Chapter 11
The Influence of Sexual Orientation on Human Olfactory Function

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Abstract Sexual orientation influences human olfactory function. Following a brief review of the biological basis of homosexuality, this chapter explores exactly how olfactory function varies as a result of sexual orientation. Three separate areas of research are considered: recent studies on the neural processing of social odorants by heterosexuals and homosexuals; the influence of sexual orientation on the production and perception of body odours; and the influence of female sexual orientation on menstrual synchrony.

11.1 Introduction

An individual's sexual orientation is usually described in terms of one of two distinct and mutually exclusive groups, *heterosexual* (sexual interest in members of the opposite-sex) and *homosexual* (sexual interest in members of the same-sex). Some academics have questioned this form of classification, arguing that such groups reflect arbitrary and socially constructed categories (e.g., Muehlenhard 2000). Initial taxometric studies of male sexual orientation, however, strongly suggest that classifying individuals as either heterosexual or homosexual does reflect an objective system of categorization (Gangestad, Bailey and Martin 2000), as does evidence of a similar manifestation and etiology of male homosexuality across cultures with disparate views on sexuality (Whitam and Zent 1984). Although sexual orientation also appears to be biomodally distributed among females, research into this area is somewhat more complicated due to the greater degree of plasticity in female sexual expression (Chivers, Rieger, Latty and Bailey 2004). This, coupled with the lower incidence of female homosexuality (roughly 1% of the female population compared to 2% to 5% of the male population; Rahman and Wilson 2003a), has resulted in most empirical research focusing on male rather than female sexual orientation.

Several lines of research suggest a biological basis to homosexuality. Behavioural genetics studies have suggested a strong coinheritance of homosexuality among monozygotic twins compared to dizygotic twins and genetic and adopted

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siblings (e.g., Bailey, Dunne and Martin 2000; Kendler, Thornton, Gilman and Kessler 2000). A number of researchers have also noted a specific association between several genetic regions and the development of homosexuality among male siblings (Hamer, Hu, Magnuson, Hu and Pattatucci 1993; Mustanski, DuPree, Nievergelt, Bocklandt, Schork and Hamer 2005). Several studies have also documented differences between sexual orientation groups in several sexually dimorphic neural regions such as the supra-chiasmatic nucleus (Swaab and Hofman 1990), the interstitial nucleus of the anterior hypothalamus (LeVay 1991) and the midsagittal plane of the anterior-commissure (Allen and Gorski 1992). Readers seeking a more detailed overview of literature on the biological basis to homosexuality are referred to the review by Rahman and Wilson (2003a).

Given the evidence for sex differences in olfactory function (e.g., Brand and Millot 2001; Garcia-Falgueras, Junque, Gimenez, Caldu, Segovia and Guillamon 2006), and the sex-atypicality of homosexual individuals on tasks eliciting sexually dimorphic reactions (e.g., spatial rotation tasks; Rahman and Wilson 2003b), it is not surprising that several authors have investigated the influence of sexual orientation on olfactory function. The remainder of this chapter will review the literature on this topic, focusing on three separate areas of research:, recent studies on the neural processing of social odorants by heterosexuals and homosexuals, the influence of sexual orientation on the production and perception of body odours and the influence of female sexual orientation on menstrual synchrony

11.2 The Neural Processing of Social Odorants

Two substances frequently, though perhaps incorrectly, labeled as human pheromones are the progesterone derivative 4, 16-androstadien-3-one (androstadienone) and the estrogen-like estra-1, 3, 5(10), 16-tetraen-3-ol (estratetraenol). Both substances have been previously reported to influence mood state and physiological arousal in males and females, though the specific pattern of findings varies considerably between studies (Bensafi, Tsutsui, Levenson and Sobel 2004; Jacob and McClintock 2000). Bensafi et al. (2004) suggest that some of these inconsistencies may be due to the concentrations of odorants utilized in each study, as androstadienone at least appears to function in a dose-dependent fashion.

