Mind Over Age—Stereotype Activation and Olfactory Function

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Abstract

Given that context affects olfaction and the elderly exhibit olfactory deficits, the current study tested whether a subtle change in internal context, evoked by priming the elderly stereotype, would affect performance in a variety of olfactory tasks including odor sensitivity, discrimination, and identification (Experiment 1), as well as perceived odor intensity, pleasantness and familiarity, and an odor reaction time task (Experiment 2). Such internalization of the elderly stereotype has been demonstrated with slower walking speeds and fewer words recalled in a memory task. In the current study, 76 participants first listened to a presentation about age-related declines in olfaction and then participated in 3 language tasks which, unbeknownst to them, served as the elderly stereotype priming manipulation. This priming manipulation was effective at decreasing walking speed and word recall, confirming the findings of previous researchers; however, olfaction was not affected. Whether olfaction is resistant to stereotype priming is discussed.

Key words: elderly, olfaction, stereotype priming

It has been well established that the process of perception involves active construction and that responses to sensory stimuli will vary with changes in our internal state, the external environment, or a combination of the 2. That perception is modifiable based on top-down influences (e.g., context, internal state, expectations) is a ubiquitous finding across sensory systems, including chemosensory stimuli such as volatile irritants (Bulsing et al. 2010), tastes (Woods et al. 2011), and odors (Doty et al. 1981; Kuehn et al. 2008; Croy et al. 2011). Odor perception appears especially susceptible to cognitive and contextual influence (Dalton 1996; Herz 2003; Djordjevic et al. 2008).

Contextual changes can be overt, such as a change in location, or more implicit, as in the presentation of stimuli without conscious recognition. The malleability of odor perception has been demonstrated largely through the use of explicit changes in context, such as changes in how an odor is labeled, characterized, or where it is presented (Djordjevic et al. 2008). However, there is some evidence that more subtle psychosocial manipulations can also affect chemosensory perception (Smeets and Dalton 2005; Coppin et al. 2010).

Social psychology has a long tradition of studying the effects of implicitly presented prior or “top-down” information (aka “priming”) on an individual’s perceptions, attitudes, and behaviors. In this sense, priming can be believed of as a manipulation of the internal mental context, via activation of specific categories or semantic concepts. In one widely used procedure, priming a single trait (i.e., rudeness) or a stereotype category (i.e., hostility), without the subject’s awareness, has been shown to affect behavior in a manner consistent with the prime (Goldfarb et al. 2011), a phenomenon termed the behavioral assimilation effect. In these studies, priming occurs by having the participant unscramble a list of words which are consistent with either the trait (e.g., rudeness = aggression, impolite; Bargh et al. 1996) or the stereotype (e.g., African Americans = hostility; Devine 1989). Importantly, in the stereotype activation, the stereotype is implicitly activated by words associated with the demographic or social category, but not the behavior or the attitude being primed.

In a seminal study of stereotype priming on behavior, Bargh et al. (1996) demonstrated that priming stereotypes
of elderly people by having participants unscramble word lists likely to activate the category “elderly” (e.g., Florida, gray) led participants to walk more slowly as they departed from the experimental setting while being covertly observed (Bargh et al. 1996). Because then the use of this priming procedure in numerous studies has shown that priming the elderly stereotype not only reliably decreases young participants’ walking speed but also their driving speed (Branagan and Gray 2010), word recall performance (Dijksterhuis et al. 2000) (both accuracy and reaction time), their grip strength and dexterity (Banfield et al. 2003), their spatial judgments (Chambon 2009), and their word recall performance (Dijksterhuis et al. 2000) (both accuracy and reaction time) consistent with the stereotypes that the elderly are slower, less dexterous, and have memory impairments. Given the often dramatic reduction in olfactory acuity which occurs with age (Murphy et al. 2002), we employed the stereotype priming manipulation to test whether activation of the elderly category in young adults would impair any aspect of their ability to detect or process odors. Prior studies using this paradigm have been limited to documenting effects on attitudes, behaviors, and perceptual judgments. In contrast, we used priming as a tool to test, for the first time, whether a primary sensory function (i.e., olfaction) could be affected by activation of an elderly stereotype. In 2 separate studies, we tested the hypothesis that individuals primed with the category elderly would perform worse on tasks which tap into various measures of olfactory perceptual processing than unprimed individuals. In Experiment 1, we assessed how priming affects cued odor identification, quality discrimination, and detection threshold. In Experiment 2, we assessed priming effects on subjective odor ratings and odor attention performance with an odor reaction task.

