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Gender Differences in the Retention of Swahili Names for Unfamiliar Odors

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Abstract

Several studies, using different techniques, have established that women typically outperform men in naming odors. The mechanism for this effect was explored here in two experiments. In experiment 1, men and women learned randomly assigned Swahili names for a set of seven unfamiliar odors. Following multiple acquisition trials, participants were retested 1 week later. Although learning rates were identical during acquisition, after the 1 week interval, females were able to name more of the odors than men. Experiment 2 used a similar design but also included a retroactive interference task following the 1 week retention interval test. Although the week-long interval had the same effect as in experiment 1, interference had no effect on male or female performance. These results suggest that under conditions where experience is equated, female naming advantage may result from better consolidation of the learned material.

Introduction

Correctly naming an odor involves at least two processes, recognizing the odorant and retrieving its label. Naming ability has been shown to systematically differ between males and females, with females consistently better at naming odors under a variety of different conditions (Doty, 2001). Explanatory accounts of this gender difference can be broadly divided into those based upon experiential differences in olfaction and biological accounts, based upon innate differences in olfactory perception and/or verbal ability. These possibilities are explored here in two experiments, both of which use a paired associate learning procedure to determine whether male and female participants differ in acquisition, retention and proneness to interference of unfamiliar odor–name pairs.

Gender differences in naming odors have been observed using a variety of different procedures. (i) Several studies have employed the University of Pennsylvania Smell Identification Test (UPSIT), in which participants are asked to scratch and sniff an odor and then pick its name from a list of four alternatives. Using this test, a female naming advantage has been observed at all ages from 5 to 80 (Doty *et al*., 1984; Gilbert and Wysocki, 1987; Ship *et al*., 1996), in individuals who have suffered damage to their sense of smell (Deems *et al*., 1991), between male and female twins (Segal *et al*., 1993) and between males and females from a variety of different cultures (Doty *et al*., 1985). (ii) Differences in naming ability have also been observed under conditions where odors are presented with no list of names (Cain, 1982; Engen, 1987). Effects in such studies are of a similar magnitude to those observed using the UPSIT. (iii) The National Geographic smell survey, completed by 1.5 million respondents (Gilbert and Wysocki, 1987), involved scratching and sniffing six odors and selecting the most appropriate label from a list of alternatives. For each of the six odors, women outperformed men on naming. (iv) Women have also been found to be better at identifying the source (a process akin to naming) of biologically relevant odors such as sweat (Wallace, 1977; Schleidt, 1980; Schleidt *et al.*, 1981). Thus, overall, evidence from a range of procedures suggests a female superiority in odor naming.

The origin of this difference in naming ability between men and women can be fundamentally attributed to two major causes, experiential and biological. From an experiential perspective, differences between genders may emerge due to societal influences on odor exposure (Cain, 1980). For example, women, who may be more likely to prepare food and use scented products, could have a greater interest and motivation to learn the names of such odors. This might ultimately translate into a heightened interest in all olfactory stimuli, a view consistent with the findings from two recent surveys. First, women's dreams appear to contain significantly more reference to odors than men's (Zadra *et al.*, 1998). Second, women claim that smell plays a significantly greater role in their choice of sexual partner than men (Herz and Cahill, 1997). If women do pay more attention to everyday odors than men, this would result in an inevitable confound in most naming experiments. This is because naming studies, by necessity, must use familiar everyday test odors (how could you know the name of an unfamiliar odor?). It is, therefore, not currently possible to exclude experiential factors as an explanation of gender differences in naming.

Biological accounts have received far greater attention and can be divided into three classes of explanation. In the first, it has been suggested that the superior verbal ability of women may somehow account for better odor naming (Engen, 1987). This explanation is difficult to sustain, as recent meta-analytical data suggests that male–female differences in verbal ability are very small, with an average difference in ability of 0.1 SD (Hyde and Linn, 1988; Hyde and McKinley, 1997). In the light of this and other recent findings (Feingold, 1992; Hedges and Nowell, 1995), it would appear that *general* differences in verbal ability probably have little part to play in explaining female superiority in odor naming. However, it is plausible that there are *specific* differences in verbally related abilities. For example, women may be better at forming associative links between configural stimuli such as odors and faces and their verbal label. Indeed, women are better able to recall the name for a particular face than men (Witryol and Kaess, 1957; Thakur *et al.*, 1981).

