

Impact of odor exposure time on olfactory parameters

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Abstract

Objective: The aim of this study was to assess the impact of odor exposure time on odor threshold, odor identification and discrimination.

Methods: Ninety healthy volunteers were randomly divided into three groups: Group 1 underwent an olfactory test with the standard odor exposure time (3–4 sec), Group 2 had an odor exposure time of 8–10 seconds, and Group 3 had 30 seconds. Odor parameters of three groups were compared.

Results: Groups 2 and 3 had significantly better odor identification scores than Group 1. There were no statistically significant differences between the three groups in terms of mean odor threshold and discrimination scores. Males of Group 3 had significantly better odor identification scores than males of Groups 1 and 2 and females of Groups 2 and 3 had significantly better odor identification scores than females of Group 1.

Conclusion: The results of the present study showed that longer odor stimulation led to higher odor identification scores. However, odor threshold and odor discrimination were independent from the odor exposure time. The odor exposure time of olfactory screening tests may be revised according to the gender in accordance with our findings.

Keywords: Odor exposure time, odor identification, odor threshold, odor discrimination, Sniffin' sticks.

Özet: Koku maruziyet süresinin koku parametreleri üzerine etkisi

Amaç: Çalışmamızın amacı koku maruziyet süresinin koku eşiği, koku alma ve ayırt etme üzerine etkisinin değerlendirilmesi idi.

Yöntem: Doksan sağlıklı erişkin randomize olarak 3 gruba ayrıldı. Grup 1'e standart koku maruziyet süresi (3–4 sn), Grup 2'ye 8–10 saniye ve Grup 3'e ise 30 saniye koku maruziyet süresi koku testi uygulandı. Her üç gruba ait koku parametreleri karşılaştırıldı.

Bulgular: Grup 2 ve 3, Grup 1'e göre anlamlı oranda daha iyi koku tanıma skorlarına sahipti. Üç grup arasında koku eşiği ve koku ayırt etme skorları açısından anlamlı fark yoktu. Grup 3'teki erkekler Grup 1 ve 2'dekilere göre, Grup 2 ve 3'teki kadınlar ise Grup 1'ekilere göre anlamlı oranda daha iyi koku tanıma skorlarına sahip idi.

Sonuç: Mevcut çalışmanın sonuçları uzun koku uyarısının yüksek koku tanıma skorlarına yol açtığını gösterdi. Bununla birlikte, koku eşiği ve koku ayırt etme koku maruziyet süresinden bağımsız idi. Koku tarama testlerindeki koku maruziyet süreleri bizim bulgularımızla uyumlu olarak cinsiyete göre revize edilebilir.

Anahtar sözcükler: Koku maruziyet süresi, koku tanıma, koku eşiği, koku ayırt etme, Sniffin' sticks.

Olfactory testing offers valuable information in the daily practice of otolaryngologic and neurologic examinations.^[1] Several olfactory tests are used for simple, fast, and reliable evaluation of olfactory function, including the University of Pennsylvania Smell Identification Test, the "Sniffin' sticks" test, European Test of Olfactory Capabilities and the test of the Connecticut Clinical Chemosensory Research Center.^[2–4] Sniffin' sticks is a modern test of nasal chemosensory performance, developed by Kobal and Hummel, consisting of tests of odor threshold, identification, and discrimination.^[5,6]

The recommended and implemented odor exposure time on the Sniffin' sticks test is 3–4 seconds, in the validat-

ed studies.^[1,4,5] This proposal is based on basic information about the physiology of olfaction, odor adaptation, and the processing time of the peripheral and central olfactory pathways.^[5] However, recent studies demonstrated that normal olfactory function requires not only the basic sense of smell but also normal cognitive functions, odor memory, and synaptic plasticity.^[7,8] Although there are studies about the influences of presentation of odors, distractors, odor concentrations and repeated exposures on olfactory function, there are no accurate data on the objective clinical results or on how olfactory parameters are affected by odor exposure time.^[4–8]

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The aim of this study was to assess the impact of odor exposure time on olfactory parameters on the smell screening tests.

