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THE EFFECT OF AGE, AUDITORY SIGNALS AND TECHNOLOGY ANXIETY ON PEDESTRIAN CROSSING BEHAVIOR

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ÖZET

KEMALLARLI, Ece. Yaş, İşitsel Sinyaller ve Teknoloji Anksiyetesinin Yaya Karşıdan Karşıya Geçme Davranışı Üzerindeki Etkisi, Başkent Üniversitesi, Sosyal Bilimler Enstitüsü, Sosyal Psikoloji Tezli Yüksek Lisans Programı, 2025.

Teknoloji anksiyetesi, bireylerin teknolojiye yönelik duygusal ve bilişsel tepkileriyle ilişkili psikolojik bir yapı olup, teknoloji aracılığıyla yürütülen ortamlardaki davranışları önemli ölçüde etkileyebilmektedir. Yaşa bağlı bilişsel işlemleme farklılıkları ve uyum sağlama kapasitesi, özellikle karşıdan karşıya geçme gibi görevlerde belirginleşebilmektedir. Bu tez, yaş, teknolojik işitsel uyaranlar ve teknolojiye ilişkin anksiyetenin sanal gerçeklik (VR) ortamında yaya davranışına olan bileşik etkilerini incelemeyi amaçlamaktadır. Araştırma, birbirini tamamlayan iki çalışmadan oluşmaktadır. Birinci çalışmada, Kısaltılmış Teknoloji Anksiyetesi Ölçeği'nin (ATAS) Türkçeye uyarlanması ve psikometrik özelliklerinin değerlendirilmesi hedeflenmiştir. Bu kapsamda, yaşları 18 ile 70 arasında değişen 380 katılımcıdan veri toplanmıştır. Ölçeğin Türkçe versiyonu, tek boyutlu bir faktör yapısı, yüksek iç tutarlılık ve güçlü zamansal güvenirlik sergilemiştir. Ayrıca, yerleşik bir bilgisayar anksiyetesi ölçeğiyle elde edilen anlamlı ve pozitif korelasyon, ölçüm aracının ölçüt geçerliğini desteklemiştir. Elde edilen bulgular, Türkçe ATAS'ın farklı yaş gruplarındaki bireylerin genel teknoloji anksiyetesini değerlendirmede güvenilir ve geçerli bir araç olduğunu göstermektedir. İkinci çalışmada, 2 (Genç vs. Yaşlı) × 3 (Kontrol, Sabit Aralıklı, Hızlanan) faktörlü karma desenli deneysel bir tasarım kullanılarak, işitsel uyaranların yaya geçiş davranışı üzerindeki etkileri incelenmiştir. Toplam 54 katılımcı (29 genç, 25 yaşlı yetişkin) her üç işitsel koşul altında VR tabanlı bir karşıdan karşıya geçiş görevini tamamlamıştır. Deney öncesinde ölçülen teknoloji anksiyetesi puanları kovaryans değişkeni olarak analizlere dâhil edilmiştir. Bulgular, işitsel koşulların yaya geçiş süresi üzerinde anlamlı bir ana etki yarattığını; hızlanan ve sabit aralıklı koşullarda geçiş sürelerinin kontrol koşuluna kıyasla daha kısa olduğunu göstermektedir. Yaş grupları arasında anlamlı bir farklılık ya da yaş × işitsel koşul etkileşimi bulunmamıştır. Teknoloji anksiyetesi kovaryant olarak anlamlı çıkmamış, ancak işitsel koşullar ile teknoloji anksiyetesi arasında anlamlı bir etkileşim gözlenmiştir. Buna göre, işitsel uyaranların etkisinin teknoloji anksiyetesi düzeyine bağlı olarak değişebileceği yönünde ön bulgular elde edilmiştir. Elde edilen bulgular, işitsel uyaranların yaya geçiş davranışını kolaylaştırabileceğini, fakat bu etkinin teknolojiye ilişkin bireysel farklılıklar tarafından şekillendiğini düşündürmektedir. Çalışmanın sınırlı örneklem büyüklüğü ve laboratuvar ortamına dayalı kurgusu nedeniyle sonuçlar dikkatle yorumlanmalı ve gelecekte daha geniş örneklemlerle yeniden sınanmalıdır. Bununla birlikte, bu bulgular işitsel ipuçlarının, özellikle farklı yaş grupları ve teknolojiye yönelik farklı tutumlar dikkate alınarak, yaya güvenliğini destekleyici potansiyel bir araç olabileceğini göstermektedir.

Anahtar Kelimeler: Yaya davranışı, karşıya geçme, teknoloji anksiyetesi, sanal gerçeklik (VR), insan-teknoloji etkileşimi (ITE).

ABSTRACT

KEMALLARLI, Ece. The Effect of Age, Auditory Signals and Technology Anxiety on Pedestrian Crossing, Başkent University, Institute of Social Sciences, Master's in Social Psychology with Thesis, 2025.

Technology anxiety, a psychological construct associated with individuals' emotional and cognitive responses to technology, can significantly influence behavior in technology-mediated environments. Age-related differences in cognitive processing and adaptability become particularly evident in tasks such as street crossing. This thesis aims to examine the combined effects of age, technological auditory stimuli, and technology anxiety on pedestrian behavior within a virtual reality (VR) environment. The research consists of two complementary studies. The first study aimed to adapt the Abbreviated Technology Anxiety Scale (ATAS) into Turkish and evaluate its psychometric properties. Data were collected from 380 participants aged between 18 and 70 years. The Turkish version of the scale demonstrated a unidimensional factor structure, high internal consistency, and strong temporal reliability. In addition, a significant positive correlation with an established measure of computer anxiety supported its criterion-related validity. These findings indicate that the Turkish ATAS is a reliable and valid instrument for assessing general technology anxiety across different age groups. The second study, a 2 (Younger vs. Older) × 3 (Control, Fixed-Interval, Accelerating) mixed-design experimental framework was employed to examine the effects of auditory stimuli on pedestrian crossing behavior. A total of 54 participants (29 younger and 25 older adults) completed a VR-based street-crossing task under all three auditory conditions. Technology anxiety scores, measured prior to the experiment, were included as a covariate in the analyses. The findings revealed a significant main effect of auditory condition on crossing time, indicating shorter crossing times in the accelerating and fixed-interval conditions compared to the control condition. No significant differences were observed between age groups, nor was there a significant age × auditory condition interaction. Technology anxiety did not emerge as a significant covariate; however, a significant interaction between auditory condition and technology anxiety was observed. Accordingly, preliminary evidence suggests that the effectiveness of auditory stimuli may vary depending on individuals' levels of technology anxiety. These results suggest that auditory cues may facilitate pedestrian crossing performance, yet their effectiveness appears to be shaped by individual differences related to technology. Given the limited sample size and the laboratory-based nature of the design, the findings should be interpreted with caution and replicated with larger and more diverse samples in future research. Nevertheless, the results point to the potential of auditory signals as supportive tools for pedestrian safety, particularly when considering differences in age groups and attitudes toward technology.

Keywords: Pedestrian behavior, street crossing, technology anxiety, virtual reality (VR), human-technology interaction (HTI).

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1. INTRODUCTION

Declines in fertility and mortality rates, combined with advances in healthcare and improvements in living standards and well-being, have contributed to increasingly longer lifespans both in Turkey and globally. Over the last century, life expectancy has dramatically increased for both men and women. For example, in 1910, average life expectancy was 48 years for men and 52 years for women; by 2010, these figures had risen to 76 years for men and 81 years for women (Vincent, 2010). In the United States, the number of individuals aged 65 and older, which stood at 40 million in 2010, is projected to increase to 89 million by 2050 (Vincent, 2010). According to data from the Turkish Statistical Institute (2025), the population aged 65 years and over, classified as the elderly population, increased from 7,550,727 in 2019 to 9,112,298 in 2024, representing a growth of 20.7% over five years. Consequently, the proportion of elderly individuals within the total population rose from 9.1% in 2019 to 10.6% in 2024.

This growing elderly population in Turkey and around the world has prompted researchers, social policymakers, and urban planners to conduct studies aimed at improving the quality of life for older adults, developing appropriate policies, and constructing age-friendly cities. However, it is crucial first to clearly define the target population, identifying specific age groups, and to understand the primary characteristics associated with aging, particularly the cognitive and physical changes in abilities and competencies, as well as how aging itself is conceptualized across different domains.

Although various criteria are used to define aging, a universal definition remains challenging due to the gradual and incremental nature of psychological and biological changes associated with aging. Nevertheless, in many countries, the concept of old age has been defined as 65 years and older since the 1880s, primarily because this age serves as the threshold for retirement and eligibility for certain social benefits (Rue & Spar, 2006). Evaluating old age based on retirement age is fundamentally linked to individuals transitioning from active employment to benefiting from social and healthcare services (Onur, 2006). According to the World Health Organization (2002), individuals aged 65 years and older are chronologically classified as elderly. Chronological age, defined as the time elapsed since birth, does not provide definitive insights into an individual's overall health, mental capacities, or physical and psychological resilience (Onur, 2006). Therefore, it is more appropriate to assess and define aging beyond chronological age, encompassing biological, physiological, psychological, socio-cultural, economic, and social dimensions.

Biological aging refers to changes occurring in the structure and function of the human body throughout life. Indicators of biological aging typically appear earlier and more noticeably than the generally slower-developing psychological and social aspects of aging (Arpacı, 2005). Psychological aging involves changes in cognitive abilities, including learning, problem-solving, perception, and adapting personality traits as chronological age advances (Yerli, 2017). Sociological aging pertains to age-related values and norms within society, including expectations for specific age groups and their societal roles and relationships. This aspect also highlights how older individuals accept and fulfill certain roles in their social interactions within their community (Arpacı, 2005).

While definitions of aging vary across biological, psychological, and sociocultural dimensions, many of the functional and experiential aspects commonly associated with aging begin to appear in a broader range of later adulthood. In line with this approach, the following section will address the common physiological, sensory, and cognitive challenges that tend to emerge in later adulthood, regardless of strict age boundaries. These age-related changes, which are often observed among older individuals, play a critical role in shaping their daily functioning, interaction with the environment, and overall well-being, and understanding them is essential for developing effective strategies to enhance quality of life, safety, and autonomy in later years.

Age-related physical changes include decreases in muscle mass, strength, flexibility, and overall endurance. Sarcopenia, the age-related loss of muscle mass and function, can lead to reduced mobility and an increased risk of falls. Research indicates that muscle strength may begin to decline as early as in one's 30s and can progress rapidly in subsequent decades (Gomes et al., 2017; Dunsky et al., 2014; Janols et al., 2022). In addition, decreased bone density is common among older adults, with conditions such as osteoporosis increasing the risk of fractures and related complications. There is evidence that regular physical activity can counteract these declines by enhancing muscle and bone strength (Sun et al., 2013).

Another common aspect of aging is the deterioration of sensory functions, including vision, hearing, taste, touch, and proprioception (the perception of body position). For instance, visual acuity typically diminishes with age; conditions such as cataracts, glaucoma, and age-related macular degeneration are prevalent in older adults and significantly restrict their ability to perceive their environment (Correia et al., 2016; Leung et al., 2013). These visual changes can impact balance and spatial awareness, increasing the risk of falls. Similarly, hearing loss, which is frequently observed among older adults, has been linked to communication difficulties, cognitive decline, and social isolation (Soto-Pérez-de-Celis et al., 2018; Kiely et al., 2013). The senses of touch and proprioception also weaken, leading to difficulties in spatial awareness and motor coordination. Older adults often report reduced sensitivity to touch, pain, and temperature (Değerli et al., 2025). For example, diminished proprioceptive feedback can result in instability and a heightened risk of falling during walking or while performing daily tasks (Barela et al., 2013).