A number of recent studies have examined neuropsychological reactions to androstadienone and estratetraenol. Using functional magnetic resonance imaging (fMRI), Sobel, Prabhakaran, Hartley, Desmond, Glover, Sullivan and Gabrieli (1999) noted that male participants exposed to estratetraenol showed significant activation of the inferior frontal gyrus (primarily involved in language processing/production and face recognition) and anterior medial thalamus (a relay station to and from the cerebral cortex involved in arousal and the integration of sensory information). Furthermore, research by Savic, Berglund, Gulyas and Roland (2001) suggests that this form of neural activation is sexually dimorphic. Androstadienone was found to activate the preoptic and ventromedial nucleus

in females, while estratetraenol was found to activate the paraventricular and dorsomedial nuclei in males. Thus there was a sexually dimorphic pattern of activation, with androstadienone activating the hypothalamic region in females and, to a lesser degree, the olfactory region in males, while estratetraenol activated the hypothalamic region in males and the olfactory region in females.

Using positron emission tomography (PET) imaging, Savic, Berglund and Lindström (2005) examined the reactions of 12 homosexual males to both androstadienone and estratetraenol, with 12 heterosexual males and 12 heterosexual females acting as control participants. The homosexual male participants demonstrated sex-atypical reactions to the compounds, showing hypothalamic activation in response to androstadienone but not estratetraenol. A similar study by Berglund, Savic and Lindström (2006) examined reactions to these compounds by 12 homosexual females, with 12 heterosexual males and 12 heterosexual females again acting as controls. Berglund et al. (2006) also report that homosexual females demonstrated sex-atypical reactions, showing hypothalamic activation in response to estratetraenol but not to androstadienone. The differences between the two female groups were not, however, as marked as those of the two male groups. However, these findings suggest that reactions to androstadienone and estratetraenol are not simply dependent upon an individual's biological sex, but also upon their sexual orientation (i.e., the target of their sexual and romantic attractions). These findings are also commensurate with two recent reports that sexual orientation has a strong influence on neural responses to both facial images (Kranz and Ishai 2005) and sexually arousing stimuli (Ponseti Bosinski, Wolff, Peller, Jansen, Mehdorn, Büchel, and Siebner 2006), with homosexual individuals again showing reactions more consistent with members of the opposite biological sex.

11.3 The Production and Perception of Body Odour

A growing body of research suggests body odour is an effective method of communication able to convey information on, among other things, an individual's immune system characteristics (Wedekind and Füri 1997), current fertility status (Kuukasjärvi, Eriksson, Koskela, Mappes, Nissinen and Rantala 2004) and the degree of fluctuating asymmetry they demonstrate (Gangestad and Thornhill 1998). Thus far, however, virtually all research in this area has focused on the characteristics and reactions of heterosexual participants, with no focus on how body odour is either produced or perceived by homosexual individuals. To date, only one published study has examined this area. Martins, Preti, Crabtree, Runyan, Vainius and Wysocki (2005) collected body odour samples from 24 heterosexual and homosexual males and females (6 in each group) which were then rated by a sample of 80 heterosexual and homosexual males and females (20 in each group). As with other studies of body odour, the samples were collected under strictly controlled conditions, in an attempt to control for numerous potentially confounding variables associated with individual dietary, hygiene and behavioural practices.

The pattern of preferences for body odour differed noticeably between orientation groups. Homosexual males displayed a strong preference for the odour of other homosexual males and, to a lesser degree, heterosexual females. Conversely, heterosexual males and females and homosexual females found the odour of homosexual males to be the least preferred odour that was presented. Homosexual and heterosexual females provided an equivalent pattern of responses, preferring odours from heterosexual rather than homosexual individuals. Heterosexual males showed no significant preferences towards the odour of any group, except for the strong dislike of odour from homosexual males. Intriguingly these findings do not appear to be based on quantitative differences between groups, as there were no significant differences in the intensity of body odour from any of the four orientation groups. This suggests that sex and sexual orientation influence body odour in a qualitative rather than quantitative manner.

Taken comprehensively these findings suggest there are clear differences in the production and perception of body odour for sexual orientation groups. In particular, the differences between heterosexual and homosexual males were more distinct than those between heterosexual and homosexual females. Differences in the production and perception of body odour may result from a combination of environmental or biological factors, for example, differences in axillary flora and gland function, lifestyle factors such as frequency of exercising or differences in HLA (human leukocyte antigen) alleles or other genetic regions. Given the wealth of information that can be conveyed through body odour, it is also possible that the behavioural effects of this information may vary between sexual orientation groups.

