



## Antisaccade and prosaccade performance in young adult women: Normative values and gender differences

Genç yetişkin kadınlarda antisakkad ve prosakkad performansı: Normatif değerler ve cinsiyet farklılıkları

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### ABSTRACT

**Aim:** The aim of this study was to investigate gender differences in antisaccade (AS) and prosaccade (PS) eye movements in young adults, with a particular focus on understanding the role of women in cognitive functions, attentional control, and decision-making processes.

**Methods:** A total of 102 healthy participants (51 men, 51 women), aged between 19 and 42 years (mean age= 27.06 ± 6 years), were included in the study. Latency, velocity, accuracy, directional error, and overall error rates in AS and PS tasks were analyzed to evaluate gender differences.

**Results:** In AS tasks, women demonstrated significantly higher mean latency, mean velocity, and directional error rates compared to men ( $p<0.05$ ). No significant gender differences were found in accuracy and overall error rates ( $p>0.05$ ). In PS tasks, women exhibited significantly higher mean velocity compared to men ( $p<0.05$ ), whereas no significant gender differences were observed in mean latency, accuracy, directional error rate, or overall error rate ( $p>0.05$ ).

**Conclusion:** When evaluating saccadometry tests, it is essential to consider gender differences, particularly the effects of women's performance on cognitive functions, attentional control, and decision-making processes. Further comprehensive studies including different age groups and hormonal factors are recommended to develop gender-specific assessments and interventions.

**Keywords:** cognition; executive function; eye movements; young adult

### ÖZ

**Amaç:** Bu çalışmanın amacı, genç yetişkinlerde antisakkad (AS) ve prosakkad (PS) göz hareketlerinde cinsiyet farklılıklarını araştırarak kadınların bilişsel işlevler, dikkat kontrolü ve karar verme süreçlerindeki rolünü anlamaktır.

**Yöntem:** Çalışmaya yaşları 19–42 arasında değişen (ortalama= 27.06 ± 6 yıl) 102 sağlıklı birey (51 erkek, 51 kadın) dahil edilmiştir. Cinsiyet farklılıklarını değerlendirmek amacıyla AS ve PS görevlerinde latans, hız, doğruluk, yönsel hata ve genel hata oranları analiz edilmiştir.

**Bulgular:** AS görevlerinde kadınların ortalama latans, ortalama hız ve yönsel hata oranı erkeklerle göre anlamlı derecede yüksek bulunmuştur ( $p<0.05$ ). Doğruluk ve genel hata oranlarında ise anlamlı cinsiyet farkı saptanmamıştır ( $p>0.05$ ). PS görevlerinde kadınların ortalama hız değerleri erkeklerle göre anlamlı derecede daha yüksek bulunmuştur ( $p<0.05$ ). Ancak latans, doğruluk ve genel hata oranlarında cinsiyet farkı gözlenmemiştir ( $p>0.05$ ).

**Sonuçlar:** Sakkadometri testleri değerlendirilirken cinsiyet farklılıklarının, özellikle kadınların bilişsel işlevler, dikkat kontrolü ve karar verme süreçleri üzerindeki etkilerinin dikkate alınması önemlidir. Yaş grupları ve hormonal faktörleri kapsayan daha kapsamlı çalışmalar, cinsiyete özgü değerlendirmeler ve müdahalelerin geliştirilmesine katkı sağlayacaktır.

**Anahtar kelimeler:** biliş; genç erişkin; göz hareketleri; yürütücü fonksiyon

### Introduction

Oculomotor functions play a critical role in the regulation of visual perception (Hutton & Ettinger, 2008). Eye movements are a key component of motor control and coordination. Young adults in particular encounter tasks that require high levels of visual attention and motor skills in their work, education and social lives. Therefore, the ability to move the eyes accurately and quickly is important for us to correctly perceive and interpret visual stimuli in our environment.

Saccades are short and abrupt eye movements performed during rapid target orientation. These movements reorient the visual axes to fixate successive visual stimuli at the fovea (Leigh & Zee, 2015). Saccadic eye movements operate under two main control mechanisms: automatic responses to environmental stimuli and conscious control processes based on attention and task demands. Pro-saccadic (PS) and anti-saccadic (AS) tasks are important tests to assess these two systems.