A second type of biological explanation is based upon the much better supported notion that women are usually better at all olfactory tasks than men (Engen, 1987). One possible source for such effects is the menstrual cycle, as it is well established that women's odor sensitivity fluctuates over its course (Synder and Wolf, 1955; Doty *et al.*, 1981). However, it is unlikely that variations in sensitivity resulting from the menstrual cycle play any role in the enhanced ability of women to name suprathreshold odors. First, in all the naming studies we are aware of, menstrual cycle was a random variable, yet female naming advantage was consistently observed. Second, female advantage in naming is evident prior to puberty (i.e. before menstruation starts) *and* is present after menopause, without any obvious reduction in effect size (Doty *et al.*, 1984; Gilbert and Wysocki, 1987). This is not to suggest that the menstrual cycle has no effect on naming, but merely that female superiority in naming, as currently observed, is unlikely to result from this cause.

A third biological explanation for gender differences in naming could arise from some difference in brain structure or function (Nopoulos and Andreasen, 1999; Swaab *et al.*, 2001). At its simplest, this might mean enhanced olfactory receptor mechanisms in females. This would presumably suggest generalized benefits in olfactory sensitivity, as have been observed for many odors where menstruation is a random variable (Koelega and Koster, 1974). Note, however, such effects have not manifested in all such studies (Venstrom and Amoore, 1968). Only one study, to date, is consistent with the notion of higher-level differences in brain structure or function as an explanation of gender differences in odor-naming ability. Lehrner (Lehrner, 1993), found that women were better able to recognize suprathreshold odors at time intervals varying from 30 min to 3 weeks in a recognition memory paradigm. Interestingly and consistent with a biological explanation of this type, familiarity (as indexed by the ability of participants to label odors) was not the source of the gender difference in recognition memory.

The experiments reported here examined whether there are gender differences in the acquisition, retention or proneness to interference of unfamiliar odor–name pairs. This approach should reduce the impact of prior experience as the relatively unfamiliar odors and names should not have been encountered before. However, if experiential effects manifest motivationally, then female participants should acquire the odor–name associations faster than men. The effect of differences in odor sensitivity should also manifest in terms of acquisition rate. If female participants are better at forming a representation of the olfactory stimulus and thus better able to discriminate the odors, this should also speed acquisition. Differences in retention were established by retesting participants following a 1 week interval. In experiment 2 a further phase explored the effects of retroactive interference. Gender differences in retention and proneness to interference would be more suggestive of some form of memory difference, such as encoding, forgetting, retrieval or consolidation effects. This would likely favor a biologically based explanation, centered upon structural or functional differences in the brains of men and women.

Experiment 1

Experiment 1 used a set of seven odors, each of which was paired with a novel Swahili word (equated for novelty and pronounceability in a pilot study). Participants received two training trials with each odor, in which the name was provided by the experimenter. They then received 10 further blocks of trials, with each block containing seven trials and each trial consisting of one of the seven odors (sampled without replacement). On each trial participants sniffed the odor, were asked to name it and were then given feedback. Each block of trials was timed. After completing the final block of trials, participants received an association test, in which each of the seven odors was presented, with a list of the seven odor names. One week later participants returned and received two more blocks of trials, identical to those described above (i.e. give name, receive feedback), followed by a final association test.

Materials and methods

Participants

Thirty-six Macquarie University psychology undergraduates participated for course credit. There were 16 males (mean age = 20.6 years; range 18–35 years) and 20 females (mean age = 22.9 years; range 17–47 years).

Odors and names

Based on results from pilot data, seven unfamiliar odors were selected (values in parentheses indicate the amount of odorant placed on a cotton wool ball in each blue opaque plastic squeezy bottle): 1-octonal (0.70 g); mandarin aldehyde (4.0 g); patchouli (0.06 g); bornyl acetate (0.32 g); acetyl methyl carbinol (0.06 g); phenyl acetylene (0.16 g); and methyl anthranilate (0.40 g).

The odor names were Swahili words selected by pilot testing for novelty and pronounceability. The words were: *kabali*, *watu*, *juma*, *kesho*, *vitabu*, *siri* and *mabaya*.