**Experiment 1**

**Methods and materials**

**Participants**

Thirty-six (18 women) healthy participants with a mean age of 26 years (standard deviation = 4.8 years) were randomly assigned to either the priming or the control group and tested in a single session. Participants were screened prior to inclusion by a self-report survey for numerous nasal and tested in a single session. Participants were screened prior to inclusion by a self-report survey for numerous nasal and neurological disorders known to affect olfactory function. None of the participating women were pregnant, and all had regular menstrual cycles of normal length. All aspects of the study were approved by the University of Pennsylvania’s Institutional Review Board and all participants signed informed consent prior to participation in Experiment 1.

**Olfactory sensory tests**

*Odor Detection Threshold* for n-Butanol (Fisher Scientific, Pittsburgh, PA) was assessed with the Sniffin’ Sticks delivery system (Hummel et al. 1997) using a 3 alternative, forced-choice (AFC) ascending staircase paradigm (Wetherill and Levitt 1965). A total of 16 steps with a binary dilution series starting at 4% using 1,2 propanediol (Fisher Scientific, Pittsburgh, PA) as the diluent were used. The tester presented the 3 alternatives in a randomized order; 2 sticks contained only the solvent, whereas the third contained a given concentration of odorant solution, and the blind-folded participant had to identify the odor-containing stick. Reversal of the staircase occurred when the odor was correctly identified in 2 successive trials with a subsequent reversal of the staircase when participants failed to correctly identify the odor. A total of 7 reversals were collected, with the geometric mean of the last 4 reversals serving as a threshold estimate. *Cued Odor Identification* was assessed using a 40-item cued odor identification test (Freiherr et al. 2012). For each pen, participants were asked to select which of 4 odor choices (words shown on cards) best described the odor they smelled. *Odor Quality Discrimination* was assessed using the Sniffin’ Sticks 16-item, 3 AFC, odor discrimination test. In each trial of this test, participants are presented with 3 odor-containing sticks in a randomized order, one at a time. Two sticks smell the same and one smells qualitatively different. Participants are asked to identify the stick which smells different. Each trial uses a different odor combination.

**Priming material**

Two general tasks were used to prime the participants: an audio-visual presentation (explicit prime) and 3 separate language tasks (implicit prime). The priming group contained participants primed with the elderly stereotype, whereas the control group underwent similar priming tasks with neutral words instead of stereotype-eliciting ones.

**Audio-visual presentation:**

Initially, participants viewed an audio-visual presentation (~7 min) during which the “primed” (experimental) participants listened and watched a presentation describing the presence of a profound age-related decline in olfactory function, whereas the control participants were presented with general information regarding the olfactory system. Before the presentation began, participants were told that it contained general information about the purpose of the study and that they needed to pay close attention because they would be asked questions regarding the presentation at the end of the study as a part of a memory test. This test was not administered.