AS tasks require the individual to suppress the urge to look at a target and consciously look in the opposite direction. This is a strong indicator of executive functions and inhibitory control (Hutton & Ettinger, 2008). Being able to suppress the automatic response in favor of voluntary movements is an important skill in everyday life. PS tasks, on the other hand, involve quickly focusing on a visually presented target and are a reflexive eye movement process (Leigh & Zee, 2015). Eye movements can vary in a variety of ways when there are abnormal conditions associated with executive functions. Research shows that saccadic eye movements are controlled by a large brain network, which largely involves both excitatory and inhibitory pathways (Coe & Munoz, 2017; Munoz & Everling, 2004). The saccadic system is considered to be one of the most important behavioral control systems of the brain, sometimes functioning with highly automatic movements and sometimes functioning under a high level of conscious control (Hutton & Ettinger, 2008).

Saccadometry is an advanced test method that analyzes eye movements in detail and evaluates the brain regions and



neural circuits that control these movements. The saccadometry test, which consists of AS and PS tasks, reveals that neurological degeneration or dysfunction may affect saccade performance. AS tasks require suppression of reflexive saccades by inhibitory signals sent from the dorsolateral prefrontal cortex to the superior colliculus. This process ensures that cognitive processes such as motor inhibition and attentional inhibition work effectively (Aron & Robbins, 2014). It is known that there are age-related differences in neurological development with age due to human physiology. However, the prevalence of some neurodegenerative diseases may also differ according to gender (Young et al., 2023). For example, Parkinson's disease is more common in men (Dahodwala et al., 2018), while Alzheimer's disease is more common in women (Beam et al., 2018). Although neurodegenerative disorders usually occur with age, some diseases that also affect neurological structures such as migraine (Allais et al., 2020; Men et al., 2025), tension-type headache (GBD 2016 Headache Collaborators, 2018), multiple sclerosis (Habbestad et al., 2024; Magyari et al., 2014), and depression (Parker & Brotchie, 2010) are more common in women and young adults. Therefore, establishing normative values for young adults, especially women, becomes particularly important.

In the literature, AS and PS studies have been examined in both healthy individuals and various pathological conditions. However, gender-based research is limited. The aim of this study is to examine the gender-dependent role of AS and PS eye movements in cognitive functions, attention control, and rapid decision-making processes in young adults exposed to numerous distractions in daily life. Additionally, the importance of these eye movements in the diagnosis and monitoring processes of neurological diseases, particularly those observed at a young age, will be evaluated based on gender.

## Methods

### Participants

This study involved 102 healthy participants (51 males, 51 females). Data collection occurred from August to October 2024 at the Audiology Laboratory at the University of Health Sciences. Participants were chosen among students at the University of Health Sciences and hospital personnel through a voluntary sampling procedure. The sample size was established at a minimum of 102 individuals utilizing the G\*Power 3.1 software, with a modest effect size of 0.5, 90% power, and a 0.05% margin of error. Participants with balance, visual, neurological, otological, mental, and cognitive impairments were excluded from the study. Furthermore, the individuals' hearing thresholds were established at a maximum of 25 dB HL, speech discrimination scores were assessed at a minimum of 88%, and central vestibular function was confirmed as intact based on oculomotor evaluations. Pure tone audiometry, speech audiometry, acoustic immittance measurement, and oculomotor testing were conducted to evaluate the subjects' eligibility for inclusion.

### Assessment tools

#### Pure tone and speech audiometry

The tests were performed using a clinical audiometer (Madsen Astera; Denmark) in quiet rooms in accordance with

IAC (Industrial Acoustic Company) standards. Airway hearing thresholds were measured between 125-8000 Hz.

#### Immittancemetry

Tympanometric evaluations (with 226 Hz probe tone) and measurements of both stapedius reflexes were performed using a tympanometer (Madsen Otoflex 100; Denmark).