Procedure

Experiment 1 was conducted over two sessions, separated by a 1 week interval (see Table 1). On the first session (day 1) participants received two learning blocks, ten test blocks and an association test.

The first *learning block* consisted of seven trials, with a new odor–name pair presented on each trial. Assignment of odors to names was random. Presentation order across blocks was also random. Each learning block trial started with the participant smelling the target odor for ~ 2 s (it was self paced). This involved placing the tip of the plastic squeezy bottle 2–3 cm below the nose and sniffing while the bottle was squeezed. After the odor bottle was returned to the experimenter, she read out the odor's name, then spelt it out, while participants copied it down on to their response sheet. This ensured they fully attended to the name. The participant then sniffed the odor a second time and made three ratings, each on a seven-point category scale. First, whether they had ever smelled the odor before (anchors; 1 = no, 4 = unsure, 7 = yes). Second, how familiar the odor was (anchors; 1 = unfamiliar, 7 = very familiar). Third, how strong the odor smelled (anchors; 1 = no smell, 7 = very intense). This procedure was repeated for the six remaining odor–name pairs. There was then a 2 min interval which was followed by an *identical* second learning block.

On completion of the second learning block, participants received another 2 min interval before the first *test block* commenced. Each test block also consisted of seven trials. On each test block trial, a participant sniffed one of the seven odors and was asked to provide its Swahili name and rate how confident they were in their judgment. Confidence ratings are not reported here as they revealed little of interest in either experiment. If the participant correctly named the odor, they were told 'That's correct'; if they were incorrect, the appropriate Swahili name was provided ('No, that's X'). After repeating this process for the remaining six odors, there was an interval of 1.5 min, followed by the next test block. Each test block was timed and participants moved at their own pace (see Figure 2 for test block length). This pattern was then repeated until all ten test blocks had been completed.

Table 1 Design of experiment 1

Day	Phase	Repeats	Treatment
1	Learning blocks	2	each odor sniffed, name provided by experimenter
	Test blocks	10	each odor sniffed, participant provides name, experimenter gives feedback
	Association test	–	each odor sniffed with all names available
8	Test blocks	2	each odor sniffed, participant provides name, experimenter gives feedback
	Association test	–	each odor sniffed with all names available

Following a 2 min interval after the final test block, participants received an *association test*. This was composed of seven trials. On each trial one of the seven odors was presented along with a list of the seven Swahili names. Participants task was to select the correct name. No feedback was provided in this test. The test was timed.

The second session was completed 1 week later in the same room with the same experimenter (R.A.D.). The session commenced with two test blocks identical in form to those from the first session. This was followed by an association test, again identical to the one from the first session.

Analysis

As in both experiments reported in this paper, all data met the necessary assumptions for parametric testing.

Results

Odor characteristics

The ratings of familiarity and intensity obtained on the first learning block, collapsed across the different odors, did not

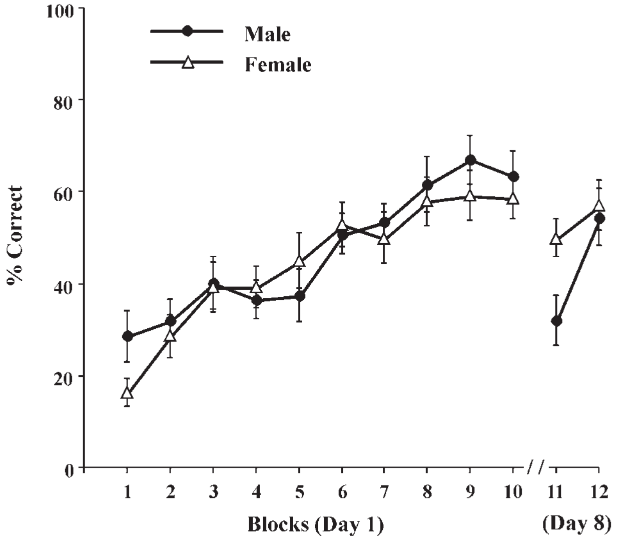

Figure 1 Correctly named odors, expressed in mean percent (plus standard error), for male and female participants during; test blocks on session 1 (day 1; blocks 1–10) and 1 week later on session 2 (day 8; blocks 11 and 12).

significantly differ between males and females (independent *t*-test). Collapsed across odor, the mean ratings were: ever smelled before, male = 4.1/7 (SE = 0.2), female = 4.2/7 (SE = 0.3); familiarity, male = 4.1/7 (SE = 0.2), female 4.0/7 (SE = 0.3); and intensity, male = 4.7/7 (SE = 0.1), female = 4.7/7 (SE = 0.2).