**Language tasks:**

Next, control and primed participants completed 3 computer-based language tasks (*sentence scramble, word recognition, and word recall*) which served to further prime
the experimental participants with the elderly stereotype (Srull and Wyer 1979; Bargh et al. 1996; Dijksterhuis et al. 2000). The order of testing was counterbalanced between the sentence scramble and the word recognition tasks, but the word recall was always performed last so as to equalize the length of the retention interval between participants. In the sentence scramble task, participants were asked to construct 30 complete and logical sentences using 4 out of 5 provided words. They were given 30 s to complete each sentence on a computer. For the experimental group, 1 word primed the elderly stereotype (e.g., enjoys playing she bingo winning), whereas only neutral words were used for participants in the control group (e.g., enjoys playing she games winning). In the word recognition task, participants were shown 36 words on a computer screen, one at a time, in a random order, for a maximum of 2.5 s each. These 36 words were each presented twice for a total of 72 words presented. The primed group received words commonly associated with the category elderly (e.g., Florida, wrinkled), whereas the control group received unrelated words (e.g., Iowa, qualified). Eleven of the 36 words described an emotion, which also differed by group assignment (e.g., primed: grief, depressed; control: joyful, elated). Participants were told to press a computer key when a word that described an emotion appeared, a task designed to increase attention toward the words. A response time of 2.5 s (maximum) per word was allowed. Lastly, participants were presented with the word recall list of 36 words for 4 minutes and were told that they would be asked to recall as many of these words as possible at the end of the study. The word recall list used the same 36 words used in the word recognition task described above. The stimulus presentation program E-Prime 2.0 Professional (Psychology Software Tools Inc., Pittsburgh, PA) was used to administer and record responses during the 3 language tasks.

Social priming assessment tasks

Walking speed.

Previous studies priming the social stereotype elderly have demonstrated a consistent effect on walking speed. Therefore, to test whether our priming task successfully induced priming, participants’ walking speed was assessed at the end of the testing session. To this end, we measured the time it took participants to travel down a hallway (26 m). Participants were informed that the final task required clean hands and that they had to wash their hands in a bathroom down the hall. Unbeknownst to them, the experimenter timed the duration of their walk from a floor marker at the near end of the hallway to another marker at the far end of the hallway.

Memory recall task.

Participants were given 2 min to write down (free recall) on a piece of paper as many of the words from the word list mentioned above.

Procedures

After providing signed consent and demographic information, participants sat in front of a computer screen to watch the audio-visual presentation containing information about either the connection between aging and loss of olfactory functions (priming group) or the general knowledge about the olfactory system (control group). Directly after the presentation, the 3 language tasks were administered on the same computer screen. Participants were then moved to a room constructed specifically for chemosensory testing, and the 3 odor tasks were administered in a counter-balanced fashion. Upon debriefing at the end of the study, none of the participants indicated any suspicion of the connection between the initial presentation about olfaction and the rest of the study.

Statistical analyses

Differences in performance between the 2 groups (control and primed) were assessed with separate 2-tailed independent-sample $t$-tests.

Results

Consistent with results from prior studies, priming the elderly stereotype effectively altered walking speed and memory. Primed participants walked more slowly, $t(34) = 2.56, P < .02$, and remembered fewer words, $t(34) = 2.49, P < .02$, compared with control participants (see Figure 1). This confirmed a successful priming of the elderly construct. In contrast, olfactory function, as measured by tests of sensitivity, discrimination, and identification was unaffected, with no group differences on any measure: threshold sensitivity: $t(34) = .496, P = n.s.$; discrimination: $t(34) = .26, P = n.s.$; and identification: $t(34) = .15, P = n.s.$ (see Figure 1).

To our knowledge, only one study has found an influence of the elderly prime on sensory function. In this study, young adults either primed or unprimed with the elderly stereotype were asked to judge the length and slope of a hill—both subjective properties of visual perception (Chambron 2009). Hills were judged to be steeper and longer after stereotype priming. Accordingly, we wondered whether similarly subjective properties of olfactory perception might be more susceptible to the priming stereotype. Additionally, given that the elderly stereotype appeared to evoke a general behavioral reduction in motor speed, we reasoned that reaction times to detect odors might also be affected. Experiment 2 was designed to explore these possibilities.

Experiment 2

Methods and materials

Participants

In Experiment 2, 40 new participants (20 women) with a mean age of 25 years (standard deviation = 3.5 years) were
recruited to participate. Participants were screened prior to inclusion by a self-report survey for numerous nasal and neurological disorders known to affect olfactory function. Participants were randomly assigned to the priming or control group. None of the participating women were pregnant, and all had regular menstrual cycles of normal length. All aspects of the study were approved by the University of Pennsylvania’s Institutional Review Board and all participants signed informed consent prior to participation in Experiment 2.