Materials and Methods

Study design

This prospective clinical trial was performed at the Department of Otorhinolaryngology at the Faculty of Medicine of Ondokuz Mayıs University, with the permission of Clinical Trials Ethics Committee (B.30.2.ODM.0.20.08/1225). Informed consent was obtained from all participants before the study began, and all investigations were conducted in accordance with the Declaration of Helsinki on biomedical studies involving human subjects. Ninety healthy volunteers from the ages of 18 to 60 years underwent an otolaryngologic examination and an olfactory test. The 90 subjects were randomly divided into three groups: Group 1 underwent an olfactory test with the standard odor exposure time (3–4 sec), Group 2 had an odor exposure time of 8–10 seconds, and Group 3 had 30 seconds.

Subjects with obstructive nasal pathologies (e.g., severe nasal septum deviation, nasal polyposis) causing conductive-type olfactory dysfunction, severe systemic disease (e.g., uncontrolled diabetes, hypertension, malignancy), neurologic or psychiatric disorders, a history of drug use (e.g., antithyroid drugs, steroids, antidepressants), upper respiratory infections within the past four weeks, or a current history of smoking were excluded from the study.

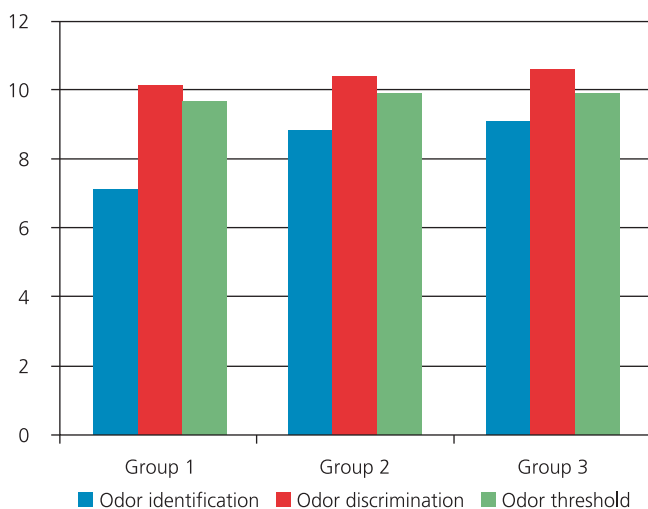


Fig. 1. The comparison of odor parameters of three groups (odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds).

Olfactory testing

Sniffin' sticks (Burghart GmbH, Wedel, Germany) test was applied beside routine otolaryngologic examinations by the blinded researchers.^[9] The odor threshold test was performed with n-butanol and was evaluated using a single-staircase, triple-forced choice procedure.^[9,10] The use of 12 common odors determined odor identification, and discrimination. Odorants were presented using commercially available felt-tip pens. During odor presentation, the tip of the pen was placed 15 mm to 25 mm in front of the participant's nostrils and the pen's cap was removed by the experimenter for 3–4 seconds for Group 1, 8–10 seconds for Group 2 and 30 seconds for Group 3. Using a multiple forced-choice paradigm, the subjects identified individual odors from a list of four verbal descriptors each, with an interval of at least 30 seconds, to prevent olfactory desensitization.^[10] The test result was the sum score of the correctly identified odors. The maximum score for each subtest is 12, resulting in a maximum composite score of 36 (threshold, discrimination and identification scores).^[5,9,10]

Statistical analyses

Statistical analyses were performed through SPSS 21.0 for Windows™ (SPSS Inc., Chicago, IL, USA). The normality of data in each group was tested using the Kolmogorov–Smirnov test. Differences between the groups were analyzed with analysis of variance (ANOVA) and post hoc Tukey tests were also performed to identify the differences among the groups. To explore olfactory function in relation to the odor exposure time in this study, data were submitted to an ANOVA using the general linear model. Correlational analyses were calculated according to Pearson. The level of significance was set at .05.

Results

This study was carried out in 90 volunteers (42 female, 48 male) between the ages of 18 and 60 years. The mean age of the volunteers was 36.4 ± 11.7 years. There were no significant differences between the three groups in terms of age and gender distribution ($p > 0.05$). Groups 2 and 3 had significantly better odor identification scores (OIS) than Group 1 (7.1 ± 0.6 , 8.8 ± 0.5 and 9.1 ± 0.6 for Groups 1, 2 and 3, respectively; $p < 0.001$). There were no statistically significant differences among the three groups in terms of mean odor threshold scores (OTS) and odor discrimination scores (ODS) ($p = 0.808$ and $p = 0.642$, respectively). The demographic data and olfactory parameters of the three groups are presented in Table 1 and Fig. 1.