Correct naming during acquisition

Figure 1 depicts mean percent correct naming, across test blocks, on sessions 1 (day 1) and 2 (day 8). The data from session 1 were analyzed by a two-way repeated-measures ANOVA, with one between factor (Gender) and one within factor (Test block). The analysis revealed a main effect of Test block [$F(9,34) = 28.69$, $P < 0.001$], indicating, as can be seen in Figure 1, that correct naming increased across test blocks. Importantly, there were no effects involving Gender.

Naming speed during acquisition

Figure 2 illustrates mean speed in seconds, at which men and women produced names for the seven odors (*en masse*), in each test block, on sessions 1 (day 1) and 2 (day 8). The data from session 1 were also analyzed by a two-way repeated-measures ANOVA, with one between factor (Gender) and one within factor (Test block). Although production times significantly decreased over Test blocks [$F(9,34) = 13.59$, $P < 0.001$], there were no effects involving Gender.

Association test

Mean percent correct responses did not significantly differ between men and women (independent *t*-test; males = 46%; females = 57%). There was no significant difference in test length (s) between males and females either.

Retention of names

Figure 1 also shows percent correct naming following the 1 week interval. It is readily apparent that men performed worse following the interval than women. This was confirmed by a two-way ANOVA, with one repeated-measure Test block (block 10 versus block 11) and one between factor Gender. The analysis revealed a significant interaction between Gender and Test block [$F(1,34) = 12.44$, $P < 0.001$], indicating poorer retention in men following the interval. There was also a main effect of Test block [$F(1,34) = 38.35$, $P < 0.001$], but no main effect of Gender.

Recovery

By the second test block of day 8 (see Figure 1) there was no longer a significant difference in naming performance between men and women (independent *t*-test).

Naming speed and retention interval

These data are illustrated in Figure 2. There was no significant change in naming speed between test block 10 and 11, nor any difference by gender (using ANOVA). In addition, there was no significant gender differences in naming speed on the final test block 12 (independent *t*-test).

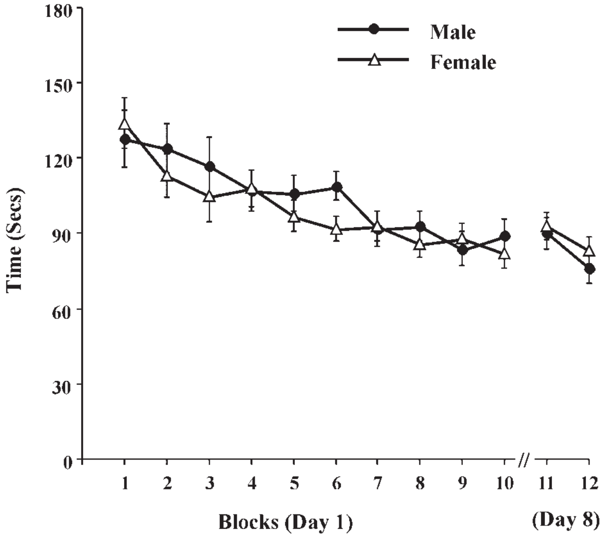

Figure 2 Mean time in seconds taken to complete the naming of one test block of odors (plus standard error), for male and female participants during; test blocks on session 1 (day 1; blocks 1–10) and 1 week later on session 2 (day 8; blocks 11 and 12).

Final association test

Mean percent correct responses did not significantly differ between men and women (independent *t*-test; males = 50%; females = 51%). There was no significant difference in test length (s) between males and females either.

