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Olfactory function and the social lives of older adults: a matter of sex

Sanne Boesveldt^{1,2}, Jason R. Yee³, Martha K. McClintock⁴, & Johan N. Lundström^{2,5,6}

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Social factors play a critical role in a panoply of health processes, including, as recently demonstrated, olfaction. Here, we investigated sex-dependent differences in the relationship between social lives and ability to identify odors in a large sample of nationally representative older US adults (n = 3005, National Social Life and Aging Project (NSHAP)). Social life was measured by the number of friends and close relatives as well as frequency of socializing. We here confirm the association between social lives and olfactory function and extend the notion by showing specifically that olfactory identification ability is modulated by sex in older adults. The connection between olfactory performance and social lives could reflect social modulation of aging as has been reported for health in general. Future studies are necessary to elucidate the precise mechanisms underlying this association and sex difference.

The olfactory sense is an often overlooked but significant factor for a vital social life. It has recently been demonstrated that odors are involved in social communication between humans where tentative evidence suggests that body odors communicate the age and health status of an individual to others^{1,2}, as well as emotional state^{3–5}, thus highlighting the social relevance of chemosignals. Moreover, most social interactions involve the act of drinking or eating where an impaired sense of smell will severely impair one's experience given that smell is a principal component of the flavor percept when tasting food and drinks⁶ and an olfactory impairment will severely limit one's ability to detect rotten or spoiled food⁷. Several recent studies have found links between olfactory loss and impaired overall health and well-being (e.g. ref. 8 and 9) and individuals who are ill or feel unwell tend to limit their social interactions. In addition, a recent survey amongst members of the Fifth Sense, a British patient organization of people suffering from olfactory loss, reported that 59% of respondents have issues with social interactions¹⁰; also, people with congenital anosmia exhibit social insecurity, resulting for example in a decreased number of sexual contacts¹¹. Taken together, data from a range of various sources exists that indicate a link between the sense of smell and the ability to maintain a vital social life. It came as no surprise that a recent paper demonstrated a link between social network size and olfactory function¹².

In a small homogenous sample of young adult ethnic Chinese, Zou and colleagues¹² demonstrated a positive correlation between the number of an individual's social contacts and their olfactory sensitivity as well as with functional connectivity between amygdala and the orbitofrontal cortex. However, they did not find an association with the ability to identify odor, in which there are well-established sex differences. Women outperform men in odor identification throughout the lifespan^{13,14}, and maintain more salient social connections¹⁵. Unfortunately, limited sample size necessitated by Zou and colleagues¹² neural imaging measures preclude any meaningful examination of sex difference with sufficient statistical power. Moreover, the sample employed by Zou and colleagues was not representative of the diverse US population and did not include older adults over age 50. Therefore, we set out to determine if the failure to identify an association between social network and olfactory identification could result from sex-dependent differences in the relationship between social life and ability to identify odors. We utilized a large sample of nationally representative older US adults (n = 3,005) using data obtained from the National Social Life, Health and Aging Project (NSHAP).

NSHAP is a population-based study of health and social factors on a national scale, aiming to understand the well-being of older, community-dwelling Americans by examining the interactions between physical health and social factors. It is unique in including health of sensory function, such as olfaction, as well as illness, medication use, cognitive function, emotional health, health behaviors, and social connectedness¹⁶. Older adults are the fastest growing division of the population, and a large proportion of those will experience age-related chemosensory loss^{13,17}, and older people generally have smaller social networks and are often socially more isolated. In line with

¹Division of Human Nutrition, Wageningen University, Wageningen, the Netherlands. ²Monell Chemical Senses Center, Philadelphia, PA, USA. ³Dept. of Psychology, Northeastern University, Boston, MA, USA. ⁴Depts. of Psychology and Comparative Human Development, University of Chicago, Chicago, IL, USA. ⁵Dept. of Psychology, University of Pennsylvania, Philadelphia, PA, USA. ⁶Dept. of Clinical Neuroscience, Karolinska Institutet, Stockholm, Sweden. Correspondence and requests for materials should be addressed to S.B. (email: sanne.boesveldt@wur.nl)

Sex (m/f)	1455/1550
Age (range/mean/SD)	57–85/69.3/7.9
Odor ID scores (range/mean/SD)	0–5/4.1/1.0
Education (<hs/hs, equiv/vc, assoc/bchl)	699/793/856/657
Smoking (current/former/no)	444/1287/1272
Self-reported physical health (poor/fair/good/very good/excellent)	224/582/906/921/360
Self-reported mental health (poor/fair/good/very good/excellent)	53/288/837/1098/719

Table 1. Participant characteristics (total population). ID = identification; <hs = less than high school; hs, equiv = high school diploma/equivalency; vc, assoc = associate's (2-year college) or post-HS vocational certificate; bchl = bachelor's (4-year college) degree or more.

the results of Zou *et al.*¹², we hypothesized that smaller social lives would be manifested in individuals exhibiting reduced ability to identify odors and that these associations would be more pronounced in women.