#### Oculomotor tests

Spontaneous Nystagmus, Eye Tracking, Smooth Pursuit, Random Saccades and Optokinetic Nystagmus tests were performed with VNG (Interacoustics VisualEyes™ 525; Denmark) to exclude central vestibular system functions.

#### Saccadometry

Saccadometry assessments were performed utilizing VNG (Interacoustics VisualEyes™ 525; Denmark). Eye movements were documented with a video-oculography (VOG) headset. The test parameters were modified in accordance with the manufacturer's standard specifications. Participants were positioned on a stationary chair 1.2 meters from the screen. This study employed red targets against a black background in the horizontal plane, occupying 1% of the screen width, to assess participants' saccadic eye movements. A stationary point was positioned centrally in front of the participants during the experiment. A target point emerged to the left or right of this fixed center, being illumination after a random duration of 1 to 2 seconds, with an average of 1.5 seconds. The test configuration sought to assess the participants' attention and reaction times, while documenting the illumination duration of each target and the participants' replies. Calibration was conducted prior to initiating the test. Cameras, mirrors, and focus were calibrated to enhance pupil detection and reduce stimulus-related artifacts. Prior to commencing the exam, the participants were apprised of the testing procedure. To reduce response-related artifacts, participants were directed to maintain open eyes, keep their heads stationary, and adhere to the instructions. In the PS test, participants were instructed to focus their gaze towards the flashing point on the screen and subsequently to the continually illuminated central point. In the AS test, participants were directed to gaze in the opposite direction of the presented dot and thereafter return their focus to the center after each new dot appeared. Initially, the audiometry and oculomotor assessments were conducted, followed by a rest period for the individual of at least 30 minutes. The test completed with the administration of the PS followed by the AS tests. Each test comprised a total of 60 trials (150 s), with 30 directed to the right and 30 to the left. Each technique was executed as a trial block under identical settings. Upon conclusion of the test, the subsequent parameters computed by the software were assessed: Velocity (degrees/second): the rate at which the eyes transition between points. Latency (ms): the interval between the visual input and the initiation of the saccade; Accuracy (target ratio of eye movement): denotes the capacity of the eyes to directly attain the target. Directional error rate: the proportion of ocular movements directed incorrectly. Overall error rate: indicates the cumulative noise and artifacts present in the recording (Demian et al., 2023). This study statistically assessed average values for both eyes and both target directions.

#### Statistical method

IBM SPSS 26.0 package program was used for statistical analysis of the study. Descriptive statistics (frequency, percentage, median, min-max values, mean, standard

deviation) of the demographic data, PS and AS data of the participants were calculated. Wilcoxon signed ranks test was used to compare PS vs. AS latency, velocity, accuracy, directional error and overall error scores of the participants since the data were not normally distributed. In the comparison of PS and AS latency, velocity, accuracy, directional error and overall error scores according to the gender of the participants, Mann-Whitney U test was used because the data were not normally distributed. Shapiro Wilk test was used to determine whether the data were normally distributed. All statistical analyses were evaluated at  $p < 0.05$  level.

**Ethics committee approval**

Ethics committee approval for this study was received from the University of Health Sciences, Hamidiye Faculty of Health Sciences, Ethics Committee and approved by the scientific committee (Decision no: 9/31, Date: 22.08.2024).

**Results**

The distribution of demographic characteristics of the participants is shown in Table 1. Of the participants, 51 (50%) were female and 51 (50%) were male. The mean age of the participants was  $27.06 \pm 6$  years, with the youngest being 19 and the oldest 42 years old.