Discussion

Experiment 1 revealed that men and women can acquire novel odor–name associations at the same rate. This suggests that the ability to learn odor names is not impaired by either differences in sensitivity between males and females or by overt differences in motivation. The key difference to emerge was that following the 1 week retention interval. Here, male participants were significantly worse at correctly naming the target odors than female participants. This retention effect appears analogous to typical laboratory naming tasks, as they employ familiar odors (as were the test odors here at that point) which may not have been recently smelled or named. However, this analogy is complicated by the intrusion of the association test between test block 10 and 11. This is because the association test could have inadvertently functioned as an interference task. Some evidence for this can be found in the fact that male performance on the first association test was worse, though not significantly so, than female performance. Consequently a second experiment was conducted to determine: (i) if this retention interval effect could be repeated under circumstances where there was no intervening association task; and (ii) where the effects of interference could be more explicitly examined.

Experiment 2

Experiment 2 employed the same training procedure as experiment 1, except that the association test at the end of the first session was dropped. As in experiment 1, a second session took place 1 week after the completion of the first. This second session started with two further test blocks, as had experiment 1. This was followed by an interference phase in which participants learned new odor–name pairs, i.e. the same odors and names were used, but were randomly reassigned for each participant. This was followed by two further test blocks to determine how well participants had acquired these new odor–name associations. Finally, this was followed by two further test blocks, in which participants were asked to provide the original odor names, to test for retention of the *old* material following interference.

Materials and methods

Participants

Thirty-two Macquarie University psychology undergraduates participated for course credit. There were 16 males (mean age = 22.6 years; range 18–34 years) and 16 females (mean age = 22.6 years; range 18–45). No participant had taken part in experiment 1.

Materials

These were identical to experiment 1.

Procedure

The design of experiment 2 is illustrated in Table 2. Session 1 was identical in all respects to experiment 1, except there was no association test. One week later, session 2 commenced with two test blocks, again identical to experiment 1. Following a 2 min interval, participants then received two new learning blocks. Although the design of these new learning blocks was the same as for experiment 1, the odor–name pairs were re-randomized, with the caveat that no pair should remain the same (i.e. if patchouli had been named *vitabu* in the original learning blocks, it could not be named *vitabu* in the new learning blocks). After another 2 min interval, two further test blocks followed. These were identical in design to experiment 1, except that participants were asked to recall the *new* names they had just learned. Finally, after a further 2 min interval, participants completed two more test blocks, again identical to experiment 1, except now participants were asked to retrieve the names that they first learned – the *old* names.

Table 2 Design of experiment 2

Day	Phase	Repeats	Treatment
1	Learning blocks	2	each odor sniffed, name provided by experimenter
	Test blocks	10	each odor sniffed, participant provides name, experimenter gives feedback
8	Test blocks	2	each odor sniffed, participant provides name, experimenter gives feedback
	Learning blocks	2	each odor sniffed and a *new* name provided by experimenter
	Test blocks	2	each odor sniffed, participant provides *new* name, experimenter gives feedback
	Test blocks	2	each odor sniffed, participant provides *old* name, experimenter gives feedback

Results

Odor characteristics

The ratings of familiarity and intensity obtained on the first learning block, collapsed across the different odors, did not significantly differ between males and females (independent *t*-test). Collapsed across odor, the mean ratings were: ever smelled before, male = 4.0/7 (SE = 0.2), female = 4.5/7 (SE = 0.3); familiarity, male = 3.7/7 (SE = 0.2), female 3.9/7 (SE = 0.2); and intensity, male = 4.1/7 (SE = 0.2), female = 4.4/7 (SE = 0.3).

Naming during acquisition

Figure 3 shows mean percent correct naming, across test blocks, on sessions 1 (day 1) and 2 (day 8). The data from session 1 were analyzed by two-way repeated-measures ANOVA, with one between factor (Gender) and one within factor (Test block). The analysis revealed a main effect of Test block [$F(9,30) = 31.62$, $P < 0.001$], indicating, as can be seen in Figure 3, that performance increased across test blocks on day 1. Importantly, there were no effects involving Gender.

Speed of naming during acquisition

Figure 4 illustrates mean speed in seconds, at which men and women produced names for the seven odors (*en masse*) in each test block, on sessions 1 (day 1) and 2 (day 8). The session 1 data were also analyzed by a two-way repeated-measures ANOVA, with one between factor (Gender) and one within factor (Test block). Although production times significantly decreased over Test blocks [$F(9,30) = 5.79$, $P < 0.001$], there were no effects involving Gender.