Table 1. The demographic data and olfactory parameters of three groups (odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds).

	Group 1 (n=30)	Group 2 (n=30)	Group 3 (n=30)	p Value
Age (years)	37.5±13.5 (19–58)	35.7±12.6 (18–57)	36.1±9.8 (19–60)	0.552
Gender (F/M)	14/16	15/15	13/17	0.824
Odor identification	7.1±0.6 (3–10)	8.8±0.5 (3–12)	9.1±0.6 (4–12)	<0.001
Odor discrimination	10.1±0.7 (4–11)	10.4±0.8 (4–12)	10.6±0.9 (6–11)	0.808
Odor thresholds	9.7±0.8 (3–10)	9.9±0.7 (3–11)	9.9±0.8 (3–12)	0.642

F: female, M: male

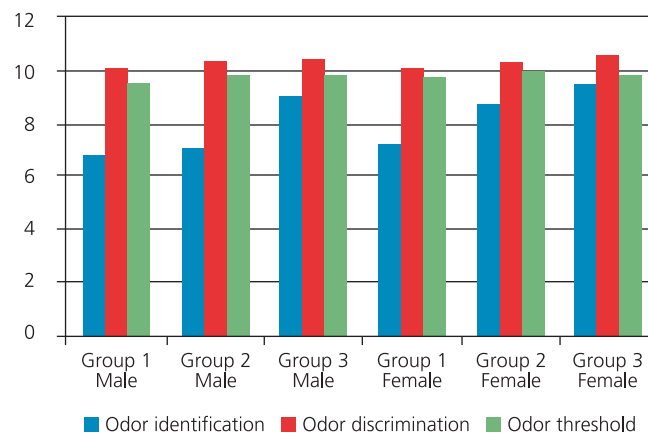
The comparisons of olfactory parameters for the three groups among males and females showed that males of Group 3 had significantly better odor identification scores than males of Groups 1 and 2 (mean OIS of males: 6.8±0.8, 7.1±0.6 and 9.1±0.6 for Groups 1, 2 and 3, respectively; $p<0.01$), and there were no statistically significant differences among the males of the three groups in terms of mean odor threshold or discrimination ($p=0.691$ and $p=0.772$, respectively) (Table 2).

Females of Groups 2 and 3 had significantly better odor identification scores than females of Group 1 (mean OIS of females: 7.3 ±0.5, 8.8±0.7 and 9.5±0.6 for Groups 1, 2 and 3, respectively; $p<0.05$). There were no statistically significant differences among the females of the three groups in terms of mean odor threshold or odor discrimination scores ($p=0.486$ and 0.790, respectively) (Table 2).

There were no significant differences among the genders in Group 1 and Group 3 in terms of odor parameters (Table 2). However, females of Group 2 had better odor identification scores than males of group 2 (8.8±0.7 and 7.1±0.6, respectively; $p<0.001$). There were no significant differences among the genders in terms of olfactory threshold and discrimination scores in Group 2 ($p=0.754$ and 0.887, respectively) (Table 2). Also, there were no significant differences among the genders in terms of olfactory threshold, identification and discrimination scores

($p=0.631$, 0.081 and 0.654, respectively), when all participants have evaluated. The comparisons of mean olfactory parameters according to the gender are presented in Table 2 and Fig. 2.

Although significant decreases in olfactory parameters were detected with aging, there were no significant differences in terms of effects of odor exposure time on olfactory parameters when the younger (under 45-years-old) and older age groups (over 45-years-old) were compared. The

**Fig. 2.** The comparison of odor parameters of three groups among the genders (odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds).**Table 2.** The olfactory parameters of three groups among the genders (odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds).

	Group 1 (n=30)		Group 2 (n=30)		Group 3 (n=30)		p value	
	Female (n=14)	Male (n=16)	Female (n=15)	Male (n=15)	Female (n=13)	Male (n=17)	Female	Male
Odor identification	7.3±0.5 (3–10)	6.8±0.8 (3–9)	8.8±0.7 (3–12)	7.1±0.6 (4–11)	9.5±0.6 (4–11)	9.1±0.6 (4–12)	<0.001	0.004
Odor discrimination	10.1±0.7 (5–10)	10.1±0.6 (4–11)	10.4±0.8 (4–12)	10.4±0.8 (5–12)	10.6±0.9 (7–11)	10.5±0.8 (6–11)	0.078	0.843
Odor thresholds	9.8±0.7 (4–10)	9.6±0.9 (3–10)	10.0±0.7 (5–11)	9.8±0.7 (3–10)	9.9±0.6 (4–12)	9.9±0.9 (3–11)	0.653	0.775

Table 3. The olfactory parameters of three groups among the age groups (odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds).