Methods

Subjects. Data were collected from a nationally-representative sample of 3,005 American adults ranging from 57 to 85 years of age (mean age 69.3 years, SD = 7.9; 1455 men, 1550 women; for more detailed description of relevant participant characteristics, see table 1; for a complete description of the NSHAP sample design, see ref. 18). Biomeasure collection and face-to-face interviews performed by trained interviewers took place in respondents' homes. The protocol was approved by the institutional review boards of the University of Chicago and NORC (National Opinion Research Center), and was in accordance with the Declaration of Helsinki; all respondents provided written informed consent.

Olfactory function testing. Olfactory function was assessed using a validated brief odor identification test^{16,19}. Five odorants in suprathreshold concentration were presented in a multiple forced-choice format with four possible descriptors of each odorant presented as a word-picture combination. Following a forced-choice paradigm, respondents were not permitted to answer "don't know". Each pen was held approximately 2 cm in front of the nostrils for 2–3 seconds, with an interval of 20–30 seconds between each pen. Olfactory identification scores were defined as the number of correct responses.

Social lives. Size of social life was assessed by an in-person interview, asking subjects how many friends they have ('number of friends'; none, one, 2–3, 4–9, 10–20, >20), how many family members or relatives they feel close to ('number of close relatives'; none, one, 2–3, 4–9, 10–20, >20) and what the frequency of socializing with friends or relatives in the past year has been ('frequency of socializing'; never, less than once a year, about once or twice a year, several times a year, about once a month, every week, several times a week). These measures are more extensively described in ref. 20.

An 'overall social life' measure was computed by first *z*-transforming the measure (number of friends, number of close relatives, and frequency of socializing) and then summing them up to create a score that closely resembles the Cohen's 1991 "Social Network Size" measure²¹ used by Zou and colleagues¹².

Data analysis. Subjects with missing values on the odor identification test ($n = 227$), the social life questions ($n = 209$ for 'close relatives', $n = 197$ for 'number of friends', $n = 533$ for 'frequency of socializing') were excluded from the respective analyses.

Survey weighted data were used to incorporate a non-response adjustment based on age and urbanicity as well as oversampling to provide power for analyzing race and age differences¹⁸. Thereby, the reported results reflect the diverse US population, not just the random sample interviewed. All further results are based on these weighted data.

Spearman correlation coefficients were computed to determine the correlation between olfactory function and social life measures, for all participants combined as well as for men and women separately. As did previous work (12), we excluded the possibility of confounding effects on the observed relations between olfactory identification and social lives, by also conducting partial correlation controlling for age (years), education (less than high school, high school diploma/equivalency, associate's [2-year college] or post-high school vocational certificate, bachelor's [4-year college] degree or more), self-reported physical health (poor, fair, good, very good, excellent), current smoking (yes/no) and self-reported mental health (poor, fair, good, very good, excellent). To determine the difference in odor identification between subjects with large and small social lives, we computed non-parametric tests comparing median and distribution of olfactory function scores between the upper and lowest quartile of the overall social life measure. Finally, to formally test differences between the sexes for the relation between odor identification and social life, we performed regression analyses with overall social life as predictor and olfactory function as dependent variable, and compared the separate regression coefficients for men and women²². All analyses were performed with IBM SPSS Statistics, version 23.

Results

Respondents typically correctly identified four of the five odors (mean $4.2 \pm$ SD 1.0, median 5.0) in the olfactory identification test, and women performed better than men (women $4.3 \pm$ 0.9, median 5.0; men $4.1 \pm$ 1.1, median

	Number of friends (M/F) Total n = 2,808	Number of relatives feels close to (M/F) Total n = 2,796
0	60/71	44/25
1	36/46	83/55
2–3	277/270	360/351
4–9	381/475	557/654
10–20	298/351	202/262
>20	300/243	93/110
	Frequency of socializing in past year (M/F Total n = 2,472)	
Never	26/25	
Less than once a year	8/12	
About once or twice a year	62/57	
Several times a year	219/202	
About once a month	267/295	
Every week	423/466	
Several times a week	175/235	

Table 2. Social Life Characteristics Number of subjects (male/female) per ‘social category’.