Table 1. Demographic characteristics of the participants

Demographic Characteristics	n (%)
<b>Gender</b>	
Female	51 (50)
Male	51 (50)
<b>Age mean±SD (Min-Maks)</b>	27.06±6 (19-42)

The comparison of average latency, velocity, accuracy, directional error, and overall error for PS and AS by gender is shown in Table 2. There is a statistically significant difference between the participants according to their gender in terms of AS mean latency (Mann-Whitney U test;  $U=924.5$ ;  $Z=-2.287$ ;  $p=0.022$ ). AS mean latency scores of women are significantly higher than AS mean latency scores of men. There is a statistically significant difference between the participants in terms of AS mean velocity according to their gender (Mann-Whitney U test;  $U=874$ ;  $Z=-2.632$ ;  $p=0.008$ ). The AS mean velocity scores of women are significantly higher than the AS mean velocity scores of men. There is a statistically significant difference between the participants according to their gender in terms of AS directional error (Mann-Whitney U test;  $U=969$ ;  $Z=-1.999$ ;  $p=0.046$ ). AS directional error scores of women are significantly higher than AS directional error

Table 2. Comparison of average latency, velocity, accuracy, directional error, and overall error of PS and AS by gender

	Female			Male			p
	Median (IQR)	Min-Max	Mean±SD	Median (IQ)	Min-Max	Mean±SD	
<b>Prosaccade (n=51)</b>							
Mean Latency (ms)	234	199-349	239.08±26.5	223	193-286	232.12±26.7	0.134
Mean Velocity (°/s)	276.5	179-310	274.83±21.5	270	241-311	268.07±19.8	0.048*
Mean Accuracy (%)	96	86-105	96.42±4.7	95	87-102	95.67±4.5	0.409
Directional error rate (%)	0	0-2	0.28±0.5	0	0-4	0.38±1	0.372
Overall error rate (%)	4	0-13	3.82±3	3.5	1-12	3.98±3	0.981
<b>Antisaccade (n=51)</b>							
Mean Latency (ms)	318	247-403	318.27±37.1	301	258-425	305.38±38.4	0.022*
Mean Velocity (°/s)	227.5	160-357	232.57±41.8	208	167-269	208.64±31.8	0.008**
Mean Accuracy (%)	87	61-133	90.57±19.5	85	58-125	87.19±22.2	0.311
Directional error rate (%)	6	0-12	5.85±2.8	5	0-14	4.95±3.7	0.046*
Overall error rate (%)	9	2-20	9.52±4	8.5	2-18	10.1±4.4	0.633

\* $p < 0.05$ , \*\* $p < 0.01$ , SD: Standard Deviation, IQR: Interquartile Range, Min: Minimum, Max: Maximum, ms: Milliseconds, °/s: Degrees per second.

scores of men. There is no statistically significant difference between the participants in terms of PS mean latency, mean accuracy, directional error and overall error and AS mean accuracy and overall error according to their gender ( $p > 0.05$ ).

Figure representative results from the antisaccade and prosaccade tests are illustrated.