**Priming material**

The priming material was identical to Experiment 1; namely, an initial 7-min long audio-visual presentation and 3 separate language tasks served as priming stimuli. In Experiment 2, however, we did not assess word recall or walking speed for 2 reasons. First, due to the length of the reaction time task, we wanted to limit additional measures. Second, results from Experiment 1 demonstrated that our paradigm was successful at inducing the aforementioned, established priming effects.

**Odor stimuli**

We used 4 different odors which differed in hedonic tone: 2 of the odors are generally regarded as pleasant and 2 are generally regarded as unpleasant. The 2 pleasant odors were orange oil (“orange” odor; complex mixture; Sigma Aldrich; St. Louis, MO) and phenylethyl alcohol (PEA; “rose” odor; monomolecular; Sigma Aldrich; St. Louis, MO). The 2 unpleasant odors were fish oil (“bad fish” odor; complex mixture; Givaudan, Inc.; East Hanover, NJ) and isovaleric acid (IVA; “smelly socks” odor; monomolecular; Sigma Aldrich; St. Louis, MO). Odors were diluted in 1,2 propanediol from neat concentrations to a 70% v/v for orange, 27% v/v for fish, 90% v/v for PEA, and 40% v/v for IVA. Pilot data ($n = 20$) indicated that these concentrations were iso-intense. Odors of varying hedonic tone (pleasant, unpleasant) and chemical composition (monomolecular, complex mixture) were used to ensure the generalizability of any results across a variety of odor types (Lundström et al. 2006; Boyle et al. 2009).

**Odor ratings and reaction time task**

For the perceptual ratings, odors were presented in amber 100 ml glass bottles and participants were asked to rate them on the dimensions of intensity, pleasantness, and familiarity. Intensity was assessed using a general labeled magnitude scale (Bartoshuk et al. 2004), whereas pleasantness and familiarity were scored using a visual analog scale. For the odor reaction time task, odors were presented with a computer-controlled, 8-channel olfactometer to ensure accurate odor onset and a steep odor rise-time (Lundström et al. 2010). Before reaching the olfactometer’s birhinal nosepiece, a stimulus airstream (3 liters per minute, LPM)—containing either control air (clean, de-odorized) or odorized air—mixes with a continuous, low-flow airstream (0.5 LPM), resulting in a birhinal airflow of 3.5 LPM total or 1.75 LPM per nostril. The continuous, low-flow component of the olfactometer design ensures masking of the tactile cues which might otherwise alert the subject to channel switching and, therefore, odor delivery. The delay to odor delivery, the lapse between the time at which a computer triggers the solenoid valve to the time at which the delivered odor reaches 90% strength at the nose, was approximately 450 ms, as measured by a photoionization detector (miniPID 200A, Aurora Scientific Inc, Aurora, ON, Canada). This calculation is based on the combined lengths of stimulus onset (400 ms, measured from computer trigger) and 10/90% odor rise-time (53 ms, from 10% to 90% odor strength). The stimulus presentation program E-Prime 2.0 Professional (Psychology Software Tools Inc., Pittsburgh, PA) was used to trigger the olfactometer, present the visual cues, and record participants’ reaction time.