Deterioration in sensory abilities limits access to environmental information and negatively affects physical performance. A decline in visual and proprioceptive feedback, for example, impairs balance and coordination, thereby increasing the risk of falls and injuries (Correia et al., 2016; Xiong et al., 2023). Furthermore, impairments across multiple sensory modalities have been associated with physical frailty and may exacerbate physiological limitations in older adults (Soto-Pérez-de-Celis et al., 2018; Kiely et al., 2013).

In addition to physical and sensory decline, cognitive abilities are also significantly affected by aging. Cognition plays a central role in older adults' ability to live independently and manage essential daily activities such as maintaining a household, handling finances, driving, and navigating their environment (Murman, 2015). Cognitive aging encompasses various changes, primarily characterized by declines in processing speed, memory, and executive functions. Studies have shown that older adults typically exhibit slower information processing speeds (Salthouse, 1991; Salthouse, 1996). Age-related structural reductions in gray matter volume, particularly in the prefrontal cortex, are associated with deteriorations in executive functions such as problem-solving, planning, and multitasking (Lindenberger et al., 2008; Di et al., 2014).

As discussed above, aging is accompanied by a range of physical, sensory, and cognitive changes that can significantly impact an individual’s ability to interact with their surroundings and maintain independence. These functional declines are not only relevant in clinical or care-related contexts, but also manifest in ordinary, day-to-day activities that require coordination, attention, and decision-making. One of the most critical of these is the act of crossing the street, a routine behavior that forms an essential part of daily mobility and autonomy. For older adults, street crossing presents a unique set of challenges that stem from the combined effects of age-related sensory deterioration, slower information processing, reduced physical agility, and environmental factors such as traffic complexity (Butler, Lord & Fitzpatrick, 2016; Dommes et al., 2015). Given its centrality to safe pedestrian navigation and urban participation, the topic of street-crossing behavior warrants focused attention in aging-related research. In the following section, key aspects of pedestrian behavior and the street-crossing process will be discussed in greater detail, with a specific emphasis on how these are affected by the aging process.

1.1. Pedestrian Behavior and Street Crossing

Under everyday traffic conditions, pedestrians exhibit a wide range of self-organized behavior patterns shaped by environmental cues (Deb et al., 2017). When we examine the traffic psychology literature, it becomes evident that such pedestrian behaviors, shaped by environmental cues, have been investigated from various perspectives, including walking speed (Ishaque & Noland, 2008; Finnis & Walton, 2008), zone of comfort, defined as the accepted gap from other road users or objects (Meng & Kang, 2015; Wang et al., 2010), and trip purpose and route choice (Lavalette et al., 2009; Robin et al., 2009; Hoogendoorn & Bovy, 2004). One critical dimension addressed in this context is pedestrian safety (Tiwari, 2020). The increasing global prominence of pedestrian safety as a public health concern has amplified its importance as a research topic. According to the World Health Organization (2023), pedestrian fatalities account for 23% of all traffic-related deaths worldwide, highlighting pedestrians as the most vulnerable group among road users. The traffic environment, especially situations involving street crossing, represents a routine aspect of daily life that demands the integration of various physical, sensory, and cognitive abilities, all of which can significantly impact pedestrian safety. According to data from the General Directorate of Highways, 9.04% of accidents resulting in death or injury in 2023 were caused by pedestrian error. Furthermore, 42.6% of pedestrian-related accidents occurred due to "failure to comply with traffic rules while crossing the street" and "failure to obey traffic lights and signals" (General Directorate of Highways, 2023). As one of the most vulnerable road users in pedestrian-vehicle collisions, pedestrian safety has become a key area of focus in transportation psychology and traffic engineering research (Deb et al., 2017).

Considering that the majority of safety-threatening pedestrian errors, as highlighted by recent national statistics (General Directorate of Highways, 2023), are related to street-crossing behavior, crossing the street is defined as the act of a pedestrian moving from one side of a roadway to the other, typically involving stepping off a sidewalk or curb into the traffic flow and negotiating the presence of moving vehicles (Obeng-Atuah et al., 2017).

There are several distinct types of street crossings. The designated or controlled crossings comprise signalized crossings, with traffic or pedestrian signals that provide mandated intervals for safe passage, and marked zebra crossings, which rely on painted lines and signage to alert drivers to yield (Anciaes & Jones, 2018; Obeng-Atuah et al., 2017). Additionally, grade-separated facilities such as footbridges, underpasses, and overpasses physically segregate pedestrians from vehicular traffic, although these are less common due to issues of accessibility and convenience (Anciaes & Jones, 2018).

The challenges and dangers associated with crossing the street are multifaceted. Infrastructure deficiencies play a major role; for example, many crosswalks suffer from faded markings, malfunctioning traffic signals, and inadequate street lighting, all of which diminish their effectiveness and reduce pedestrian safety (Pau et al., 2018). On the other hand, human factors also contribute significantly to risk. The decision-making process regarding when it is safest to cross a street requires the acquisition and interpretation of visual and auditory information within a limited timeframe (Zito et al., 2015). As seen in the 2023 data (General Directorate of Highways, 2023), this can be a challenging task for all pedestrians and may increase the risk of accidents. Individual characteristics such as age, mobility, walking speed and cognitive capacity directly affect gap acceptance, the time interval that pedestrians consider safe for crossing, which leaves vulnerable groups like children, the elderly, and those with disabilities at a higher risk when engaging in street crossing (Rasouli et al., 2017; Stoker et al., 2015; Zito et al., 2015). While these individual characteristics may adversely affect a range of vulnerable populations (including children and individuals with disabilities) the present study concentrates on how such factors influence the street-crossing behaviors of older adults.

The impact of age-related differences on street-crossing behavior has been investigated in numerous studies (Dommes et al., 2012; Holland & Hill, 2010; Lobjois et al., 2013; Oxley et al., 1997; Oxley et al., 2005), and age-related changes profoundly affect the way older pedestrians perform street crossings, compromising their safety in complex traffic environments (Hassan et al., 2021). Among the factors influenced by such age-related changes, walking speed stands out as one of the most significantly affected components, despite its well-established importance for pedestrian safety. As mentioned in previous sections, although there are numerous age-related changes that affect older adults' walking performance, such as physiological decline, and sensory and perceptual deterioration, walking speed is significantly influenced by vision, reaction time, and balance (Tiedemann, Sherrington, & Lord, 2005). Moreover, advancing age is linked to shorter step length, wider step width, and a general decline in walking speed (Bohannon, 1997; Callisaya et al., 2008). Concurrently, sensory and perceptual declines, such as reduced visual acuity and impaired contrast sensitivity, impair the ability to accurately gauge the speed and distance of oncoming vehicles, leading to misjudgments in gap acceptance (Butler et al., 2016; Wilmut & Purcell, 2022). These perceptual limitations are compounded by slower cognitive processing and decision-making, resulting in much longer hesitation periods or start-up times when initiating a crossing compared to younger adults (Tournier et al., 2016; Wilmut & Purcell, 2022).

Furthermore, older adults face difficulties processing multiple sources of information simultaneously when confronted with dynamic traffic conditions; they often concentrate on the near lane while neglecting to adequately monitor vehicles in the other lanes, which results in a higher propensity to misjudge safe gaps (Butler et al., 2016; Wilmut & Purcell, 2022). This selective attention is especially problematic on multi-lane roads, where an inability to scan traffic from all directions may lead to choices that appear safe in one direction but are inadequate for the full crossing scenario. Moreover, age-related changes affect self-perception and multitasking abilities; older pedestrians sometimes struggle to manage distractions or to quickly recalibrate their crossing strategy in response to unexpected events, such as changes in vehicle speed or direction, further elevating their risk (Hassan et al., 2021; Butler et al., 2016).

In fact, the age-related decline in walking speed among older pedestrians does not directly pose a threat to pedestrian safety. However, the real risk stems from the constant speed of traffic flow despite pedestrians' slower pace, and particularly from automated signal systems that fail to provide sufficient time for older individuals to cross safely and completely. Older adults typically walk at a slower pace and exhibit diminished balance and coordination, meaning they require more time to complete the crossing process, which narrows the available safety margin when vehicles are approaching (Hassan et al., 2021; Rasouli & Tsotsos, 2019). Research by Dommès et al. (2015) indicated that more than 50% of elderly pedestrians experience difficulties crossing streets at signalized intersections within the allocated time, primarily due to slower decision-making processes and physical limitations.

Because of the above-mentioned challenges, older pedestrians often adopt compensatory strategies to counterbalance their functional declines; for example, they tend to pause for an extended period before stepping into the roadway and frequently rely on pedestrian signals to guide their crossing decisions (Dommes et al., 2015; Tournier et al., 2016). Empirical studies have shown that while older pedestrians may deliberately choose larger temporal gaps to compensate for their slower pace, such compensatory measures do not always translate into larger effective safety margins in practice because delayed response times erode the intended benefit (Wilmut & Purcell, 2022; Tournier et al., 2016). However, such strategies may inadvertently create additional hazards. By focusing intently on ensuring safe footing, often manifested as an increased tendency to gaze downwards, their overall situational awareness becomes compromised, potentially causing them to overlook vehicles approaching from the far lane (Dommes et al., 2015; Wiczorek et al., 2016).

Overall, these cumulative effects of slower walking speed, reduced balance, impaired visual and cognitive processing, and inefficient attention allocation underscore the heightened vulnerability of older pedestrians during street crossings, highlighting the need for urban design interventions such as extended crossing times and improved signalization to better accommodate aging road users (Wilmut & Purcell, 2022; Tournier et al., 2016).

In today's increasingly complex urban environments, ensuring the safe crossing of streets by older adults has become a pressing concern that demands an integrated approach combining advanced technological interventions with refined urban design and traffic planning strategies (Wilmut & Purcell, 2022). Aging is inherently associated with declines in physical mobility, sensory perception, and cognitive processing speed, factors that complicate the decision-making process in traffic environments and make it more challenging for older pedestrians to correctly judge gaps, monitor vehicle speeds, and choose safe crossing opportunities (Wilmut & Purcell, 2022). These declines contribute to heightened accident risks by rendering older adults more susceptible to errors in estimating safe crossing intervals and comprehending rapidly changing traffic conditions (Geraghty et al., 2016).

To address these multifaceted challenges, researchers and practitioners have developed a range of technologically supported adaptations that not only simplify the street-crossing task but also reduce pedestrian accidents and the cognitive load experienced by older adults (Arafat, 2023). For instance, traffic infrastructure has been upgraded with systems that synchronize visual signals with audible cues, allowing older pedestrians to receive clear, immediate feedback about safe crossing opportunities (Hasan, 2023). This strategy minimizes uncertainty at intersections, as the simultaneous delivery of auditory and visual signals reinforces the message conveyed by traffic lights and pedestrian signals (Tournier et al., 2016). Among these interventions, auditory stimuli have emerged as one possible method for supporting pedestrians by providing external temporal cues. How such cues may influence walking pace or crossing behavior will be addressed in the following section.

1.2. Auditory Technological Stimulus

It has been suggested that the effectiveness of the auditory cues may be related to the human tendency to respond to rhythmic patterns. This tendency is thought to contribute to the observed synchronization between auditory rhythms and motor behavior.