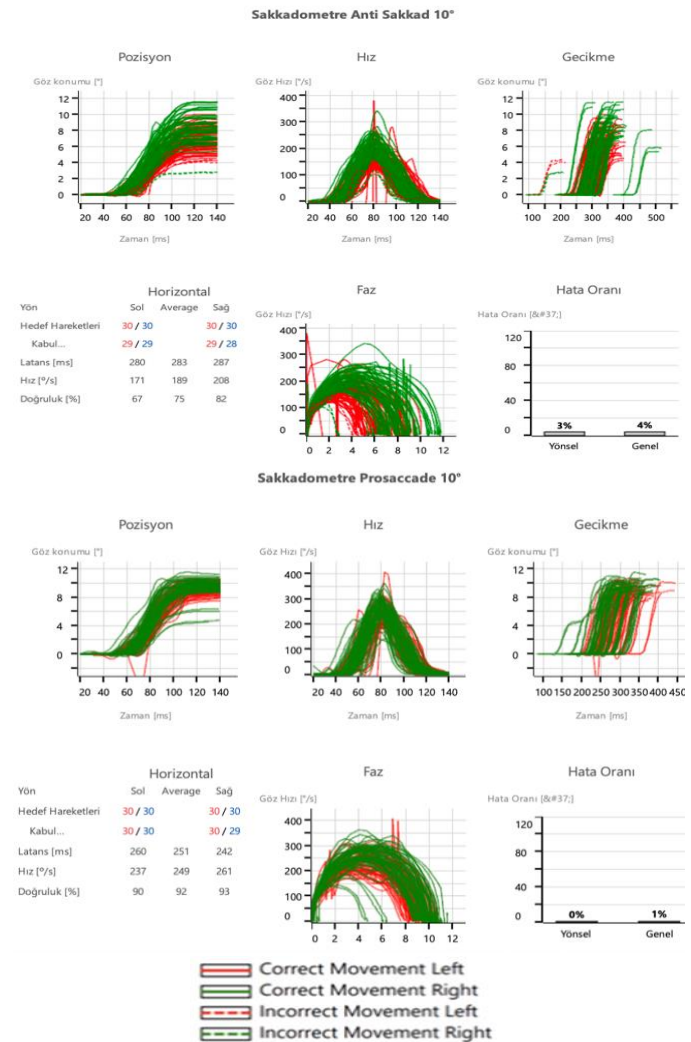


Figure 1. Example result graph from the Antisaccade and Prosaccade test

\*Latency (ms): The time elapsed from the visual stimulus to the initiation of the eye movement. Velocity (degrees/second): The velocity at which the eyes move from one point to another. Accuracy (%): The percentage of eye movements that accurately landed on the target. Directional error rate (%): The percentage of trials in which the eyes moved in the wrong direction. Overall error rate (%): The total percentage of errors and artifacts recorded during the tests.

## Discussion

In this study, we examined the roles of AS and PS eye movements in cognitive functioning, attentional control, and rapid decision-making in young adults exposed to multiple distractions in daily life, and assessed the importance of these eye movements in diagnostic and monitoring processes for neurological health. Our study provided PS and AS data on four measures of this protocol: error, latency, velocity and accuracy. We found that women showed significant differences ( $p < 0.05$ ) in latency, velocity and error rates compared to men in AS tasks. In the PS tasks, only the difference in velocity was significant. These results suggest that saccadometry tests provide important information in the assessment of cognitive function by taking gender differences into account.

Performance differences in AS and PS tasks are among the topics frequently examined in the literature. In the Leigh and Zee study, it was emphasized that AS tasks are an important measure of executive functions and inhibitory control processes (Leigh & Zee, 2015). In this context, the high latency, velocity and error rates in AS tasks in our current study, which included more errors than PS results, are consistent with these findings in the literature. In a normalization study conducted by Demian et al., (2023) it was shown that participants had more difficulty in AS tasks than PS tasks. Compared to our study, while some parameters were in agreement, some differences were noteworthy. In terms of latency durations, women in both studies were found to have longer latencies in AS tasks, indicating gender differences in inhibitory control processes. AS velocity findings were similar for females, whereas PS velocity findings differed; females were found to be faster in our study, whereas males were reported to be faster in the study by Demian et al. Moreover, there are significant differences between the two studies in terms of error rates. In our study, women were found to make more directional errors in the AS task, whereas women made fewer errors in the study by Demian et al. (2023). It is thought that these differences may be due to factors such as sample groups, environmental conditions and cultural influences.

Studies have reported that PS tasks measure more automatic and reflexive eye movements (Butler et al., 1999; Leigh & Zee, 2015). In the present study, women's mean velocity scores in PS tasks were significantly higher than men's, suggesting that automatic processing velocity in these tasks may differ depending on gender. We suggest that velocity differences in PS tasks are related to individuals' automatic motor responding abilities and that these abilities may differ between genders. The findings suggest that female individuals respond faster in automatic responding processes, but that these faster responses may have negative effects on accuracy and control.

Performance differences between genders reveal that cognitive control processes and executive functions may vary depending on gender. Li et al. (2009) emphasized that gender differences show neural differences in cognitive control and response inhibition processes and that men and women use different neurological strategies. The findings in our study confirm that female individuals exhibit higher error rates in AS tasks, which suggests that they experience more difficulty in inhibitory control processes or use different strategies. This suggests that there may be different needs in the

management of cognitive load depending on gender. These results will shed light on the development of gender-specific psychopathological profiles.