Retention of names

Figure 3 also shows percent correct naming following the 1 week interval. It is again apparent, as in Experiment 1, that male participants performed worse following the interval (i.e. block 11) than women. This was confirmed by a two-way ANOVA, with one repeated-measure Test block

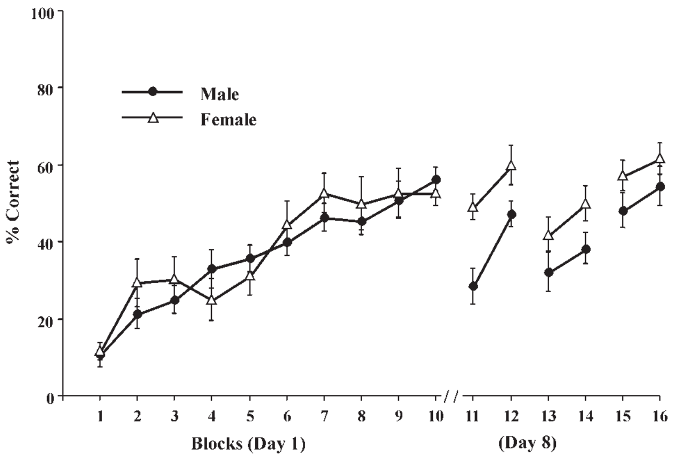

Figure 3 Correctly named odors, expressed in mean percent (plus standard error), for male and female participants during: test blocks on session 1 (day 1; blocks 1–10); one week later on session 2 (day 8; blocks 11 and 12); testing for new names (blocks 13 and 14); and retesting for old names (blocks 15 and 16).

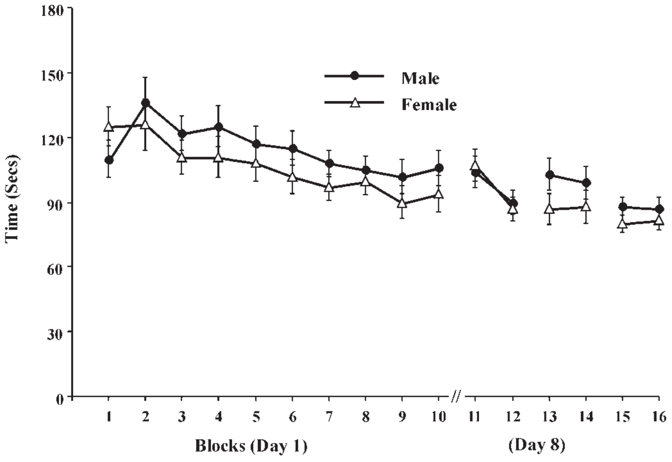

Figure 4 Mean time in seconds taken to complete the naming of one test block of odors (plus standard error), for male and female participants during: test blocks on session 1 (day 1; blocks 1–10); 1 week later on session 2 (day 8; blocks 11 and 12); testing for new names (blocks 13 and 14); and retesting for old names (blocks 15 and 16).

(block 10 versus 11) and one between factor Gender. This analysis revealed a significant interaction between Gender and Test block [$F(1,30) = 15.55$, $P < 0.001$], indicating poorer retention in men following the interval. There was also a main effect of Test block [$F(1,30) = 26.14$, $P < 0.001$] and a main effect of Gender [$F(1,30) = 4.19$, $P < 0.05$].

Recovery

By the second test block of day 8 (see Figure 1) there was still a significant difference in naming performance between men and women [$t(30) = 2.05$, $P < 0.05$], unlike in experiment 1 where this difference had dissipated.

Speed of naming and retention interval

These data are illustrated in Figure 4. There were no significant changes in naming speed between Test block 10 and 11, nor any difference by Gender (using ANOVA). In addition, there was no significant difference by gender in naming speed on Test block 12 (independent *t*-test).

Acquisition of new odor–name associations

Figure 3 illustrates the difference between men and women for the acquisition of the new odor–name associations on session 2 (day 8; blocks 13 and 14). A two-way ANOVA (Gender and Test blocks) revealed a significant main effect of gender [$F(1,30) = 4.54$, $P < 0.05$], with women performing slightly better than men. There were no other significant effects.