![Figure 1](image_url)  
**Figure 1** Walking speed and word recall performances (A) were impaired by stereotype priming, whereas odor threshold, discrimination, and identification (B) were unaffected. Error bars indicate standard error mean. * $P < .05$. 
Procedure
Initially, participants were seated in front of a computer screen, presented with each of the 4 odor bottles once, and asked to rate each, one at a time, for intensity, pleasantness, and familiarity using a computerized scale. Participants were then fitted with the nose pieces of the olfactometer. They watched the initial audio-visual presentation and completed the 3 language tasks. In the subsequent reaction task, they were asked to respond as soon as they detected either a word on the screen or an odor via the nosepieces by pressing a computer key. To limit the influence of nasal inhalation on stimulus delivery, participants were instructed to breathe through the mouth for the duration of the task. To exclude the possibility that auditory cues from the airstream might influence participants’ performances, low-volume brown noise (noise with a decreasing density along the frequency spectrum) was played through headphones throughout the task. The aforementioned 4 odors were used along with 4 words which were either neutral (e.g., jumping) or stereotype-activating (e.g., balding) for the control and primed participants, respectively. One of the 4 words described an emotion (e.g., worried). When this emotional word was presented, participants were instructed to press a different computer key. As soon as they responded to the word or odor, the screen went blank or the olfactometer switched to clean air. The maximum response time allowed was 3 s, after which the word or odor was removed and the trial became designated a “no-response” trial. Participants were presented with 2 blocks of 32 trials, each, and both blocks were divided evenly between 16 olfactory trials (4 per odor) and 16 visual trials (4 per word); this resulted in 8 presentations of each odor and each word per participant. A 5-min break was inserted between the 2 blocks to prevent fatigue and odor adaptation. No performance feedback was given to the subject at any time. Lastly, to determine whether the priming manipulations altered subjective odor assessments, participants were re-presented with the 4 odors and once again asked to rate odor intensity, pleasantness, and familiarity. After this, participants were interviewed and debriefed. None of the participants indicated any suspicion about the connection between the initial presentation about olfaction and the rest of the study.

Statistical analyses
To explore potential odor valence-dependent differences, responses to the 2 pleasant and the 2 unpleasant odors were averaged. Reaction time responses faster than 150 ms were excluded. Furthermore, responses and subjective ratings were averaged within the pleasant (rose, orange) and unpleasant (IVA, fish) odor groups. No participant had an exclusion proportion larger than 10% of the trials. Differences in odor ratings between priming groups (control, primed) were first assessed using a multivariate analyses of variance (MANOVA) with priming as the between-group variable and phase (pre, postpriming ratings) and odor valence (pleasant, unpleasant) as within-group variables. To assess effects within individual variables, separate repeated-measures analyses of variance (ANOVA) with priming as the between-group variable and phase (pre, postpriming ratings) and odor valence (pleasant, unpleasant) as within-group variables. Differences in behavioral performance between the 2 groups (control, primed) were assessed with separate 2-tailed independent-sample *t*-tests for each dependent measure (reaction time and word label accuracy).

Results
Reaction time to odors was unaffected by priming, pleasant: *t*(38) = .41, *P* = ns; unpleasant: *t*(38) = .32, *P* = ns (see Figure 2a). However, primed participants took longer to respond to the presented words, *t*(38) = 2.55, *P* < .02, and labeled fewer of the emotional words as such, *t*(38) = 3.30, *P* < .005 (see Figure 2b). There was no main effect of priming on the perceptual ratings, as demonstrated by the MANOVA (*P* > .10). Furthermore, there was no main effect of priming for ratings of intensity (*P* > 0.08), pleasantness (*P* > 0.17), or familiarity (*P* > 0.11). Taken together, it seems that priming a subject with an elderly stereotype is sufficient to affect verbal and motor behaviors but not sufficient to alter olfactory sensation, perception, or reaction time.