McCarrey et al., (2016) assessed cognitive functions in healthy adults with cognitive tests in various domains such as mental status, verbal learning and memory, figural memory, language, attention, perceptual-motor velocity, integration, executive functions and visuospatial abilities. In their study examining gender differences in cognitive trajectories, they emphasized, consistent with our study, that at younger ages, males have an advantage over females in certain cognitive domains. However, over time, they reported that women were more resilient to age-related cognitive decline (McCarrey et al., 2016). The findings suggest that neurophysiological differences between the sexes may change dynamically with age. This suggests that the neuropathological processes of age- and sex-related cognitive differences should be closely monitored. In this context, the use of saccadometry tests as a practical and effective tool for such follow-up in the clinical setting may make a significant contribution to the monitoring of neurological changes.

Alarcon et al. (2018) examined gender differences in self-referential processing (SRP) and cognitive control processes during adolescence. SRP refers to thinking about oneself and incorporating others' perceptions into one's own evaluation, and is supported by the brain's default mode network (DMN). Cognitive control, on the other hand, involves attention and response management in external tasks and is controlled by the frontoparietal network (FPN). Research shows that during cognitive control tasks, the DMN and FPN networks often work in reverse, meaning that when one is active, the other is inactive. However, disruption of the balance between these two networks has been associated with mental disorders such as depression (Alarcon et al., 2018). Distractions encountered in everyday life can significantly affect cognitive functioning and attentional control, especially in young adults. This study suggests that differences in performance on AS and PS tasks provide important clues in understanding how young adults respond to these distractions and how they manage resources in their cognitive processes. The higher latencies and error rates on AS tasks in females suggest that they have more difficulty than males in suppressing automatic responses and consciously generating alternative responses. This is thought to be related to the influence of hormonal factors, especially in young women. By affecting inhibitory control processes and attentional management, hormonal changes may negatively affect women's performance on AS tasks compared to men. Our study supports that saccadometry tests can be an important tool in the assessment of cognitive functions and neurological health conditions. In particular, differences in performance on AS tasks play a critical role in understanding sex differences in executive functions and inhibitory control processes. Studies by Pretegeiani and Optican (2017) and Molitor et al. (2015) suggest that taking into account gender-based performance differences in Parkinson's and Alzheimer's diseases may allow the development of more effective interventions in patients' treatment processes. Similarly, research suggests that understanding gender differences in traumatic brain injury may help to develop personalized approaches in rehabilitation processes (Young et al., 2023). In this context, our findings

suggest that gender differences should be taken into consideration in clinical practice.

### Limitations

Saccadometry is an important method for analyzing eye movements in detail and assessing the brain regions and neural circuits that control these movements. This study supports saccadometry tests as a potential biomarker for the assessment of cognitive functions and neurological health conditions. However, our study has some limitations. First, our study sample consists of young adults and therefore generalization of results to other age groups may be limited. Furthermore, although we focused on gender differences, we were not able to examine the effects of hormonal and biological factors in detail. Future studies should conduct more comprehensive analyses taking into account different age groups and hormonal conditions.

### Conclusion

This study provides normative saccadic parameters for young adult women and men and demonstrates gender-related differences particularly in antisaccade latency, velocity, and directional error rate. Women exhibited longer latency and higher velocity in antisaccade tasks, as well as higher velocity in prosaccade tasks. These findings suggest potential gender-related variations in inhibitory control and oculomotor dynamics. The presented normative data may serve as a reference framework for future cognitive-vestibular research and for clinical interpretation of saccadic performance.

### Ethics Committee Approval

Ethics committee approval was obtained Hamidiye Faculty of Health Sciences Ethics Committee, of University of Health Sciences (Board Decision No: 09/31) on August 22, 2024.

### Informed Consent

Written consent was obtained from the participants.

### Peer-Review

Externally peer-reviewed.

### Author Contributions

A.F.M.: Research Idea, Design of the Study, Data Collection, Data Analysis, Interpretation of data for the Study, Drafting the Manuscript, Revising It Critically for Important Intellectual Content, Final Approval of the Version to be Published.

A.K.C.: Revising It Critically for Important Intellectual Content, Final Approval of the Version to be Published.

### Conflict of Interest

There is no conflict of interest.

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