Auditory rhythms are strong incentives for initiating movement (Damm et al., 2020). The potential of music to guide movement is associated with the natural human tendency to synchronize with rhythmic events (Repp, 2005). Auditory stimuli serve not only as motivational drivers but also as temporal frameworks that align with internal movement patterns, thereby promoting synchronization between external cues and motor output (Buhmann et al., 2016). Daily life provides a myriad of examples of individuals consciously or subconsciously tapping their fingers, swaying their bodies, or modulating their walking pace in response to musical beats (Leman et al., 2013).

A review of the literature reveals that multiple studies have demonstrated how the speed of different types of auditory stimuli can influence participants' walking/running pace (Edworthy & Waring, 2006; Powell, Stevens, Hand, & Simmonds, 2010). In the study conducted by Edworthy & Waring (2006), participants were asked to walk on a treadmill for 10 minutes while listening to fast-paced music (measured at 200 beats per minute (bpm)) and slow-paced music (measured at 70 bpm). As a result of the study, it was found that participants produced higher treadmill speeds when the music was fast.

Almarwani et al. (2019) compared uncued walking with metronome-cued walking at slower, preferred, and faster speeds. Their findings indicated that while the walk ratio (step length divided by cadence) was maintained at a stable level during self-paced (preferred speed) walking, significant differences emerged at non-preferred speeds. Specifically, slower speeds combined with a metronome resulted in a higher walk ratio, whereas faster metronome cues lowered the walk ratio relative to uncued walking. These effects imply that temporal coordination is altered when the external beat deviates from an individual's intrinsic pacing (Almarwani et al., 2019).

Similarly, Ducharme et al. (2018) examined the effect of rhythmic auditory cuing on gait by instructing participants to match their steps to metronome tempos ranging from 80 to 140 beats per minute. Their results showed that cadence increased linearly with the tempo of the metronome, while step length increased at a much slower rate. Consequently, overall gait speed rose predictably with a rise in cadence, which supports the idea that cadence is a readily modifiable parameter under auditory pacing (Ducharme et al., 2018).

Findings from the reviewed literature indicate that auditory stimuli (such as rhythmic cues and metronome pacing) may influence walking speed by engaging temporal synchronization processes. These mechanisms suggest that auditory cues could potentially serve as tools for regulating gait in time-sensitive contexts, including street crossing. However, individuals may differ in how they perceive and respond to such technological inputs, depending on their experience with and attitudes toward technology. One psychological construct that may shape these responses is technology anxiety. How this form of anxiety may influence pedestrian behavior, particularly for older pedestrians, will be further examined in the following sections.

1.3. Technology Anxiety

Building on the discussion of auditory technological cues and their potential to facilitate movement and support pedestrian behavior, it is important to recognize that such technologies, while increasingly embedded in everyday environments, may not be universally accessible or beneficial. Over the past two decades, the rapid acceleration of technological innovations and the widespread integration of Information and Communication Technologies (ICT) have made technology a central component of daily life. According to the Turkish Statistical Institute (2024), internet usage among individuals aged 16 to 74 in Turkey has reached 88.8%. Although technologies such as the internet and smartphones are most commonly referenced, a wide array of other devices—including household appliances like washing machines, microwave ovens, and robotic vacuum cleaners—have also become integral to daily routines. In addition, various public systems, such as ATMs, card-based access systems, and traffic control devices (e.g., lights and auditory alerts), further illustrate the extent to which technology has permeated both private and public life.

However, users may not always possess the necessary digital skills or inclination to adopt new technologies (Azoulay & Jones, 2020). Therefore, the constant changes in the quantity and scope of technologies and technological products do not always provide solutions that make life easier and may, in some cases, create negative experiences for certain users. Some individuals may face challenges in adapting to rapidly evolving new technologies. For instance, studies have shown that integrating technology into daily life can negatively impact individuals' well-being and cause stress (Hauk et al., 2019; Nimrod, 2018).

These findings suggest that for some individuals, particularly those who may lack prior experience or confidence in using digital tools, the rapid and ongoing technological changes in everyday life may lead not only to frustration but also to heightened emotional responses. In this context, increased stress levels associated with unfamiliar or overly complex technologies can contribute to the emergence of technology-related anxiety. This phenomenon, often referred to as technology anxiety.

Troisi et al. (2022) define technology anxiety as “a complex set of emotional states such as nervousness, uncertainty, and fear associated with the use and learning of technology". This construct reflects concerns regarding the potential negative outcomes of technology use, such as the loss of critical data or the making mistakes (Compeau & Higgins, 1999). It incorporates both an (objective) lack of technical skills and a (subjective) low level of confidence in utilizing specialized tools. Furthermore, technology anxiety can be associated with the user's perceptions of general technological tools (Meuter et al., 2003) or underlying social and psychological factors, such as concerns about cost, dependency, trust in technology providers and adopting organizations, and issues related to privacy (Troisi et al., 2022). Investigating technology anxiety in contemporary contexts is essential, as it is recognized as a significant determinant of resistance to technology and a critical barrier to individuals' engagement with technological systems (Thatcher & Perrewé, 2002).

Considering these points, if the aim is to make technology-based interventions (such as the auditory technological stimulus discussed in the previous section) more beneficial for the general population, it is important to understand psychological constructs like technology anxiety. This is especially relevant for older adults, who tend to be more affected by technology anxiety due to age-related changes. Understanding how and why this group is influenced is essential for developing services that are both effective and accessible. Research shows that technology anxiety in older adults stems from a variety of factors.

For older adults, technology anxiety is exacerbated by factors such as cognitive decline, physical limitations, and a lack of self-confidence, which creates significant barriers to digital inclusion. Falk (2024), identified the causes of technology anxiety among the elderly as follows: generational technological divide, cognitive decline and physical limitations, fear of cybersecurity threats and privacy concerns, lack of tailored training and support, negative stereotypes and societal attitudes, and past negative experiences with technology.

Generational technological divide highlights the gap between older adults and the "digital native" generation due to their upbringing in a pre-digital world. This lack of early interaction with technology often makes modern digital tools and terminology feel unfamiliar and overwhelming. As a result, older adults may find it challenging to adapt, leading to frustration and a tendency to avoid engaging with technology altogether. For example, studies indicate that this generational gap manifests in difficulties when older adults attempt to navigate complex smartphone interfaces or digital systems that employ technical jargon and constantly evolving functions (Falk, 2024). This gap not only increases the cognitive burden associated with learning new devices but also creates an emotional barrier as older individuals perceive these systems as alien and intimidating (Choudrie et al., 2022). Moreover, the digital divide is further compounded by socio-economic and cultural factors that disproportionately affect ethnic minority older adults, who may have had even less exposure to technology during their formative years (Choudrie et al., 2022; Fang et al., 2019). Some studies have also pointed to the fact that intergenerational comparisons, as observed in research exploring ageism in digital contexts, intensify feelings of inadequacy and frustration, thereby strengthening the divide and discouraging technology use (Köttl et al., 2021).

Cognitive decline and physical limitations are additional barriers that older adults face when interacting with technology. Age-related challenges, such as memory issues and slower cognitive processing, make it harder to comprehend and use complex digital interfaces. Furthermore, physical limitations like impaired vision and reduced dexterity add another layer of difficulty, contributing to feelings of frustration and heightened anxiety. For instance, reduced working memory and slower cognitive processing—effects that are commonly observed in the natural aging process—make it especially challenging for older users to keep up with rapidly updating software and multifaceted applications (Wang & Wu, 2022). In addition to cognitive constraints, physical limitations such as impaired vision, reduced fine motor skills and diminished manual dexterity can significantly impair interaction with devices that require precise tap or swipe gestures (Falk, 2024; Di Giacomo et al., 2019).

Fear of cybersecurity threats and privacy concerns, significant, though sometimes underappreciated, source of anxiety for many older adults stems from fears of cybersecurity threats and privacy breaches. The digital landscape is replete with warnings about scams, phishing attacks, and identity theft, and these messages disproportionately resonate with older populations who may lack up-to-date knowledge about digital security practices (Holgersson et al., 2021, July). Many older adults perceive the online environment to be inherently unsafe and feel ill-equipped to defend themselves against sophisticated cyber threats. This fear is often further magnified by media reports and personal anecdotes of cyber fraud that paint a grim picture of the risks associated with technology use (Nicholson et al., 2019, May; Frik et al., 2019). In some cases, the anxiety triggered by cybersecurity concerns correlates with a lack of confidence in one's ability to manage security settings or understand the technical language associated with cybersecurity protocols (Fujs et al., 2025). Beyond concerns over immediate financial loss or personal data breaches, there is also an underlying apprehension about the erosion of privacy—older adults worry that their personal information may be exploited or misused without their full understanding or consent (Frik et al., 2019). Such apprehensions contribute to a pervasive reluctance to engage with digital services, even when these platforms could bridge critical gaps in healthcare, communication, and social support (Holgersson et al., 2021, July).

Lack of tailored training and support is another challenge that impedes older adults' adoption of technology. Many conventional technology education programs are modeled on the learning styles and pre-existing knowledge bases of younger users, leaving older adults with insufficient support to navigate the complexities of modern digital tools (Iancu & Iancu, 2020). As a result, older learners are frequently left feeling isolated and unprepared, with many reporting that training sessions are too fast-paced, use overly technical language, or fail to relate digital skills to everyday practical needs (Sen et al., 2022).

Negative stereotypes and societal attitudes contribute to the perception that older adults are unwilling or unable to learn new technologies. These stereotypes can discourage them from attempting to engage with digital tools, while also undermining their confidence. Negative images that portray older individuals as resistant to change or incapable of mastering modern technology can create a self-fulfilling prophecy, where the internalization of these stereotypes undermines their self-confidence and willingness to learn (Chu et al., 2022). Research indicates that when older adults are repeatedly exposed to ageist narratives, both in the media and through interpersonal interactions, they are more likely to doubt their technological abilities and experience increased anxiety during digital interactions (Köttl et al., 2021; Mannheim et al., 2019).

Finally, past negative experiences with technology can shape how older adults view digital tools. Difficulties with poorly designed systems, instances of data loss, or experiences with cyber threats can leave lasting impressions, leading to distrust and avoidance (Fang et al., 2019; Nicholson et al., 2019). In some cases, observing peers struggle with digital devices or hearing about others' negative experiences further solidifies a cautious or even avoidant stance toward technology use (Di Giacomo et al., 2019; Rodrigues et al., 2022). Understanding these factors is crucial for addressing the challenges older adults face in adapting to technology and for developing solutions that promote their digital inclusion.

Therefore, investigating the effects of technology anxiety on older pedestrians and their behavior in traffic environments can provide valuable insights into the effectiveness of technological interventions, such as auditory cues, designed to support this population.

To investigate these complex interactions in a controlled yet ecologically valid manner, this thesis employed Virtual Reality (VR) technology. In the following section, detailed information will be provided about the characteristics, advantages, and applications of VR technologies within pedestrian research.

1.4. Virtual Reality (VR) Technologies and Pedestrian Studies

Traditional laboratory experiments allow rigorous control of variables but may lack realistic contexts, whereas field studies capture natural behavior but suffer from safety and logistical constraints. VR technologies bridge this gap by providing immersive, multidimensional environments that allow the systematic manipulation of stimuli while maintaining a high degree of realism. Researchers have leveraged VR across diverse disciplines such as marketing, psychology, neuroscience, and traffic safety, demonstrating its advantages in replicability, safety, comprehensive behavioral measurement, and cost-effectiveness (Alcañiz et al., 2019; Cipresso et al., 2018).