11.4 Menstrual Synchrony among Homosexual Females

Menstrual synchrony is the purported tendency of females who either co-habit or interact over an extended period of time to have co-occurring menses (Wyatt 2003). This process was first documented by McClintock (1971), but has since been corroborated by several other researchers (e.g., Graham and McGrew, 1980; Weller and Weller 1997). Furthermore, experimental evidence suggests this phenomenon relies on a semiochemical mechanism; axillary secretions collected from females at different stages of their menstrual cycle have the potential to accelerate or delay the onset of menses in other females (Preti, Cutler, Garcia, Huggins and Lawley 1986; Stern and McClintock 1998). However, other researchers have found no evidence for synchrony between heterosexual females (Strassman 1997; Wilson, Hildebrandt Kiefhaber and Gravel 1991), while other authors have highlighted that research on menstrual synchrony is often flawed due to a failure to statistically control for female participants with an irregular menstrual cycle or the convergence of menses by chance (Schank 2001).

Given inconsistent findings, the use of homosexual females as participants provides three distinct advantages compared to heterosexual females (Weller and

Weller 1992). Firstly, as synchrony is based on the interaction between closely affiliated females, the high degree of intimacy within a homosexual female couple should maximize the degree of synchrony that occurs. Secondly, studying homosexual female couples effectively eliminates the likelihood of female participants interacting sexually with males, which also influences synchrony (Cutler, Garcia and Krieger 1980; Veith, Buck, Getzlaf, Van Dalfsen and Slade 1983). Finally, homosexual females are less likely to be using hormone-based contraceptives to prevent pregnancy, though they may be used by homosexual females for other purposes such as to control acne or heavy menstrual bleeding (Cochran et al. 2001). This is important as hormone-based contraceptives have been demonstrated to influence olfactory function (Caruso, Grillo, Agnellio, Maolino, Intelisano and Serra 2001).

To date, no experimental study has assessed whether female axillary secretions can accelerate or delay the onset of menses in homosexual females. As a result it is difficult to comment on whether there is an analogous mechanism of synchronization among heterosexual and homosexual females. However, three studies have assessed whether homosexual female couples demonstrate the behavioral consequence of synchronization; a gradual convergence of menstrual cycle timing. As part of a larger study of sexual responsiveness, Matteo and Rissman (1984) examined the menstrual cycle timing of 7 homosexual female couples over a period of 14 consecutive weeks. Due to the small sample size involved the researchers were unable to statistically analyze menstrual cycle data, but they did report that none of the homosexual female couples were perfectly synchronized and that there was considerable variance in menstrual cycle timing. In a more detailed study, Weller and Weller (1992) examined the degree of synchrony among 20 homosexual female couples. The researchers noted that synchrony occurred at more than chance levels, with approximately half of the couples menstruating within 2 days of each other. Furthermore, synchrony was more noticeable among couples with regular menstrual cycles and a high degree of emotional intimacy and shared activities. These findings stand in stark contrast to those of Trevathan, Burleson and Gregory (1993), who found no evidence for menstrual synchrony among 29 homosexual female couples. Over the course of three consecutive menstrual cycles, there was no evidence for synchrony among couples, with the timing of menstruation appearing to diverge rather than converge in many cases. Furthermore, these findings did not differ when irregularity in menstrual cycle length or possible interactions with other roommates were taken into account.

Given the inconsistent findings for menstrual synchrony among heterosexual females, it is difficult to interpret the above findings for homosexual females. While one study (Weller and Weller 1992) appears to demonstrate that homosexual females do synchronize their cycles, two other studies detected no evidence of synchronization among homosexuals (Matteo and Rissman 1984; Trevathan et al. 1993). It is apparent that further research is required to interpret menstrual synchrony among homosexual females. In particular, there is a need for experimental studies to address whether a potentially analogous mechanism of synchronization described among heterosexual females exists in homosexual females.

11.5 Conclusions

Several avenues of research now suggest that sexual orientation has a noticeable impact on human olfaction. In particular, it has been demonstrated that homosexual individuals show neural reactions to social odorants that are similar to heterosexual members of the opposite biological sex (Berglund et al. 2006; Savic et al. 2005) and that sexual orientation influences the production and perception of body odour (Martins et al. 2005). With regard to menstrual synchrony among females, the influence of sexual orientation is less clear and is complicated by numerous conflicting studies based on heterosexual females. This may be further complicated by the comparative differences between sexual orientation groups for males and females. The reactions of homosexual females were comparatively similar to those of heterosexual females with regard to both the neural processing of odorants and perceptions of body odour. The reactions of homosexual males differed noticeably from those of heterosexual males in both of these areas. Such findings are consistent with the greater differences documented for other characteristics based on sexual orientation for males rather than females (Chivers et al. 2004).

