/?view_only=0a1c534d2e494a72aac09d66bbe429fc

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Author contributions

Conceptualization: Gaby, J.M. and Zayas, V.; Methodology: Gaby, J.M., Gunaydin, G., and Zayas, V.; Data analysis: Zayas, V. in consultation with Gaby, J.M.; Writing – Original draft preparation: Gaby, J.M. and Zayas, V.; Writing: Review and editing: Gaby, J.M., Gunaydin, G., Zayas, V.; Funding acquisition: Zayas, V. and Gaby, J.M.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

Explicit informed consent was obtained from the participants for both study participation AND for the publication of identifying information/images in an online open-access publication. This experiment received ethics approval from the Cornell IRB under Protocol 1,203,002,865. All methods were performed in accordance with the Declaration of Helsinki. Preregistration: This study was not preregistered, as the data were collected in 2014 before preregistration of this type of work was common. We report all conditions, measures, and data exclusions.

Additional information

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