Traffic psychology research also benefits significantly from VR's ability to simulate complex, dynamic traffic environments in a controlled, safe manner. Traffic and pedestrian crossing studies may sometimes create dangerous environments for participants (Zito et al., 2015). Nonetheless, VR makes it possible to simulate high-risk street-crossing scenarios that would be ethically unacceptable to test in real-world conditions. This enables researchers to study vulnerable groups, such as children and older pedestrians, within a fully controlled and safe environment (Farooq et al., 2018). As an alternative to real-life settings, controlled environments with restricted or regulated traffic flow can be used in pedestrian crossing studies. However, such arrangements often involve extensive legal procedures and incur high costs, posing significant disadvantages. Due to its cost-effectiveness and its ability to provide a realistic yet safe experience for participants, virtual reality (VR) environments have been widely utilized in various studies (Fink et al., 2007; Luu et al., 2022; Sanz et al., 2015; Tan & Timmermans, 2006).

In VR studies, participants experience a virtual world composed of sounds, visuals, and landscapes that closely resemble real-life conditions. Additional VR equipment, such as joysticks and gloves, allows participants to interact with the virtual environment, enhancing their sense of immersion (Reid, 2002). VR technologies have been employed to investigate various factors influencing pedestrian behavior in immersive and controllable settings under standardized conditions (Feng et al., 2021).

When examining several pedestrian studies conducted using VR technologies, Deb et al. (2017) developed an advanced VR pedestrian simulator using a head-mounted display (HTC Vive) that allowed free movement, real-time tracking of position and gaze, and integration of 3D positional audio. Their work demonstrated that participants' walking speeds, crossing times, and gap acceptance metrics in VR closely matched field-established norms, thereby validating VR as an effective proxy for real-world behavior. Tang, Wu, and Lin (2009) developed a VR-based game to examine how emergency signage conveying different types of information influences wayfinding behavior among pedestrians. Li et al. (2019) investigated pedestrian route selection behaviors in a VR environment featuring an overhead perspective with various obstacles. Sprenger et al. (2023) conducted a cross-cultural VR study to compare pedestrian behaviors and their variations among individuals living in Japan and Germany. Additionally, VR has also been integrated into road safety education programs that target younger populations. Studies in this domain use gaming and interactive simulations to teach children safe street-crossing behaviors and hazard perception. Khan et al. (2021) developed an adaptive game-based learning system that employs VR to instruct children on proper pedestrian behaviors such as recognizing traffic signals, understanding road signs, and correctly executing safe crossing maneuvers. Their approach leveraged gesture recognition technology (using sensors like Kinect) to create engaging interactions that not only maintain the children's focus but also provide immediate feedback based on performance.

1.5. Objective of the Research

This thesis primarily aims to explore how age and technology anxiety come together to influence pedestrian behavior (crossing street), particularly in environments where individuals must interpret and respond to external technological cues. While previous studies have separately examined age-related physical and cognitive changes or technology-related psychological constructs, there is limited research integrating these two domains in real-time decision-making contexts like street crossing. By integrating the constructs of technology anxiety and aging with empirical evidence from street-crossing contexts, the current research seeks to contribute to the broader literature on human–technology interaction, particularly within safety-critical environments.

At the same time, the study places a strong emphasis on street-crossing as a psychologically demanding task that requires the coordination of perceptual, cognitive, and motor abilities within dynamic traffic environments. In this sense, the thesis aligns closely with the field of traffic psychology by examining how individual differences shape behavior in high-risk pedestrian scenarios. More broadly, the findings of this research are intended to inform how public spaces—especially streets, intersections, and traffic systems—can be designed or adapted to better accommodate not only the general population but also vulnerable groups such as older pedestrians. By highlighting the behavioral and psychological factors that influence pedestrian crossing performance, this work aims to support the development of more inclusive, safe, and responsive urban environments.

In Study 1 of the current thesis, the Abbreviated Technology Anxiety Scale (ATAS), originally developed by Wilson et al. (2023), was translated and adapted into Turkish to provide a valid and reliable instrument for assessing general technology-related anxiety in empirical research involving Turkish-speaking populations.

Prior to the development of ATAS, various scales had been constructed to measure attitudes and anxiety toward different aspects of technology, particularly in domains such as computer use and educational technologies (Askar & Umay, 2001; Efe, 2011; Heinssen et al., 1987; Yavuz, 2005). However, many of these instruments include terminology and conceptualizations that have become outdated due to rapid technological advancements, and they tend to assess domain-specific concerns rather than generalized anxiety toward everyday technologies. The ATAS was designed to address these limitations by capturing anxiety related to the broad, contemporary use of digital tools in daily life. Given the absence of an equivalent instrument in Turkish, the adaptation of the ATAS aimed to fill a critical gap in the literature by offering a valid and reliable instrument to assess technology anxiety in broader, modern contexts. Furthermore, this step was essential for ensuring the methodological integrity of the experimental component that followed.

The aim of Study 2, which was designed to fulfill the main objective of the thesis and aligns with its overall purpose, was to investigate the effects of different auditory technological stimulus conditions (control, fixed-interval sound, and accelerating sound) and age groups (younger and older adults) on pedestrian crossing performance. In this context, auditory stimuli were employed as representations of auditory traffic signals, conceptualized as extensions of information and communication technologies. These auditory cues, typically activated alongside traffic lights, are generally intended to signal when it is safe to start or stop moving. However, in real-world settings, there is no widely implemented auditory signal that regulates the speed of pedestrian movement during crossing.

Based on findings in the literature, it is known that auditory stimuli with varying tempos can influence walking speed. Accordingly, this study aimed to examine how the tempo of auditory signals affects pedestrian movement during street crossing. Additionally, participants' levels of technology anxiety were measured to explore whether individual differences in anxiety related to technology could help explain variations in pedestrian crossing performance within a virtual pedestrian simulation environment.

H1: Regardless of auditory condition, older participants are expected to cross the pedestrian crossing slower than younger participants.

H2: Regardless of age group, crossing times are expected to vary across auditory conditions, such that participants will cross fastest in the accelerating condition, followed by the fixed-interval condition, and slowest in the control condition.

H3: The effect of auditory condition on crossing times is expected to differ between age groups, such that older adults will exhibit smaller or negligible changes across conditions, whereas younger adults will show greater improvements in crossing speed from control to fixed-interval and accelerating conditions.

H4: The interaction between age group and auditory condition is expected to covary with technology anxiety, such that older adults with high technology anxiety will show minimal changes in crossing speed across auditory conditions, while younger adults with low technology anxiety will display the largest gains.

2. STUDY 1: SCALE ADAPTATION

2.1. Method

2.1.1. Participants

For scale adaptation study, data were obtained from a sample of 380 individuals. Participants' ages ranged from 18 to 70 years, with a mean age of 24.60 (*SD* = 9.07). The mean age was 24.01 (*SD* = 8.03) for female participants and 26.27 (*SD* = 11.12) for male participants. Of the total sample, 72.9% were female (*n* = 277), 26.6% were male (*n* = 101), and 0.5% (*n* = 2) chose not to disclose their gender. In terms of educational background, most participants were at the undergraduate level (*n* = 266, 70.0%). The remaining participants were at the high school (*n* = 47, 12.4%), associate degree (*n* = 34, 8.9%), master's degree (*n* = 30, 7.9%), and doctoral (*n* = 3, 0.8%) levels.

2.1.2. Materials

The study utilized the Demographic Information Form, the Abbreviated Technology Anxiety Scale (ATAS), and the Computer Anxiety Scale (CAS).

Demographic Information Form: This form collects demographic information about participants, including age, gender, and education level.

Abbreviated Technology Anxiety Scale (ATAS): The ATAS, developed by Wilson et al. (2023), is a self-report scale designed to measure technology-related anxiety. The scale was developed in three phases, focusing on content validity, internal structure validity, and criterion-related validity throughout the process. The initial phase started with 21 items, and after improvements, the scale was finalized with 11 items. The items in the scale are not linked to any specific technological tool, application, or feature. Instead, the content related to all types of technology is expressed using the general term "technology." This approach ensures that the validity of the scale is not affected by changes and advancements in technological tools, applications, or trends. The Cronbach's alpha internal consistency coefficients obtained from five different applications conducted during the scale development process range from .92 to .63. It includes 11 items scored on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). Total scores range from 11 to 55, with higher scores indicating higher levels of technology anxiety. The original version of the scale, which is used as a single-factor measure, does not contain any reverse-coded items.

Computer Anxiety Scale (Bilgisayar Kaygı Ölçeği/BKÖ): The CAS, developed by Ceyhan and Namlu (2000), measures anxiety related to computer use. Its validity and reliability studies indicate a Cronbach's alpha of .94. The scale consists of 28 items rated on a 4-point Likert scale (1 = Never, 2 = Sometimes, 3 = Often, 4 = Always). Total scores range from 28 to 112, with higher scores indicating higher computer anxiety. In its original form, the scale is used as a three-factor measure and includes four reverse-coded items (items 17, 21, 26, and 27) to reduce response bias.

2.1.3. Procedure

At the first step of preparing the scales to be used in the study, the necessary permissions were obtained from the developers of the scales, and the Ethics Committee of Başkent University granted ethical approval for the study.

The second step involved the adaptation of the Abbreviated Technology Anxiety Scale (ATAS) into Turkish and was carried out by a panel of three researchers fluent in both Turkish and English. In this process, the translation and back-translation steps were completed. Initially, the ATAS items were translated into Turkish by the three researchers. To ensure consistency with the original scale, the Turkish version was then back-translated into English. The back-translated form and the original version of the scale were reviewed by a panel of four experts (two social psychologists and two clinical psychologists) to ensure semantic and linguistic equivalence. Based on their feedback, the items were revised and re-translated into Turkish. The Turkish version of the scale was finalized after further review by the expert panel, which included faculty members, to ensure cultural and contextual appropriateness.

Following the translation process, data collection commenced. The Demographic Information Form, the Turkish version of the ATAS, and the Computer Anxiety Scale (BKÖ) were transferred to an online format via www.qualtrics.com and distributed to participants using a unique survey link. Additionally, to enable the matching of responses for the second phase (test-retest), participants were asked to create a unique identifier consisting of the first two letters of their first and last names and the last two digits of their birth year.

During the main data collection phase, which was conducted to test the validity and reliability of the scale, participants were reached through third- and fourth-year psychology students at Başkent University. These students received extra course credit for fully completing the scales. They were also awarded additional credit for each survey completed by others to whom they distributed the scale within their social networks. On average, completing the scales during this phase took approximately seven minutes.

To assess test-retest reliability, a second administration was conducted with the same third- and fourth-year psychology students who participated in the initial phase. Two weeks after the first administration, participants were sent a new survey link via www.qualtrics.com containing only the Turkish version of the ATAS, along with a field to enter their previously created unique identifier. Students who participated in the test-retest phase also received extra credit in their respective courses. The average completion time during this phase was approximately three minutes.

2.1.4. Analysis

The exclusion criteria for the study were being under the age of 18 and failing to respond to all scale items. Before analysis, the dataset was adjusted accordingly, and responses that did not meet these criteria were removed.

The validity and reliability of the Turkish adaptation of the ATAS were evaluated through a series of statistical analyses. To examine the construct validity of the scale, both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were conducted. For criterion-related validity, the correlation between the Turkish version of the ATAS and the Computer Anxiety Scale was examined using Pearson’s correlation test.