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References

Allen, L.S. and Gorski, R.A. (1992) Sexual orientation and the size of the anterior commissure in the human brain. P. Natl. Acad. Sci. USA 89, 7911–7202.

Bailey, J.M., Dunne, M.P. and Martin, N.G. (2000) Genetic and environmental influences on sexual orientation and its correlates in an Australian twin sample. J. Pers. Soc. Psychol. 78, 524–536.

Bensafi, M., Tsutsui, T., Levenson, R.W. and Sobel, N. (2004) Sniffing a human sex-steroid derived compound affects mood and autonomic arousal in a dose-dependent manner. Psychoneuroendocrinol. 29, 1290–1299.

Berglund, H., Savic, I. and Lindström, P. (2006) Brain response to putative pheromones in lesbian women. P. Natl. Acad. Sci. USA 103, 8269–8274.

Brand, G. and Millot, J.L. (2001) Sex differences in human olfaction: beyond evidence and enigma. Q. J. Exp. Psychol-B 54, 259–270.

Caruso, S., Grillo, C., Agnellio, C., Maolino, L., Intelisano, G. and Serra, A. (2001) A prospective study evidencing rhinomanometric and olfactometric outcomes in women taking oral contraceptives. Hum. Reprod. 16, 2288–2294.

Chivers, M.L., Rieger, G., Latty, E. and Bailey, J.M. (2004) A Sex Difference in the Specificity of Sexual Arousal. Psychol. Sci. 15, 736–744.

Cochran, S.D., Mays, V.M., Bowen, D., Gage, S., Bybee, D., Roberts, S.J., Goldstein, R.S., Robison, A., Rankow, E.J. and White, J. (2001). Cancer-related risk indicators and preventive screening behaviors among lesbians and bisexual women. Am. J. Public Health 91, 591–597.

Cutler, W.B., Garcia, C.R. and Krieger, A.M. (1980) Sporadic sexual behavior and menstrual cycle length in women. Horm. Behav. 14, 163–172.