	Group 1 (n=30)		Group 2 (n=30)		Group 3 (n=30)		p value	
	45↓ (n=21)	45↑ (n=9)	45↓ (n=20)	45↑ (n=10)	45↓ (n=23)	45↑ (n=7)	(45↓)	(45↑)
Odor identification	7.7±0.6 (5–10)	6.7±0.9 (3–9)	8.9±0.6 (5–12)	7.1±0.6 (4–11)	9.8±0.7 (4–11)	9.1±0.9 (4–12)	<0.001	0.003
Odor discrimination	10.3±0.6 (6–10)	10.0±0.4 (4–10)	10.6±0.7 (4–11)	10.4±0.8 (4–12)	10.6±0.8 (6–11)	9.7±0.7 (5–11)	0.065	0.816
Odor thresholds	9.9 ± 0.7 (5–10)	9.5±0.9 (3–9)	9.0±0.7 (5–9)	9.8±0.7 (3–10)	9.6±0.5 (5–12)	9.9±0.7 (3–10)	0.516	0.675

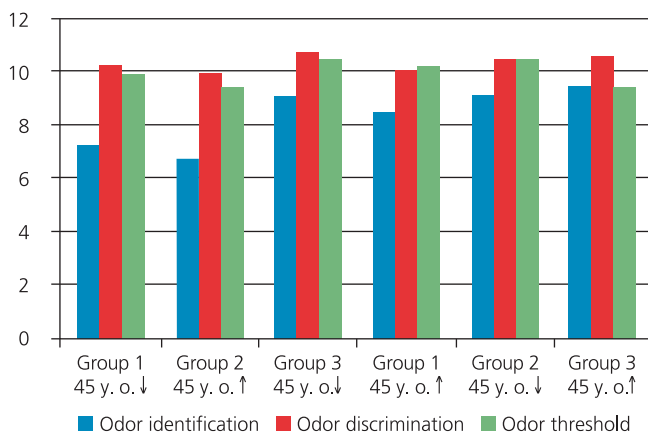
45↓: under 45-year-old, 45↑: over 45-year-old.

comparisons of olfactory parameters according to the age groups have presented in Table 3 and Fig. 3.

Discussion

Odor perception is highly dependent on an individual's age, gender, motivation, and previous experiences, as well as his or her social, cultural, mental, and spiritual status.^[11] Many diseases that impair cognitive function, such as Alzheimer's disease, Parkinson's disease, schizophrenia, and depression, are known to negatively affect the sense of smell.^[12,13] Repeated exposure to odors induces affective habituation of perception and sniffing and previous studies which investigated the effect of exposure on odor discrimination showed that unreinforced exposure to odors can improve discrimination.^[14,15] Although these studies have shown that repeated exposure to odors improves odor perception, the impact of odor exposure time on odor identification and discrimination remains under-studied.

Subjects are often able to recognize an odor as familiar and pertaining to some general category, but they are still

**Fig. 3.** The olfactory parameters of three groups among the age groups [45↓: under 45-year-old (y.o), 45↑: over 45-y.o, odor exposure time for Group 1: 3–4 seconds, Group 2: 8–10 seconds, Group 3: 30 seconds].