4.0; $Z = -3.61$, $p < 0.01$). For social life characteristics, see Table 2. There was no significant difference between men and women for ‘overall social life’ ($Z = -1.1$, $p = 0.27$).

Link between overall social life and olfactory performance. A significant positive correlation was found between odor identification performance and the measure for overall social life using a Spearman correlation coefficient analysis, $\rho = 0.08$, $p < 0.01$ as well as a significant difference in odor identification between the upper and lower quartile of overall size of social lives (lower quartile mean 4.1 ± 1.0 , median 4.0, upper quartile 4.3 ± 1.0 , median 5.0; $Z = -2.35$, $p = 0.02$).

When calculating the correlation coefficient separately for men and women, a significant positive correlation was found for women between odor identification and overall social life size ($\rho = 0.15$, $p < 0.01$), but not for men ($\rho = 0.01$, $p = 0.67$). Regression analyses confirmed significant sex differences in the relation between odor identification and overall social life ($p = 0.02$; women (standardized beta = 0.16, $p < 0.01$) vs. men (standardized beta = 0.05, $p = 0.10$). Women in the upper quartile of overall social life score performed significantly better on the odor identification test (mean score 4.4 ± 0.9 , median 5.0) than women in the lower quartile (mean score 4.2 ± 0.9 , median 4.0; $Z = -3.51$, $p < 0.01$). This difference was not observed for men ($Z = -0.18$, $p = 0.86$).

After controlling for several possible confounding factors (age, education level, current smoking, physical, and mental health status), the significant correlation between odor identification and overall social life was still present ($\rho = 0.08$, $p < 0.01$). When re-analyzing the link between overall social life and odor identification using this more controlled model for men and women separately, a significant positive correlation was found for women between odor identification and overall social life, $\rho = 0.13$, $p < 0.01$, but not for men, $\rho = 0.04$, $p = 0.18$.

Equal contribution of individual measures for social life. After demonstrating a significant association between social life and odor identification performance, we asked whether this overall relationship resulted primarily from one of the three attributes of social life (number of friends, number of close relatives, and frequency of socializing). After controlling for several possible confounding factors (age, education level, current smoking, physical and mental health status), all measures contributed to the overall effect, albeit not all significantly: positive correlations were found between odor identification and number of friends, $r = 0.07$, $p < 0.01$, number of close relatives, $r = 0.07$, $p < 0.01$, and a trend for frequency of socializing, $r = 0.04$, $p = 0.09$.

When analyzing these data separately for men and women, significant positive correlations were found for women between odor identification and number of friends, $r = 0.12$, $p < 0.01$, number of close relatives, $r = 0.09$, $p < 0.01$, and frequency of socializing, $r = 0.07$, $p = 0.02$. For men, there was a trend between odor identification and number of friends, $r = 0.05$, $p = 0.10$ but no significant correlations for number of close relatives, $r = 0.04$, $p = 0.15$, or frequency of socializing, $r = -0.009$, $p = 0.76$.

Discussion

We here demonstrate that there is a connection between odor identification performance and measures of social life for women, but not for men. These findings extend the results recently published by Zou and colleagues¹². The current data are consistent with the large body of evidence that social interactions are intimately linked to health status (20–25), and includes olfactory identification performance as another key aspect of health.

We found that all three attributes of social life show a similar pattern: a positive correlation between odor identification and social life, even after correcting for several possible confounding factors, indicates that this is a robust result. Moreover, that an olfactory test this brief^{16,19} can detect the phenomenon also indicates its robustness.

Zou and colleagues¹² did not report a significant result for olfactory identification, although they did for olfactory sensitivity. Given the relatively low sample size ($n = 31$) employed by Zou and colleagues¹², our different results could be explained by our large sample providing achieved explanatory power, $pw > 0.99$.