For the reliability assessment of the scale, internal consistency reliability, split-half reliability, item-total correlation, and test-retest reliability analyses were conducted. In the split-half reliability analysis, the total scores of odd and even numbered items were calculated separately, and the correlation between these two sets of scores was examined using Spearman-Brown’s coefficient. For item-total reliability, the correlation between each item and the total scale score was analyzed using Pearson's correlation coefficient (r). A high correlation between each item and the total score indicates the internal consistency of the measurement tool (Tezbaşaran, 1997). Test-retest reliability was evaluated by administering the scale twice to a subsample of 81 participants with a two-week interval. The correlation between the scores from the first and second administrations was calculated using Pearson's correlation coefficient (r).

All statistical analyses, except for Confirmatory Factor Analysis, were conducted using IBM SPSS Statistics 25 to ensure a robust psychometric evaluation of the adapted scale. CFA was performed using Jamovi software (version 2.6).

2.2. Results

2.2.1. Validity-related findings

An exploratory factor analysis (EFA) was conducted on the 11-item Abbreviated Technology Anxiety Scale (ATAS) using principal component analysis as the extraction method. The suitability of the data for factor analysis was assessed before extraction. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .948, which exceeds the recommended threshold of .60, indicating that the data were appropriate for factor analysis. Bartlett's Test of Sphericity was significant, χ^2 (55) = 2631.27, $p < .001$, suggesting sufficient inter-item correlations.

The analysis revealed a one-factor solution based on the eigenvalue greater than one criterion. The single factor accounted for 59.65% of the total variance. The communalities ranged from .398 to .719, indicating acceptable levels of shared variance among the items. Factor loadings of the items ranged from .616 to .848, with all items exceeding the .30 threshold (Erkuş, 2014). The scale items and their factor loadings are presented in Table 2.1.

No rotation was applied since only one factor was extracted. These results support the unidimensional structure of the ATAS and suggest that the scale items collectively represent a single underlying construct: technology anxiety.

Table 2.1. Factor Structure of the ATAS

Item	Factor I	Corrected Item-Total Corr.
Teknolojiyi kullanmak beni gerer.	.85	.80
Teknolojiyi kullanırken rahatsız hissederim.	.83	.77
Teknolojinin yeni özelliklerini öğrenmeye karşı isteksizimdir.	.82	.77
Teknolojiyi kullanırken huzursuz hissederim.	.81	.76
Teknoloji bana göre değildir.	.80	.75
Teknolojinin basit işleri karmaşıklaştırdığını hissediyorum.	.80	.74
Teknolojiyi kullanırken sık sık sinirlerim bozulur.	.80	.74
Teknolojiyi verimli şekilde kullanamam.	.77	.72
Teknolojiyi kullanırken kontrolün bende olmadığını hissederim.	.73	.68
Teknoloji, hayat kalitemi yükseltmez.	.63	.56
En yeni teknolojiyi takip etmek imkansızdır.	.62	.56
Explained variance (%)	59.65	
Eigenvalue	6.56	
Cronbach’s Alpha	.93	

To evaluate the factorial validity of the Abbreviated Technology Anxiety Scale (ATAS), a confirmatory factor analysis (CFA) using the maximum likelihood estimation method was conducted in JAMOVI version 2.6.26 to assess the adequacy of the factor structure identified through the preceding exploratory factor analysis. A one-factor model was specified based on the theoretical structure of the scale, comprising 11 observed variables (A1 to A11). Model fit indices indicated an acceptable fit to the data: $\chi^2(44) = 178.00$, $p < .001$; $\chi^2/df = 4.05$; $CFI = .949$; $TLI = .936$; $SRMR = .034$; and $RMSEA = .089$, 90% CI [.076, .103]. Although the RMSEA value slightly exceeded the recommended cutoff of .08 (Browne & Cudeck, 1993), other fit indices (CFI, TLI, SRMR) suggest that the model provides a reasonable approximation of the observed data.

All standardized factor loadings were statistically significant ($p < .001$), ranging from .564 to .843. The highest standardized loading was observed for item A10 ($\beta = .843$), followed by A3 ($\beta = .819$) and A2 ($\beta = .806$), indicating that these items contribute most strongly to the latent construct. The lowest loading was found for A8 ($\beta = .564$), though it still exceeded the commonly accepted threshold of .40 (Hair et al., 2010). Taken together, these results provide support for the unidimensional factor structure of the ATAS and confirm its structural validity. The standardized factor loadings, R^2 values, and z-statistics for each item of the ATAS can be found in Table 2.2.,

Table 2.2. Confirmatory Factor Analysis Results of the ATAS

Factor: Technology Anxiety											
Indicators	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
β	.78	.81	.82	.59	.69	.79	.77	.56	.74	.84	.78
R^2	.60	.65	.67	.34	.47	.63	.60	.32	.54	.71	.60
Z	(17.7)	(18.7)	(19.2)	(12.2)	(14.9)	(18.3)	(17.6)	(11.7)	(16.5)	(20.1)	(17.7)

Note: A1–A11 refer to the items of the ATAS. Standardized factor loadings *(β)*, R^2 values, and Z statistics (in parentheses) are presented respectively. All factor loadings are statistically significant.

2.2.2. Criterion validity

To examine the criterion-related validity of the Abbreviated Technology Anxiety Scale (ATAS), its relationship with the Computer Anxiety Scale (BKÖ) was assessed. Descriptive statistics showed that the mean score for the ATAS was $M = 22.10$, $SD = 7.90$, while the BKÖ had a mean score of $M = 47.81$, $SD = 13.52$.

A Pearson correlation analysis revealed a strong and statistically significant positive correlation between the ATAS and BKÖ total scores, $r(380) = .72$ ($p < .001$). This finding provides evidence for the criterion-related validity of the ATAS, as it demonstrates a substantial association with an established measure of technology-related anxiety.

2.2.3. Reliability-related findings

In this study, the reliability of the Abbreviated Technology Anxiety Scale (ATAS) was examined both through internal consistency and test-retest procedures. To evaluate the internal consistency of the ATAS, Cronbach's alpha coefficient was calculated. The analysis was conducted on a sample of 373 participants. The Cronbach's alpha was found to be .93, indicating excellent internal consistency (Nunnally & Bernstein, 1994). In addition, internal consistency was re-examined within the test-retest subsample (N = 81), yielding a similarly high alpha coefficient of .93. These findings support the scale's internal reliability across both the primary and follow-up administrations.

2.2.4. Split-half reliability

Split-half reliability was assessed by dividing the scale into two halves: odd-numbered and even-numbered items. The mean score for the odd-numbered items was M = 12.08, SD = 4.47, and for the even-numbered items, M = 10.02, SD = 3.65. A Pearson correlation analysis between the two halves yielded a strong positive correlation, $r = .89$, $p < .001$. To estimate the reliability of the full scale, the Spearman-Brown coefficient was calculated and found to be r_sb = .94, indicating excellent internal consistency. These results provide further support for the reliability of the ATAS, confirming that both halves of the scale are measuring the same underlying construct consistently.

2.2.5. Item-total correlation analysis

Item-total correlation analysis was conducted to evaluate how well each item of the Abbreviated Technology Anxiety Scale (ATAS) contributed to the overall internal consistency of the scale. All corrected item-total correlations were statistically significant and ranged from r = .56 to .80 ($p < .001$).

Specifically, the item *"Teknolojiyi kullanmak beni gerer."* showed the highest item-total correlation (r = .80), followed by *"Teknolojiyi kullanırken rahatsız hissederim."* (r = .77) and *"Teknolojinin yeni özelliklerini öğrenmeye karşı isteksizimdir."* (r = .77). On the other hand, the lowest item-total correlation was observed for the item *"Teknoloji, hayat kalitemi yükseltmez."* (r = .56).

These results suggest that each item is positively associated with the overall construct of technology anxiety and contributes meaningfully to the internal consistency of the ATAS.

2.2.6. Test-retest reliability

In order to evaluate the test-retest reliability of the Abbreviated Technology Anxiety Scale (ATAS), the scale was administered to participants who had completed the scale during the first phase. The reassessment was conducted after a two-week interval. Participant responses were matched using coded identifiers, and data were obtained from 81 individuals. Of these, 88.9% were female (n = 72) and 11.1% were male (n = 9). The participants' ages ranged from 19 to 30 years (M = 22.15, SD = 1.68). Regarding educational background, the majority held a bachelor's degree (n = 67, 82.7%), while the remainder held a high school diploma (n = 12, 14.8%) or an associate degree (n = 2, 2.5%).

Pearson's correlation coefficient between the first administration (M = 23.22, SD = 8.26) and the second administration (M = 23.96, SD = 7.92) was found to be r = .78, p < .001. This result indicates a strong and statistically significant level of test-retest reliability, demonstrating that the ATAS provides stable scores over time. As Kline (2015) suggests, coefficients above .70 reflect acceptable temporal consistency in psychometric instruments.

3. STUDY 2: EXPERIMENTAL STUDY

3.1. Method

3.1.1. Participants

The study included 54 participants, composed of 29 younger adults (aged 18–28 years) and 25 older adults (aged 60–85 years), who were recruited through snowball sampling. Participation was voluntary, and all participants provided informed consent prior to the study. The age distribution of participants across gender and age groups is presented in Table 3.1.

Table 3.1. Age Distribution of Participants by Gender and Age Group

Gender	Age Group	*N*	Mean	*SD*	Min	Max
Female	Younger	17	21.90	2.22	18	27
	Older	11	68.60	7.92	60	85
Male	Younger	12	23.90	1.98	21	28
	Older	14	68.00	6.20	61	82

In the younger group (n = 29), the mean age was 22.8 years (SD = 2.31). The group consisted of 17 females and 12 males. Regarding educational background, 24 participants held a bachelor's degree, two held a master's degree, and three had completed high school. Most younger participants were residing in metropolitan areas (n = 20), while others lived in cities (n = 5) or small districts (n = 4).

In the older group (n = 25), the mean age was 68.3 years (SD = 6.86). The group consisted of 11 females and 14 males. In terms of education, nine participants held a doctoral degree, five held a master's degree, four had a bachelor's degree, three had an associate degree, two had completed high school, and two had completed primary or middle school. Most older participants also resided in metropolitan areas (n = 21), followed by city centers (n = 4); none lived in small districts.

3.1.2. Materials

Demographic Information Form: This form was designed to gather detailed background information from participants, including their age, gender, educational background, place of residence (metropolitan, city, or district), any vision or hearing impairments, transportation preferences, and any past involvement in pedestrian-related traffic accidents.

Abbreviated Technology Anxiety Scale – Turkish Version (ATAS): The Abbreviated Technology Anxiety Scale (Wilson et al., 2023) was translated and adapted into Turkish as part of Study 1 of the current thesis. The Turkish version consists of 11 items rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), with total scores ranging from 11 to 55. Higher scores reflect greater levels of technology-related anxiety.

The psychometric properties of the Turkish adaptation were established through the scale development procedures conducted in Study 1. Confirmatory factor analysis supported a unidimensional factor structure. The internal consistency of the scale was found to be high (Cronbach's $\alpha = .93$; $N = 380$). Test–retest reliability was evaluated with a two-week interval on a subsample of 81 participants, yielding a Pearson correlation of $r = .78$, which indicates strong temporal stability. Evidence of concurrent validity was also observed through a significant positive correlation with the Computer Anxiety Scale ($r = .72$, $p < .001$).

VR Setting: To create a realistic traffic setting and pedestrian-crossing experience, the Meta Quest 2 VR headset was utilized. Equipped with integrated motion sensors and built-in speakers, this device delivers both visual and auditory stimuli, yielding an immersive and interactive environment. Its wireless design preserved participants' freedom of movement throughout the session, while minimizing external interferences during the experiment.