Discussion
Priming of the elderly construct successfully slowed motor performance and decreased verbal recall of participants but did not affect any measure of olfactory perception or performance, despite the fact that age-related declines in olfactory function were the focus of a presentation given to all elderly primed participants.
Consistent with prior research, activating the elderly stereotype category decreased walking speed and word recall in primed participants. Furthermore, although this prime of the elderly stereotype was capable of affecting participants’ reaction time for recognizing emotion-laden words among neutral ones, it had no effect on reaction time to odors. Priming the elderly stereotype had no effect on olfactory sensitivity, discrimination, or identification, or it did not have any effect on ratings of intensity, pleasantness, or familiarity, again despite the fact that the elderly primed participants began the study by listening to a presentation regarding age-related declines in olfactory function. Thus, it seems that odor processing is resistant to priming of the elderly stereotype.
That olfaction was not affected by the priming paradigm was somewhat surprising given the fact that olfactory perception has a long history of being exceptionally malleable and susceptible to top-down (i.e., contextual) influences.
There are several possible explanations for the discrepancy between the lack of observed effects of stereotype priming on olfaction and the robust effects observed for memory and motor behavior. First, there could have been a stronger automatic association of the elderly construct with physical slowness and decreased memory performance than with olfactory deficits, a factor that even the earlier information presentation on age-related declines could not overcome. The strength of the association between the construct and the behavior often arises from direct experience or contact with exemplars of the social category and subsequently affects the strength of the stereotype activation and its effect on behavior (Dijksterhuis et al. 2000). Second, it is noteworthy that the majority of behaviors that have been shown to be affected by activation of the elderly stereotype involve easily observable actions, such as walking, driving, reaching, grasping, and forgetfulness (Bargh et al. 1996; Chasteen et al. 2002; Kawakami et al. 2002; Banfield et al. 2003; Kawakami et al. 2003; Chambon 2009). In contrast, behaviors exemplifying age-related deficits in olfactory function are often not apparent to outside observers; in fact, perhaps they are even less apparent than behaviors representing dysfunction in other sensory systems, such as vision and audition. It is possible that the elderly stereotype would have greater influence on visual or auditory acuity, sensory functions which may be more overtly associated with this construct. Finally, one could argue that the priming paradigm employed may have primed a mood state rather than a social stereotype. The topic of aging could potentially be a depressing topic for some individuals and depression may cause motor slowing and impair memory, that is, the reaction time and word recall effects found in the present study could have been the result of an emotion prime. Whether the well-established priming paradigm used within these studies preferentially primes stereotypes or whether emotional aspects are involved is ripe for future studies. Nonetheless, irrespective of the exact mediating mechanism of priming or the selection of tasks assessed within the present studies, the effects of stereotype priming on odor functions appear to be limited.

The age of the participants has also been shown to be relevant in some studies of stereotype priming. Although many studies priming the “elderly” stereotype have demonstrated robust behavioral effects among very young participants, a few studies have shown a different pattern when testing both young and elderly adults. Activation of both positive and negative elderly stereotypes both improved and impaired memory performance of elderly individuals but had no effect on the performance of young participants (Levy 1996). This age-related dissociation was later confirmed in a study where a negative elderly stereotype impaired the performance of the older participants but not the younger ones (Stein et al. 2002). Thus, it is possible that we may have found priming effects if we had tested an older population.

It is particularly interesting that the priming paradigm affected reaction time to words but not reaction time to odors, both of which would appear to have a similar strength of association with the elderly stereotype. However, if we consider the differences from an ecological perspective, there is adequate reason to expect that a sensory function such as olfaction, which can signal silent invisible dangers, would be more stable and resistant to manipulations which would render it less effective. Moreover, it should be taken into consideration that the reaction time tasks differed in more than sensory modality. An additional key decision was needed to respond to the words. This decision was implemented to offset the considerable reaction time difference between the sensory modalities and to allow time for cognitive processing of the visual stimuli. It is possible that if a more cognitively demanding task had been implemented for the odor reaction time task, stereotype priming effects might have been detected. The average reaction time for the odors, influenced by the participants’ divided attention and the passive nature of the presentation (See also, Boesveldt et al. 2010), was still sufficiently long to allow cognitive processing. Nevertheless,
it would be of interest for future studies to explore differences in stereotype priming effects on odor reaction times in tasks demanding various degrees of cognitive evaluation.

In a different priming task, odor repetition priming, participants are repeatedly exposed to several odors and are later tested for how these experiences affect a variety of odor task performances (e.g., identification, subjective ratings, and reaction time). Interestingly, odor priming effects have been challenging to discover, relative to the well-established priming effects seen in visual repetition priming (Olsson et al. 2002; Schab and Crowder 1995; Olsson and Cain 2003).

Where priming effects have been found with odors, it seems as though these effects are based on odor naming and conceptual priming as opposed to the odors themselves and perceptual priming. Although these are related phenomena, the stereotype priming paradigm used herein intentionally primed a concept to assess its capacity to affect odor perception, which, similar to odor priming, was elusive.

The current experiment primed participants with the elderly stereotype to activate expectations of olfactory function deficits and test whether these expectations could affect olfaction. Whether the priming failed to elicit expectations of olfactory function deficit in this population or whether olfaction was resistant to these expectations awaits future experimentation.

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References