Speed of naming for new odor–name associations

Figure 4 illustrates the mean time in seconds for participants to produce the new names on test blocks 13 and 14. There were no significant differences between males and females nor between blocks (using ANOVA).

Effects of interference

The effects of interference can be gauged by comparing test block 12 (last test prior to interference) with test block 15 (first test post-interference). A two-way ANOVA (Gender and Test block 12 versus 15) revealed a main effect of Gender [$F(1,30) = 5.30$, $P < 0.05$]. Crucially, there was no interaction of Gender and Test block, which would have implied a differential effect of interference on males and females. Rather these results indicate that the general difference observed following the retention interval had still not dissipated. Finally, a comparison of male and female performance on the last test block 16, revealed no significant difference (independent *t*-test).

Effects of interference on naming speed

These data are illustrated in Figure 4. Using the same ANOVA strategy as above revealed no effects of Test block (12 versus 15) or Gender. Males and females did not significantly differ on the last block either (independent *t*-test).

Discussion

The pattern of results from this experiment were largely identical to experiment 1. The principal gender difference was again the decrease in naming performance which occurred following the 1 week retention interval in men. In this experiment, however, the effect could not be attributed to the intervening association test, strongly implying that the retention difference is caused by the passage of time. One further gender difference was also obtained. Males were poorer at learning new odor–name associations. The other purpose of experiment 2 was to determine if susceptibility to interference, an important cause of forgetting, might account for the retention interval effects. Interference had no differential impact on male/female performance, suggesting that it is unlikely to account for this effect. In summary, the key findings from this experiment were that the effect of retention interval was observed under conditions where it could not be attributed to any intervening experimental manipulation and that interference was an unlikely explanation of this effect.

General discussion

The experiments reported here examined gender differences in the acquisition and retention of novel Swahili names for a set of unfamiliar odors. In both experiments 1 and 2, male and female participants learned odor–name associations at the same rate and did not differ on a test where names were provided (experiment 1). However, following a 1 week retention interval, naming was significantly poorer in male participants in both experiments, although this difference diminished somewhat over subsequent blocks of trials. In experiment 2, further blocks of trials established that women were slightly better at acquiring a new set of odor–name associations, but that these new associations did not have any differential impact on recalling the original set of names. That is, men appeared no more susceptible to interference than women.

The drop in performance observed in men following the 1 week interval is, as noted before, analogous to the finding of gender differences in naming when more familiar odors are employed. This analogy stems from the fact that in most studies of naming, varying delays of hours, days or weeks must intervene between having last smelled or named a particular odor and the test where it is presented. The effect of delay in the current experiment was not trivial, as the effect size d was 1.0 for experiment 1 and 1.3 for experiment 2, both classified by Cohen (Cohen, 1969) as large (i.e. $d > 0.8$). (d was calculated by subtracting the block 11 score from the block 10 score, separately for males and females. The female difference score was then subtracted from the male difference score and the product divided by the largest of the SDs from the means used in its calculation.) To put this in some perspective, these effect sizes are considerably bigger than the average effect sizes for the most well established gender difference, that of spatial ability [largest average $d = 0.7$; (Voyer *et al.*, 1995)]. Incidentally, the effect size observed in our experiments is also larger than those seen in typical odor naming studies. Using available data, we estimated ds of ~0.4 (Doty *et al.*, 1985; Engen, 1987) and 0.7 (Segal *et al.*, 1993) for three typical naming studies. There may be at least two reasons for the larger effect size here. First, the retention interval between last exposure to an odor and its name was fixed here, while in typical naming studies it would vary between individuals. Second, the use of overlearned highly familiar odors for testing, like those found in the UPSIT, might mask or reduce gender differences in naming.

In the Introduction, two main types of explanation were suggested to account for gender differences in naming. First, those involving differences in experience between men and women (Cain, 1980) and second, those based upon a biological difference in verbal or olfactory ability (Engen, 1987; Larsson, 1997). The results from our experiments bear on these accounts in a number of ways. First, as noted above, the apparent parallel between the findings from this study and previous demonstrations of better odor naming in women suggest to us that experiential factors probably have little direct role in accounting for gender difference in naming. There are two reasons for this. (i) The stimuli used here were equally unfamiliar to males and females, as were their arbitrary names. This would obviate against any benefit of practice effects in female participants, that might readily contaminate studies using more familiar odors. (ii) There was no evidence consistent with male participants being less motivated to learn than female participants. Male participants were as quick in supplying names as females, no differences emerged across acquisition trials and all participants returned for the second test session a week later. In addition, the finding mentioned in the introduction, that gender differences in odor naming were largely independent of culture (Doty *et al.*, 1985), may also imply that experiential factors play a more limited role.