VR Scenarios: The VR software used in this study was developed in the Unity game engine. The study will be conducted using three different scenarios within the same virtual environment designed for the VR scenario (see Figure 3.1.), each incorporating a distinct auditory stimulus. The visual environment in these scenarios will depict a two-lane road with moving traffic and a designated pedestrian crossing area. Additionally, a traffic light is located at the end of the pedestrian crossing. The divided two-lane road designed for the VR scenario was built to a length of 6 m in accordance with the Turkish Ministry of Transport and Infrastructure’s General Directorate of Highways’ Marking Standards, which specify a lane width of 5.5-9.5 m for divided dual-lane roads (General Directorate of Highways, 2020). For the experimental phase, three auditory scenarios, corresponding to different conditions, were created: the fixed-interval sound condition, the accelerating sound condition, and the control condition. Each condition was associated with a unique auditory stimulus:

1) In the *fixed-interval sound* condition, beeps were presented at a constant rate of one per second for 20 seconds.

2) In the *accelerating sound* condition, beeps occurred once per second for the first four seconds, then increased to two per second for the remaining 16 seconds.

3) In the *control* condition, only a single beep was presented at the beginning to signal the start of the trial.

Each of the three conditions was activated using specific buttons displayed on the researcher’s computer screen. When a button for a particular condition was pressed, the corresponding auditory stimulus played, and the pedestrian traffic light across the crossing turned green.

Figure 3.1. Sample view from the virtual reality pedestrian crossing scenario used in Study

3.1.3. Procedure

Participants were recruited using a snowball sampling method. A participant pool was formed by collecting the contact information of individuals who expressed willingness to participate in the study, which was conducted in person at the Department of Psychology, Faculty of Arts and Sciences, Başkent University. During the creation of the participant pool, individuals were screened using predefined exclusion criteria. Specifically, participants were asked whether they had experienced any accidents within the past week that could impair their ability to walk, whether they had ongoing mobility issues, and whether they had any neurological conditions (e.g., vertigo or epilepsy) that could lead to adverse effects when using a VR headset.

Those who met the inclusion criteria were added to the participant pool and assigned a unique code consisting of the first two letters of their first name, the first two letters of their last name, and the last two digits of their year of birth. Each participant received a link to an online form created via Qualtrics (www.qualtrics.com), which included the Demographic Information Form, the Abbreviated Technology Anxiety Scale (ATAS), and the Technology Usage Scale. Experimental appointments were scheduled based on the participants' availability.

To minimize response bias caused by the experimental stimuli, participants were required to complete the scale forms at least five days prior to their scheduled session. Additionally, participants who were coming from outside the university campus were informed that transportation support would be provided upon request. A reminder message was sent to each participant one day before their scheduled session. If transportation support was requested, meeting point arrangements were made accordingly. On the day of the experiment, participants were reminded of their session time and the designated meeting point on campus.

Participants were welcomed at the entrance of the Faculty of Arts and Sciences and accompanied to the experimental room. Inside the room, there was a designated waiting area with a table located on the left side near the entrance. In line with the VR scenario, a 6-meter walking path representing a pedestrian crossing was marked on the floor using colored tape, along with additional safety zones that ensured participants could move around securely (see Figure 3.2.).

Upon entering the room, participants were first asked to sign the informed consent form. Then, they were instructed to enter their previously assigned code into the same digital form system that had been used for the pre-study questionnaires. Before proceeding to the experimental phase, participants were given a detailed explanation of the study content and tasks. Once the researcher completed the final preparations, participants were asked to move to the starting point of the designated walking area. The researcher then assisted with fitting and adjusting the VR headset.

The experimental session consisted of two main phases:

Trial Phase

This phase was designed to minimize potential issues during the experimental procedure, to help participants better understand the tasks, and to allow them to adapt to any possible discomfort caused by VR use (e.g., motion sickness, nausea). Prior to beginning, participants were informed that this was a trial/practice phase and that they could continue until they felt comfortable in the VR environment. Although there was no time limit, the phase lasted approximately three minutes, including the adjustment of the VR headset.

During this stage, participants were asked to move around freely within the VR scenario and explore the environment. They were informed that if they stepped outside the predefined area, they would automatically exit the VR scenario and see the actual experimental room. This was demonstrated by asking participants to try it themselves. Additionally, it was explained that as long as they remained within the boundaries of the pedestrian crossing, they would not collide with any physical objects in the room. This clarification was intended to ensure that participants felt safe and understood that there was no need to be afraid of bumping into anything while moving within the designated area. Participants were also told they could ask any questions during this phase. The researcher asked whether they experienced symptoms such as dizziness or nausea, or any fear while moving. Once participants reported feeling comfortable and capable of navigating the VR environment independently, the trial phase was concluded.

Before moving on to the second phase, participants were guided to the starting point of the pedestrian crossing area and informed that the experimental phase would begin.

Experimental Phase

In this phase, participants were instructed to cross the pedestrian path under three different auditory conditions. Each participant completed all three conditions, and the order of conditions was counterbalanced. The primary task required participants to begin crossing when the pedestrian traffic light turned green and to walk across the designated crosswalk to the opposite sidewalk.

The time elapsed between the onset of the green light and the moment participants reached the endpoint (a marked line representing the far sidewalk) was recorded using a professional stopwatch (see Figure 3.3.). The VR scenario was programmed so that the auditory stimulus corresponding to the green light was activated simultaneously with the visual signal. Both stimuli were controlled by the researcher via a single button.

Participants were informed that they were now entering the second phase of the study and were provided with task instructions. They were told to observe the pedestrian light and begin crossing only when the green signal appeared. Upon reaching the opposite sidewalk, they were instructed to stop, and the researcher would guide them back to the starting point. This process was repeated three times.

After the instructions were given, participants were asked if anything was unclear. If not, they were informed that the researcher would no longer answer questions during the experiment and that they should follow only the traffic light.

During the experiment, the researcher activated the appropriate auditory condition and started the stopwatch, recording the crossing time for each condition. Once participants completed all three trials, they were informed that the study had concluded and were instructed to remove the VR headset.

Figure 3.2. Older and younger participants in the marked experimental area.

Figure 3.3. Stopwatch.

Participants who wished to receive a summary of the results were asked to provide their email addresses. Afterward, participants were accompanied to the exit of the faculty building. The experimental flow for the study can be seen in Figure 3.4.

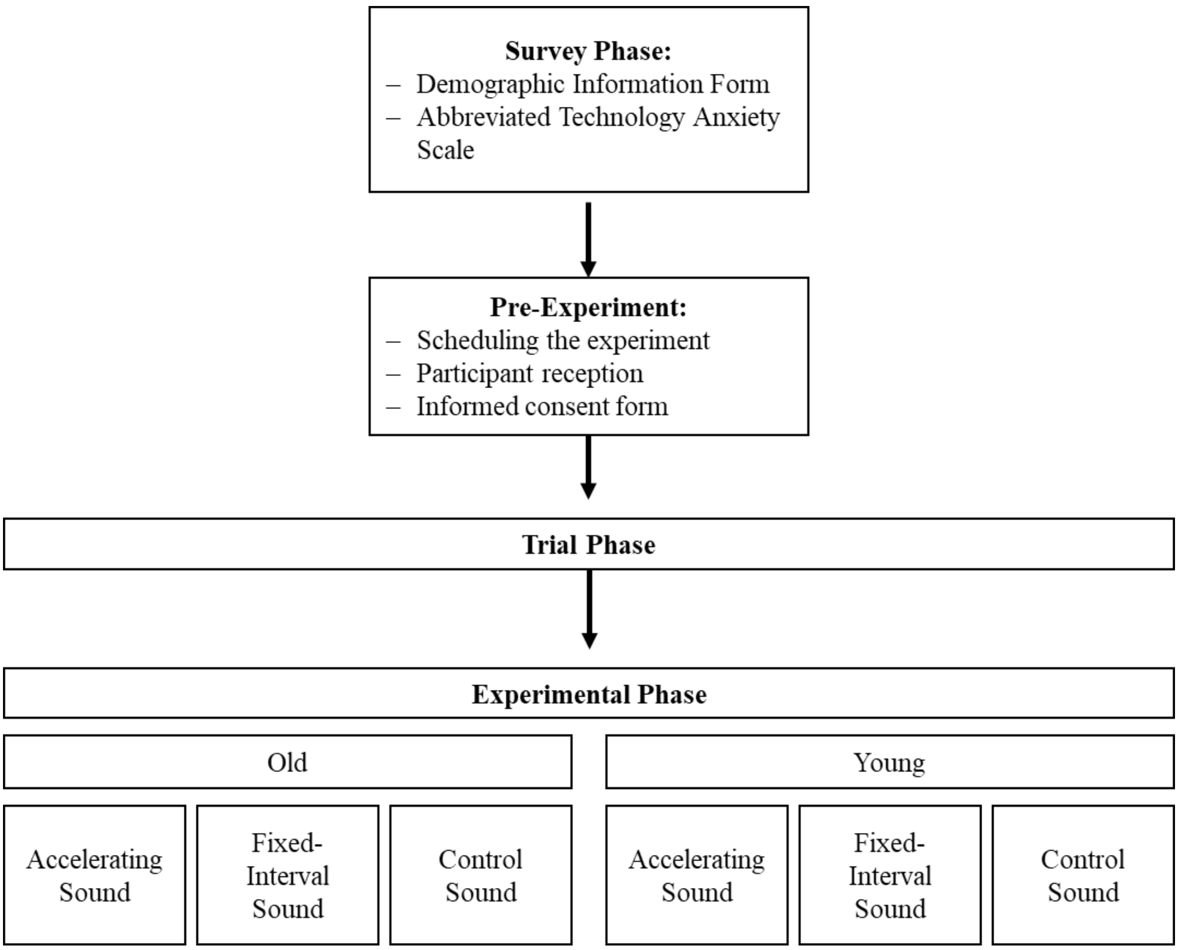

Figure 3.4. The experimental design of the study

3.1.4. Analysis

This study employed a 2 (Age Group: Younger vs. Older) × 3 (Auditory Condition: Control, Fixed-Interval, Accelerating) mixed design. The primary analysis was a mixed repeated-measures ANCOVA conducted on pedestrian crossing time in the virtual environment, with technology anxiety scores (measured by the Abbreviated Technology Anxiety Scale) included as a covariate. This analysis tested the between-subjects effect of age group, the within-subjects effect of auditory condition, and their interaction, while statistically controlling for individual differences in technology anxiety. When significant effects were found, pairwise comparisons using the LSD adjustment were conducted to further examine mean differences. All analyses were performed using IBM SPSS Statistics 25.

3.2. Results

3.2.1. 2 × 3 mixed design repeated-measures ancova

A mixed repeated-measures ANCOVA was conducted with auditory condition (control, fixed-interval, accelerating) as the within-subjects factor, age group (younger vs. older) as the between-subjects factor, and technology anxiety entered as a covariate.

There was a significant effect of auditory condition on crossing time after controlling for technology anxiety, $F(2, 102) = 3.30$, $p = .041$, $\eta^2_p = .061$. Pairwise comparisons using the LSD adjustment did not reveal significant differences between specific conditions.

The main effect of age group was not significant after controlling for technology anxiety, $F(1, 51) = 3.53$, $p = .066$, $\eta^2_p = .065$.

The interaction between age group and auditory condition was also not significant after controlling for technology anxiety, $F(2, 102) = 2.35$, $p = .059$, $\eta^2_p = .084$.

The covariate, technology anxiety, was not significantly related to crossing time, $F(1, 51) = 0.91$, $p = .344$, $\eta^2_p = .018$. However, there was a significant interaction between auditory condition and technology anxiety, $F(2, 102) = 4.06$, $p = .023$, $\eta^2_p = .137$.