Gangestad, S.W., Bailey, J.M. and Martin, N.G. (2000) Taxometric analyses of sexual oriention and gender identity. J. Pers. Soc. Psychol. 78, 1109–1121.
Gangestad, S.W. and Thornhill, R. (1998) Menstrual cycle variation in women's preference for the scent of symmetrical men. P. Roy. Soc. Lond. B 265, 927–933.
Garcia-Falgueras, A., Junque, C., Gimenez, M., Caldu, X., Segovia, S. and Guillamon, A. (2006) Sex differences in the human olfactory system. Brain Res. 1116, 103–111.
Graham, C.A. and McGrew, W.C. (1980) Menstrual synchrony in female undergraduates living on a co-educational campus. Psychoneuroendocrinol. 5, 245–252.
Hamer, D.H., Hu, S., Magnuson, V.L., Hu, N. and Pattatucci, A.M.L. (1993) A linkage between DNA markers on the X chromosome and male sexual orientation. Science 261, 321–327.
Jacob, S. and McClintock, M.K. (2000) Psychological state and mood effects of steroidal chemosignals in women and men. Horm. Behav. 37, 57–78.
Kendler, K.S., Thornton, L.M., Gilman, S.E. and Kessler, R.C. (2000) Sexual orientation in a U.S. national sample of twin and non-twin sibling pairs. Am. J. Psychiat. 157, 1843–1846.
Kranz, F. and Ishai, A. (2006) Face perception is modulated by sexual preference. Curr. Biol. 16, 63–68.
Kuukasjarvi, S., Eriksson, C.J.P., Koskela, E., Mappes, T., Nissinen, K. and Rantala, M.J. (2004) Attractiveness of women's body odors over the course of the menstrual cycle: The role of oral contraceptives and receiver sex. Behav. Ecol. 15, 579–584.
LeVay, S. (1991) A difference in hypothalamic structure between heterosexual and homosexual men. Science 253, 1034–1037.
Martins, Y., Preti, G., Crabtree, C.R., Runyan, T., Vainius, A.A. and Wysocki, C.J. (2005) Preference for human body odors is influenced by gender and sexual orientation. Psych. Sci. 16, 694–701.
Matteo, S. and Rissman, E.F. (1984).Increased sexual activity during the midcycle portion of the human menstrual cycle. Horm. Behav. 18, 249–255.
McClintock, M.K. (1971) Menstrual synchrony and suppression. Nature 229, 244–245.
Muehlenhard, C.L. (2000) Categories and sexuality. J. Sex Res. 37, 101–107.
Mustanski, B.S., DuPree, M.G., Nievergelt, C.M., Bocklandt, S., Schork, N.J. and Hamer, D. (2005) A genomewide scan of male sexual orientation. Hum. Genet. 116, 272–278.
Ponseti, J., Bosinski, H.A., Wolff, S., Peller, M., Jansen, O., Mehdorn, H.M., Büchel, C. and Siebner, H.R (2006) A functional endophenotype for sexual orientation in humans. NeuroImage 33, 825–833.
Preti, G., Cutler, W.B., Garcia, C-R., Huggins, G.R. and Lawley, H.J. (1986) Human axillary secretions influence women's menstrual cycles: the role of donor extract of female. Horm. Behav. 20, 474–482.
Rahman, Q. and Wilson, G.D. (2003a) Born gay? The psychobiology of human sexual orientation. Pers. Indiv. Differ. 34, 1337–1382.
Rahman, Q. and Wilson, G.D. (2003b) Large sexual orientation related differences in performance on mental rotation and judgment of line orientation. Neuropsychol. 17, 25–31.
Savic, I., Berglund, H., Gulyas, B. and Roland, P. (2001) Smelling of odourous sex hormone-like compounds causes sex-differentiated hypothalamic activation in humans. Neuron 31, 661–668.
Savic, I., Berglund, H. and Lindström, P. (2005) Brain response to putative pheromones in homosexual men. P. Natl. Acad. Sci. USA 102, 7356–7361.
Schank, J.C. (2001) Menstrual-cycle synchrony: problems and new directions for research. J. Comp. Psychol. 115, 3–15.
Sobel, N., Prabhakaran, V., Hartley, C.A., Desmond, J.E., Glover, G.H., Sullivan, E.V. and Gabrieli, J.D.E. (1999) Blind smell: brain activation induced by an undetected air-borne chemical. Brain 122, 209–217.
Stern, K. and McClintock, M.K. (1998) Regulation of ovulation by human pheromones. Nature 392, 177–179.
Strassmann, B.I. (1997) The biology of menstruation in homo sapiens: total lifetime menses, fecundity, and nonsynchrony in a natural fertility population. Curr. Anthropol., 38 123–129.

Swaab, D.F. and Hofman, M.A. (1990) An enlarged suprachiasmatic nucleus in homosexual men. Brain Res. 537, 141–148.
Trevathan, W.R., Burleson, M.H. and Gregory, W.L. (1993) No evidence for menstrual synchrony in lesbian couples. Psychoneuroendocrinol. 18, 425–435.
Veith, J.L., Buck, M., Getzlaf, S., Van Dalfsen, P. and Slade, S. (1983) Exposure to men influences occurrence of ovulation in women. Physiol. Behav. 31, 313–315.
Wedekind, C. and Füri, S. (1997) Body odour preferences in men and women: do they aim for specific MHC combinations or simply heterozygosity? P. Roy. Soc. Lond. B 264, 1471–1479.
Weller, A. and Weller, L. (1992) Menstrual synchrony in female couples. Psychoneuroendocrinol. 17, 171–177.
Weller, L. and Weller, A. (1997) Menstrual variability and the measurement of menstrual synchrony. Psychoneuroendocrinol. 22, 115–128.
Whitam, F.L. and Zent, M. (1984) A cross-cultural assessment of early cross-gender behaviour and familial factors in male homosexuality. Arch. Sex Behav. 13, 427–439.
Wilson, H.C., Hildebrandt Kiefhaber, S. and Gravel, V. (1991) Two studies of menstrual synchrony: negative results. Psychoneuroendocrinol. 17, 565–569.
Wyatt, T.D. (2003) *Pheromones and Animal Behavior: Communication by Smell and Taste*. Cambridge: Cambridge University Press.