Numerous studies have reported sex differences in the relation between social networks and health measures^{23–25}, and it is therefore not surprising that the current data demonstrate significant associations between social life and olfactory identification for women, but not for men. Women generally outperform men in odor identification²⁶, and, in addition, men and women appear to respond differently to social relationships which may be associated with different mediating psychobiological processes^{15,27–29}. Several studies have reported sex differences in the association between social support or network and health, demonstrating that the positive effect of social contact was much greater for women than men^{15,30}. However, others showed among men, but not women, that social integration is associated with an increased mortality risk or elevated c-reactive protein levels, an inflammatory marker^{23,24,31}.

Theoretical work on sex differences in self-representations suggests that women's self-construal is more influenced by relational concerns than in men^{32,33}, making them more susceptible to the content and quality of their relationships, both emotionally and physiologically. Consistent with this hypothesis, prior work has shown that the positive association between social behavior and lifespan is stronger for women at each age group³⁴. Furthermore, women exhibit heightened stress-induced cortisol responses when challenged with social rejection, while men exhibit heightened responses when faced with threats to achievement-related goals³⁵. Alternatively, the obtained correlation between social connections and olfactory identification might be explained by a sex-dependent difference in salience of odors in general—because they transport interpersonal information or carry signals that could be related to social activities like eating and drinking – as well as in interest in social interactions³⁶.

The potential biological link between olfactory identification performance and social life is not clear. Olfactory identification performance has been demonstrated as a measure of general health^{9,17}, and numerous studies have established that size of social networks or quality of social support play a critical role in determining health status^{37–39}. A small social network or lack of social support has been associated with a long list of negative health outcomes, e.g. increased mortality risk^{30,31,40,41}, delayed recovery from disease^{41,42}, increased risk of cardiovascular disease^{25,41,43}, memory loss⁴⁴, and general illness symptoms^{45,46}. Therefore, the association between social life and odor identification could be a result of both factors being related to positive health. In addition to this, it has been shown that body odors may convey signals of sickness², and olfaction may thus serve to protect healthy individuals from sick ones by altering patterns of interpersonal contact, whereas people with compromised olfactory function may lack this social functionality.

The observed correlation between social life and olfactory function could, alternatively, be an epiphenomenon of other co-existing factors, such as early non-diagnosed stages of neurodegenerative disorders. However, many of these diseases have a higher incidence in men, whereas our findings demonstrate a clear association between olfactory performance and social life only in women. Moreover, we tried to exclude the possibility of confounding factors or potential mediators for the observed relationship by controlling for education level, physical and mental health, age and smoking in our analyses, thereby strengthening our final results. Nonetheless, further research is needed to determine whether additional explanatory variables unavailable in the large-scale dataset we examined, such as cognition⁴⁷, mediate the relationship between maintaining a large social life and the ability to identify an odor. Moreover, future studies should collect a broader array of both social and biological measures to allow explorations of potential mechanisms through which olfaction is linked to social factors.

One of the limitations of the present study is its cross-sectional design, thereby not allowing us to make directional claim of the obtained correlations. Although social networks have been demonstrated to influence health status (e.g. ref. 30, it is plausible that an impairment in the sense of smell can affect a subject's social network. Chemosensory functions do play an important role in the safety and quality of life and has been closely linked to psychological well-being in young and old alike. A survey among patients with olfactory disorders demonstrated that over 50% of respondents reported increased concerns about personal hygiene, such as breath or body odor and problems with social interactions in general^{10,48,49}. Many older people report that they become embarrassed eating with others because they are not hungry, or are having trouble swallowing/chewing the food⁵⁰. Also, older adults that have intact olfactory function may still enjoy eating^{51,52}, and therefore continue to socialize over meals^{53,54}. In other words, olfactory dysfunction may cause subjects to become socially isolated. For instance, it is long known that there is a strong link between olfactory dysfunction and depression⁵⁵. Conversely, social isolation in itself could also contribute to limited experience with (exposure to) odors, which may negatively affect performance on odor identification. Future research using longitudinal data is needed to clarify the causality of these connections between social life and olfactory function.

In conclusion, these data extend previous findings, supporting the theory that size of social life is related to olfactory function. Strikingly, it was detected only in women. Those who perform better in a brief olfactory identification test have larger social lives than women with poorer olfactory identification ability. While the precise mechanisms underlying the association between social life and olfactory function in older adults are unclear, it is evident that this could be of significance in our aging population.

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Author Contributions

M.K.M. & J.L. initiated the idea, S.B. analysed the data and S.B., J.Y., M.K.M. and J.L. interpreted the results and wrote the manuscript.

Additional Information

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