The mean and standard deviation values displayed in Table 3.2. summarize the crossing performance across conditions, while also illustrating the distribution of times within each age group.

Table 3.2. Descriptive statistics of pedestrian crossing times (ms) across auditory conditions and age groups

Group	Control		Fixed-Interval		Accelerating	
	M	*SD*	*M*	*SD*	*M*	*SD*
Younger	6318.62	1380.41	6102.76	1390.31	6123.79	1182.92
Older	7320.00	2518.03	7541.60	2670.77	7289.20	2362.09
Total	6819.31	1949.22	6822.18	2030.54	6706.50	1772.50

Note: *M* = Mean, *SD* = Standard Deviation.

4. DISCUSSION

The present thesis consisted of two studies examining the interplay between age, auditory stimuli, and technology-related anxiety in the context of pedestrian crossing behavior. Study 1 involved the Turkish adaptation and validation of the Abbreviated Technology Anxiety Scale (ATAS), while Study 2 employed a virtual reality (VR) experimental design to test how age and technology anxiety interact with auditory pacing signals to influence crossing performance.

The primary aim of Study 1 was to adapt the Abbreviated Technology Anxiety Scale (ATAS) into Turkish and evaluate its psychometric properties among a diverse adult sample. The results of both exploratory and confirmatory factor analyses supported the unidimensional structure of the scale, aligning with the theoretical framework of the original ATAS and prior validations in other languages (Wilson, 2023; Razavi, Alizade & Amirfakhraei, 2024).

All items loaded strongly on the single factor, with factor loadings and communalities indicating that the scale items coherently reflect a single latent construct (technology anxiety) and that each item makes a meaningful contribution to the overall measurement. The confirmatory factor analysis further supported this structure, yielding generally acceptable fit indices. Although the RMSEA slightly exceeded the conventional cutoff of .08 (Browne & Cudeck, 1993), other indices fell within recommended thresholds, suggesting that the one-factor model adequately represents the observed data.

The criterion validity of the Turkish version of the ATAS was also supported by a strong positive association with an established measure of computer anxiety. This finding indicates that the ATAS captures a closely related construct and demonstrates satisfactory convergent validity.

The internal consistency of the scale was found to be excellent, surpassing widely accepted benchmarks for psychological measurement tools. This reliability was further supported by split-half analyses, which showed a high degree of agreement between both halves of the scale. The corrected item–total correlations also indicated that each item was positively associated with the total score and contributed meaningfully to the internal coherence of the scale.

In addition, the scale demonstrated strong temporal stability over the test–retest interval, indicating that technology anxiety, as measured by the Turkish ATAS, is a stable construct that does not exhibit substantial short-term fluctuations.

Taken together, the findings from Study 1 suggest that the Turkish version of the Abbreviated Technology Anxiety Scale is a psychometrically sound tool for assessing technology anxiety. Its robust internal structure, high reliability, and strong criterion validity.

In the context of the current thesis, the successful adaptation and validation of the ATAS into Turkish enabled its use as a covariate in Study 2, where the relationship between technology anxiety and pedestrian behavior in a virtual reality (VR) environment was explored. Ensuring a reliable measurement of technology anxiety was critical for examining how individual differences influence behavioral responses to auditory pacing cues in traffic-like scenarios, and how these interactions may vary across age groups. The availability of a valid and reliable Turkish version of the ATAS thus contributes both to the present study and to the broader field of technology-related psychological assessment.

Study 2 examined how age and auditory cues relate to pedestrian crossing performance and, with technology anxiety entered as a covariate.

Hypothesis 1 stated that, regardless of auditory condition, older participants were expected to cross more slowly than younger participants. Although prior work has consistently documented age-related declines in perceptual processing, motor coordination, and walking speed, the present analysis did not reveal a significant main effect of age once technology anxiety was controlled for. This suggests that age, taken alone, may not be a strong or consistent determinant of crossing performance. One explanation is that older adults in this study may have compensated for potential physical disadvantages by approaching the task with greater caution and responsibility compared to younger participants, prioritizing accuracy and completion of the crossing. Supporting this interpretation, Li et al. (2001) found that when younger and older adults were asked to perform a dual task involving walking while simultaneously completing a cognitive memorizing task, older adults prioritized the task of walking and maintaining balance, perceiving it as more critical, whereas younger adults tended to focus more on the cognitive memorizing task. In a similar vein, within the complex environment of street crossing, older adults may have prioritized the walking component of the task, which carries direct and life-threatening implications, over other competing demands. By doing so, they may have offset expected performance declines and walked at speeds more comparable to younger adults, contrary to much of the existing literature ((Bohannon, 1997; Callisaya et al., 2008). Another possibility is that earlier studies have overstated the role of chronological age without adequately considering heterogeneity within older populations; such as differences in health, mobility, prior exposure to technology, and, attitudes toward technology (e.g., comfort, interest, efficacy). Recent work with cognitively diverse older adults shows that many are both receptive to and proficient with everyday technologies, and that adoption varies across domains as a function of attitudes and context rather than age per se, underscoring that psychological and experiential factors can outweigh chronological age in shaping technology-supported behavior (Lin et al., 2025).

Hypothesis 2 predicted that crossing times would vary across auditory conditions, with participants expected to perform best in the accelerating cue condition, moderately in the fixed-interval condition, and slowest in the control condition. This hypothesis was supported by a significant main effect of auditory condition, confirming that auditory pacing influenced pedestrian behavior. The overall pattern aligned closely with predictions, with auditory signals enhancing performance compared to the absence of cues. Accelerating signals seemed to provide a dynamic temporal reference that facilitated more effective movement coordination, while fixed-interval cues offered less flexibility, producing outcomes closer to the control condition. Although pairwise comparisons did not yield significant differences between specific conditions, the general trend across auditory conditions underscores the potential of auditory pacing as a tool for guiding pedestrian movement. This finding is consistent with previous evidence that rhythmic or temporally structured auditory cues can support gait regulation and motor efficiency (Edworthy & Waring, 2006; Ducharme et al., 2018; Damm et al., 2020; Repp, 2005). Beyond its theoretical implications, this result highlights practical opportunities for incorporating auditory cues into pedestrian safety interventions.

Hypothesis 3 proposed that the effectiveness of auditory pacing would differ between age groups, with younger participants benefiting more than older ones. The interaction between age and auditory condition was not statistically significant, though the results suggested a near-significant trend in the predicted direction. Younger participants appeared somewhat more responsive to the auditory cues, while older participants maintained relatively stable performance across conditions. This pattern may reflect differences in multisensory integration: younger adults may flexibly adapt their motor responses to changing external inputs, whereas older adults may prefer more consistent strategies (Butler et al., 2016; Dommes et al., 2015). Although this hypothesis was not fully supported, the observed trend indicates that age-related variability in responsiveness to auditory cues may exist and could become more pronounced in less structured or more demanding environments. Potential limitations that may have influenced this outcome will be discussed in detail in the subsequent Limitations section.

Hypothesis 4 predicted that technology anxiety would shape crossing performance, with higher levels of anxiety associated with reduced benefits from auditory cues. As a covariate, technology anxiety was not significantly related to overall crossing time, indicating that anxiety alone did not account for performance differences. However, a significant interaction was found between auditory cues and technology anxiety, showing that the impact of these cues varied depending on participants' levels of anxiety. This suggests that technology anxiety can function as a psychological barrier, potentially diverting attentional resources or reducing trust in external signals, which in turn may weaken the effectiveness of technologically mediated safety interventions.

In this study, none of the hypotheses revealed a significant effect of age. However, the main effect of auditory cues and, more importantly, the interaction between auditory cues and technology anxiety did reach significance. These findings suggest that while age did not emerge as a meaningful predictor in this context, external signals and psychological dispositions may play a role in shaping pedestrian behavior. When considered together with the non-significant effects of age, these results suggest that age alone is not a decisive factor. Instead, factors such as external cues (like auditory signals) and psychological characteristics (such as technology anxiety) appear to play a more visible role in shaping pedestrian performance. Prior literature has often emphasized age-related differences in mobility and sensory processing, and such effects are indeed supported in some contexts (Gomes et al., 2017; Dunsky et al., 2014; Janols et al., 2022; Correia et al., 2016; Leung et al., 2013; Xiong et al., 2023). However, the present findings show that these differences may not emerge uniformly across all situations. Given that older adults are also more likely to experience higher levels of technology anxiety, it is possible that some previously observed age effects in traffic research may partly reflect uncontrolled variables like anxiety rather than chronological age itself. In this study, older participants may have drawn on motivational or compensatory strategies, such as prioritizing safe task completion or narrowing attentional focus, that helped offset expected differences with younger adults (Li et al., 2001).

Overall, the findings highlight that age, while relevant, may not be the sole or even the primary determinant of crossing behavior in technology-mediated contexts. Instead, the combination of psychological factors and responsiveness to external cues provides a more nuanced explanation of performance outcomes. This shift in perspective suggests that future interventions and urban designs would benefit from paying closer attention to these dimensions, ensuring that safety measures are not only age-inclusive but also psychologically accessible. The potential limitations that may have influenced these findings will be discussed in detail in the following section.

5. LIMITATIONS AND FUTURE DIRECTIONS

Despite the valuable insights gained, the current study is not without limitations. One prominent limitation is the relatively small sample size. In the present study, only 54 participants contributed data, with 29 younger adults and 25 older adults. While such numbers may be acceptable in some laboratory-based VR experiments, prior research has repeatedly highlighted that small sample sizes constrain statistical power and reduce the precision of effect size estimates (Ghanbari et al., 2024). A small sample may also hinder the detection of subtle differences between conditions; for example, although a main effect of auditory condition was observed, Bonferroni-corrected pairwise comparisons did not reach significance, which could be partly due to insufficient power (Mai, 2017). Moreover, small samples are more vulnerable to the influence of outliers and may not capture the full variability present in the broader population (Bakker & Wicherts, 2014). Consequently, the robustness of conclusions regarding the effects of different auditory stimuli and their interactions with moderating variables such as technology anxiety and age remains tentative (Ghanbari et al., 2024).

Another key limitation pertains to participant recruitment and demographic representativeness. The study used a snowball sampling technique, a common method in laboratory experiments, but one that may inherently produce a relatively homogenous sample (Mohamed, 2023). Snowball sampling can introduce self-selection bias (Parker, Scott & Geddes, 2019), as individuals who are more comfortable with or interested in technology are more likely to volunteer for VR research. This likely contributes to an overrepresentation of younger, tech-savvy participants while potentially excluding, and making it difficult to recruit, older adults who may not only be less familiar with VR technology but also experience higher levels of technology-related anxiety. Given that older participants tend to display more cautious crossing behavior (Butler, Lord & Fitzpatrick, 2016) and may be more affected by external cues, a limited and potentially skewed sample of older adults restricts the external validity of the findings, calling into question the extent to which the results can be generalized to real-world pedestrian populations (Fratini, Welsh & Thomas, 2023).