unable to find a correct verbal label, which is known as the “tip-of-the-nose phenomenon”.^[16,17] Odor identification has been shown to be highly influenced by the task the participant is performing: a free choice identification task is more difficult than a cued one and requires a higher degree of cognitive contribution.^[18–20] The structure, context, and concentration of odorants also affect olfactory test results. The Sniffin' sticks test battery has been validated by clinical studies and the previous studies performed the odor exposure time on the Sniffin' sticks test as 3–4 seconds.^[1,4,5,6,21,22] Our study showed significant improvement in odor identification scores when the odors were presented for 8–10 seconds instead of the standard 3–4 seconds during the Sniffin' sticks smell test, and extension of odor exposure time had no significant effect on odor thresholds or discrimination scores. We think this situation may be related with the fact that the identification test was already performed and there was a familiarity with the odors during the discrimination test. The other reason for improvement of odor identification ability with longer odor stimulus may be the distractors listed for each odor in the odor identification task of the Sniffin' sticks test, because they are typically similar. Gudziol et al. reported that, the use of more contrasted distractors in cued odor identification tasks can contribute to better discrimination, which can obtain highly valuable in a clinical context. This method may also reduce the necessary odor exposure time.^[4] Because of time constraints in clinical practice, the screening variations of these tests consist mostly of odor identification tests and so, the impact of odor exposure time on odor identification is much more important in daily practice.^[18,23,24] Our results have also showed that, odor identification test requires more time than the odor threshold test. We think, this result may be related with cognitive and memory mechanisms rather than olfactory pathways if we take into consideration that our study has ruled out on healthy subjects. In our study there was no further improvement in odor perception when the exposure time was increased to 30 seconds. This shows that 8–10 sec-

onds are sufficient for odor memory and motivation of participants to the odor, and a more prolonged time has no benefit for odor perception. In fact, a prolonged exposure time can cause problems with adaptation to the next scent. However, our study did not identify such a clinical deterioration. Our results suggest that, similar to the trigeminal system, there is a duration/concentration trade-off in the olfactory system.^[25,26] Wise et al. reported that longer stimuli are perceived as more intense than shorter ones, although the stimulus concentration is the same; thus, stimuli with lower concentrations are perceived to be as equally intense as shorter stimuli with higher concentrations.^[26,27] If the olfactory system was a perfect and pure mass detector, it would be difficult to correctly rate the duration of olfactory stimuli and subjects could clearly distinguish between different durations of chemosensory stimuli. Ferdenzi et al. reported that repeated exposure to odor induces affective habituation of perception and sniffing, and an increasing duration of odor presentation is associated with enhanced activity in the pregenual cingulate cortex, the medial orbitofrontal cortex, and the dorsolateral prefrontal cortex.^[11] These findings suggest that inter-individual differences have significant implications at the peripheral and central levels of olfactory processing. We see that the odor exposure time has been an applied standard in previous studies of the Sniffin' sticks test's normative data, and the impact of exposure time on the normative data has not been evaluated.^[28,29] Frasnelli et al. investigated the influence of stimulus duration on odor perception by the olfactory event-related potentials and reported that with regard to intensity ratings, strong stimuli and longer-lasting stimuli led to higher ratings.^[25] Their findings revealed that ratings of stimulus duration were dependent on stimulus concentration and stimulus duration.

In a recent study, Croy et al. reported that the Sniffin' sticks test of odor memory proved to be a valid odor memory test, with the advantage of being short enough to also enable testing of people with cognitive impairments.^[3] This novel method may be an alternative to extending the odor exposure time. However, our study is the first clinical study that evaluates the impact of odor exposure time on the olfactory parameters during smell-screening tests. Also, a comparison of odor exposure time between genders has not been studied before. Our study revealed that males need longer odor stimuli than females for odor identification. Males and females differ on the perceptual evaluation of odor intensity, as shown in a pioneering study by Doty et al., who observed that only adult women rated the exposure as strong or extremely strong, and a recent study demonstrated that

females have more neurons and glial cells than males do in the olfactory bulb, which theoretically supports these findings.^[30] Besides, it has been reported in odor identification tasks that, women usually outperform men, which is partly because women typically have better verbal abilities than men. Our findings support the previous studies that reported slightly higher odor identification scores in women.^[31] Our study has also revealed an age-related decrease of odor identification ability, in accordance with the previous studies.^[32] Although significant decreases in olfactory parameters were detected with aging, there were no significant differences in terms of effects of odor exposure time on olfactory parameters when the younger and older age groups were compared. One should take into consideration when comparing our findings with the others that, we have performed our study in healthy individuals and we have used Sniffin' sticks test with 12 odorants, that may reduce the reliability of comparisons with the findings of studies which have been performed with the subjects with olfactory dysfunction and using smell test with 16 odors and these were the two limitations of our study.

The results of the present study showed that longer odor stimuli led to higher odor identification scores. However, odor threshold and odor discrimination were independent from the odor exposure time. We believe that our findings will shed light on the assessment of results of the smell test in clinical practice and also the odor exposure time of olfactory screening tests may be revised according to the gender in accordance with our findings.

Conflict of Interest: No conflicts declared.

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