A second implication of these findings concerns the observation that women are more sensitive to olfactory stimuli than men, when menstruation is a random variable, as in these experiments (Koelega and Koster, 1974). One place that a sensory difference should have emerged would have been during acquisition, especially if female participants were better able to discriminate the target odors than men. This should have had the effect of speeding up acquisition in female participants. However, as is clearly apparent in Figures 1–4, there is little evidence to suggest that differences in olfactory sensitivity or discriminability played any significant role in acquisition.

A third implication of these findings concerns some more specific type of olfactory perceptual difference. Although there is no evidence here that encoding differed between males and females during acquisition, the fact that performance was so much worse following the retention interval suggests a memory related effect. Such an effect could manifest in at least three ways. First, it could be taken to indicate a specific retrieval deficit in male participants. However, this explanation is problematic, as there are currently no theories of retrieval that offer a distinction between retrieval following a relatively short retention period, such as over the test blocks within a session and retrieval following much longer periods of time, such as that following the one week interval (Blake *et al.*, 2000). Consequently, there is no clear theoretical basis to assert retrieval deficits as a cause for this effect.

A second possibility is that males are more prone to interference over the retention interval, thus subsequently affecting their ability to remember the odor–name associations on test. Two pieces of evidence suggest this is unlikely. First, there is no reason to believe that participants would encounter *any* of the target words or odors during the week interval, providing little opportunity for interference to occur. Second, in experiment 2, retroactive interference had no differential gender effect. In fact, the relative absence of an interference effect reconfirms Lawless and Engen's finding that paired associate learning with odors is typically resistant to such a manipulation (Lawless and Engen, 1977). Thus it is unlikely that differential proneness to interference could readily account for these findings.

A third possibility concerns memory consolidation effects. These involve the processing of recently acquired memory traces, by, for example, facilitating long-term potentiation (Stickgold *et al.*, 2001). Consolidation ultimately results in the incorporation of the trace into long-term memory (Sutherland and McNaughton, 2000), with these effects typically occurring across time periods of hours or days following the original learning episode (Stickgold, 1998). If consolidation processes were less effective in men, this could manifest in a number of ways. First, it could reduce odor recognition accuracy as a result of poorer consolidation of the original odor trace; this would reduce naming accuracy as male participants would be more likely to confuse odors. Second, it could result in weaker odor-name associations, so that even if a male participant were able to recognize the target odor, the association to the name would be inoperative.

Although the experiments reported here were not designed to differentiate these two possibilities, the interference phase in session 2 of experiment 2 has an interesting bearing upon this issue. If male participants did have weaker odor–name associations by virtue of poorer consolidation, this should have produced *less interference* with new odor–name learning and consequently better acquisition. Yet male participants were worse at acquiring new name–odor associations in experiment 2 than female participants (see Figure 3; blocks 13 and 14). However, this finding, is consistent with men having difficulties in discriminating the target odors, resulting from poorer consolidation of the odor trace. Further evidence in favor of this hypothesis can be found in the study by Lehrner (Lehrner, 1993) cited in the Introduction. He observed that male participants were poorer at recognizing odors over various delays, an effect attributed primarily to memorial rather than to conceptual factors (associations to names, response bias, etc.). This would suggest that male participants may have been less effective at consolidating the olfactory memory trace into long-term memory.

In conclusion, the experiments reported here demonstrate that male participants are poorer at naming odors following a 1 week interval between acquisition and testing, even though initial rates of name acquisition did not differ between genders. Although this finding suggests that gender differences in odor naming may result from poorer memory consolidation in male participants, the current experiments can not fully delineate whether this resulted from failure to consolidate the olfactory trace or the odor–name association (or a combination thereof). More intriguingly, the results observed here *could* represent a more general impoverishment of memory consolidation in men. Nonetheless, the effects reported here still demonstrate one of the largest gender differences currently identified in the psychological literature.

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