Closely related to recruitment challenges is the issue of obtaining a demographically diverse sample. Although the study did include both younger and older adults, the overall number of older participants was small (*n* = 25), and recruiting older individuals for lab-based VR experiments is consistently challenging. This challenge is further compounded by the logistical and practical difficulties of transporting older adults to laboratory settings. Factors such as limited mobility, scheduling constraints, and concerns about unfamiliar technology can make it especially difficult for elderly participants to attend in-person VR sessions. These access-related barriers may lead to the underrepresentation of individuals who are less mobile or less inclined to travel, potentially skewing the sample toward a more mobile and technologically receptive subgroup of older adults. This difficulty is compounded by the fact that older adults are more likely to have higher technology anxiety and lower prior exposure to immersive technologies, which not only may bias the sample toward those individuals who are unusually comfortable with VR but can also affect the actual performance during the experimental tasks (Mohamed, 2023). Studies in the VR field have repeatedly noted that participant discomfort and the cognitive and perceptual differences inherent to older populations may result in atypical behavior in virtual environments (Schneider & Bengler, 2020). As a result, the interaction effects and age-related differences observed in this study might not reflect genuine differences in real-world pedestrian safety but rather the properties of a non-representative sample that overrepresents certain subgroups while underrepresenting others (Fratini, Welsh & Thomas, 2023).

The phenomenon of technology anxiety represents yet another layer of complexity in VR studies. In the current experiment, technology anxiety was measured by the Abbreviated Technology Anxiety Scale, and although it did not achieve a significant main effect as a covariate, it significantly interacted with auditory condition effects. This suggests that even if the device (in this case, a VR headset) is capable of delivering a realistic environment, the user's anxiety regarding new technology may alter their behavior, causing them to react more slowly to auditory cues or leave them less engaged in the scenario (Fratini, Welsh & Thomas, 2023). Such technology anxiety can be particularly pronounced among older adults, who in this study reported significantly higher anxiety levels compared to younger participants (Mohamed, 2023). This raises the possibility that the measured differences in crossing times might be partly attributable to participants' discomfort with the device rather than to the experimental manipulations per se (Cham et al., 2024). Moreover, when technology anxiety interacts with auditory conditions, it becomes challenging to disentangle whether prolonged crossing times relate to participants’ inherent cautiousness in a perceived risk-free virtual environment or simply to their unease while using high-tech equipment (Schneider & Bengler, 2020).

Another methodological limitation concerns the ecological validity of laboratory-based VR research. Although VR offers the advantage of eliminating real-world hazards, it does so at the cost of removing contextual and situational complexities that naturally influence pedestrian behavior. In natural street-crossing situations, pedestrians are exposed to myriad dynamic cues, from unpredictable traffic flows to social cues from other road users, that are difficult to replicate in a controlled VR setting. Even though the VR scenario used in this study was carefully designed to mimic a two-lane road with moving traffic, the absence of real-world consequences may induce participants to behave differently. Participants might take more risks or, conversely, become overly cautious because they are aware that no true harm is occurring during the experiment (Schneider et al., 2022). The controlled and sanitized nature of a lab environment can lead to artificial behaviors that do not accurately mirror real-life pedestrian decisions, thereby limiting the external validity of the findings (Mohamed, 2023).

The specific design of the VR scenarios also adds constraints. The study used three distinct auditory conditions (fixed-interval, accelerating, and control) to simulate external cues from an autonomous vehicle’s interface. Although these conditions provide valuable insights into how auditory pacing might affect crossing behavior, there are intrinsic limitations in the complexity of these stimuli. In a real-world context, auditory cues from vehicles are often accompanied by complementary visual and haptic signals, which together provide rich, multimodal feedback that enhances a pedestrian’s situational awareness. Yet, in this study, only auditory variations were manipulated, which may not fully capture the synergy of multiple sensory stimuli that work together under actual traffic conditions. This reduction of the multisensory experience to just auditory cues might lead to an oversimplification of pedestrian decision-making processes.

Future studies might address these limitations by increasing the sample size, particularly among older adults, and by incorporating more representative recruitment strategies that go beyond snowball sampling. In addition, advances in VR technology, such as higher resolution displays, wider fields of view, and improved multisensory integration, could help narrow the gap between simulated and real-world experiences, thereby enhancing the ecological validity of VR studies.

Furthermore, integrating objective physiological measures (e.g., eye tracking, heart rate monitoring) alongside traditional timing and self-report methods could provide a more nuanced picture of participant responses to VR stimuli, thereby reducing reliance on subjective measures that are susceptible to bias (Mohamed, 2023). Such multimodal data collection strategies would enable researchers to more accurately isolate the effects of auditory cues and technology anxiety from other confounding variables.

Moreover, employing longer and more varied trials could mitigate potential learning or fatigue effects, thus allowing for a more reliable assessment of true pedestrian behavior under different conditions.

6. CONCLUSION

This thesis examined how aging and technology-related anxiety interact with auditory pacing cues to influence pedestrian behavior in a simulated traffic environment. Grounded in the fields of social psychology, human–technology interaction, and traffic safety, the research adopted a multidimensional perspective to address the challenges faced by older adults in crossing streets; a daily yet complex task that requires the coordination of cognitive, perceptual, and motor processes.

The study contributes to the literature in several novel and impactful ways. Most notably, it represents the first known effort to translate and validate the Abbreviated Technology Anxiety Scale (ATAS) into Turkish. By doing so, it fills a significant gap in the existing psychological assessment tools available in Turkish, offering researchers and practitioners a contemporary and domain-general instrument for evaluating technology-related anxiety across age groups. Given the rapid technological changes shaping modern life, the adaptation of a scale that captures generalized anxiety toward everyday technologies holds substantial relevance for both academic inquiry and practical application.

In addition to this methodological contribution, the thesis provides empirical evidence on how auditory cues and technology anxiety are related to pedestrian crossing performance. While the anticipated main effect of age was not observed, auditory cues significantly influenced crossing times, and technology anxiety interacted with these cues. These results suggest that psychological characteristics, together with external signals, may shape pedestrian performance more strongly than chronological age alone. In this sense, the findings highlight the importance of considering multiple factors, including both environmental conditions and individual differences, when evaluating pedestrian safety in technology-mediated contexts.

Although the results did not demonstrate consistent behavioral effects across all conditions, the findings of this thesis offer important conceptual contributions to the field of traffic psychology by emphasizing how external cues and psychological dispositions can shape pedestrian experience in complex environments. Despite limitations related to sample size and ecological validity, this study provides an early and necessary step toward integrating technology anxiety into discussions of traffic behavior. By bridging the domains of aging, human–technology interaction, and traffic psychology, the thesis contributes to a more holistic understanding of pedestrian safety and urban mobility. Ultimately, it underscores the need for future interdisciplinary research that prioritizes psychological accessibility alongside physical infrastructure, ensuring that technological solutions in public spaces are inclusive and effective for all, especially for aging populations.

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APPENDICES

Appendix 1: Informed Consent Form (Study 1)

Bilgilendirilmiş Onam Formu

Değerli katılımcı,

Bu çalışma, Başkent Üniversitesi Fen-Edebiyat Fakültesi Psikoloji Bölümü öğretim üyesi Doç. Dr. Burcu TEKEŞ TOLUNGÜÇ danışmanlığında, Sosyal Psikoloji Yüksek Lisans programı öğrencisi Psk. Ece KEMALLARLI tarafından yüksek lisans tezi kapsamında yürütülmektedir. Bu çalışma, "Abbreviated Technology Anxiety Scale'in" Türkçe uyarlamasının geçerlik-güvenirlik analizlerinin yapılması amacıyla düzenlenmiştir.

Katılım tamamen gönüllülük esasına dayanmaktadır. Katılımcılardan elde edilecek tüm kimlik bilgileri gizli tutulacak ve hiçbir aşamada kimlik bilgileri açıklanmayacaktır. Araştırma bulguları yalnızca bilimsel amaçlarla kullanılacaktır. Çalışmaya katılım kapsamında, katılımcıların demografik bilgi formu ve çeşitli değerlendirme araçlarını eksiksiz doldurmaları beklenmektedir. Çalışmanın tamamlanması yaklaşık olarak 7 dakika sürecektir. Araştırma sonuçlarının güvenilir olabilmesi için, sorulara içten ve eksiksiz yanıt verilmesi büyük önem taşımaktadır. Soruların size tam olarak uymadığı durumlarda, size en yakın gelen yanıtı işaretlemeniz yeterlidir. Bu çalışmaya katılım herhangi bir risk içermez. Katılımcılar diledikleri zaman çalışmaya katılmayı reddedebilir veya herhangi bir aşamada çalışmadan ayrılabilirler. Araştırmaya katıldığınız için şimdiden teşekkür ederiz. Bu çalışma hakkında daha fazla bilgi almak için Ece Kemallarlı adresine ulaşabilirsiniz.

Bu araştırmaya tamamen gönüllü olarak katıldığınızı, istediğiniz zaman yarıda bırakabileceğinizi, ve verdiğiniz bilgilerin bilimsel amaçlı yayınlarda kullanılmasını kabul ediyorsanız aşağıdaki "Kabul ediyorum." kutucuğunu işaretleyerek devam edebilirsiniz.

Kabul ediyorum. ☐

Kabul etmiyorum. ☐

Appendix 2: Abbreviated Technology Anxiety Scale (Atas)

Bu ölçek, teknoloji kaygınızı ölçmeyi amaçlamaktadır. Lütfen her ifadeye, kendiniz ve teknoloji hakkındaki kişisel hislerinize uygun olarak katılım düzeyinizi işaretleyiniz.

Ölçeği yanıt-larken her bir ifadeyi dikkatle okuyarak, ifadelere katılma derecesine göre "Kesinlikle Katılmıyorum", "Katılıyorum", "Ne Katılıyorum Ne Katılmıyorum", "Katılıyorum" veya "Kesinlikle Katılıyorum" seçeneklerinden birini seçiniz. Tüm ifadeleri okuyup, eksik işaretleme yapmamaya özen gösteriniz.

	Kesinlikle Katılmıyorum	Katılmıyorum	Ne Katılıyorum Ne Katılmıyorum	Katılıyorum	Kesinlikle Katılıyorum
1. Teknoloji bana göre değildir.					
2. Teknolojinin yeni özelliklerini öğrenmeye karşı isteksizimdir.					
3. Teknolojiyi kullanırken rahatsız hissederim.					
4. Teknoloji, hayat kalitemi yükseltmez.					
5. Teknolojiyi kullanırken kontrolün bende olmadığını hissederim.					
6. Teknolojiyi kullanırken huzursuz hissederim.					
7. Teknolojinin basit işleri karmaşıklaştırdığını hissediyorum.					
8. En yeni teknolojiyi takip etmek imkansızdır.					
9. Teknolojiyi verimli şekilde kullanamam.					
10. Teknolojiyi kullanmak beni gerer.					
11. Teknolojiyi kullanırken sık sık sinirlerim bozulur.					

Appendix 3: Computer Anxiety Scale (Bkö)

Bu ölçek, öğrencilerin bilgisayar başında yaşadıkları güçlükleri belirlemek için hazırlanmıştır. Bilgisayara ilişkin yaşadığınız durumları düşünerek, aşağıdaki ifadelerin her birinin size uygunluk derecesini belirleyiniz.

Ölçeği yanıt-larken her bir ifadeyi dikkatle okuyarak, yaşadığınız sıklık derecesine göre "Hiçbir Zaman", "Bazen", "Sık Sık" veya "Her Zaman" seçeneklerinden birini seçiniz. Tüm ifadeleri okuyup, eksik işaretleme yapmamaya özen gösteriniz.

	Hiçbir Zaman	Bazen	Sık Sık	Her Zaman
1. Ne zaman bilgisayarın başına otursam, yüreğim daralıyor.				
2. Bilgisayarda çalışırken kendimi hiç rahat hissedemiyorum.				
3. Bilgisayar mı! Aman benden uzak dursun…				
4. Bilgisayarda çalışırken yanlış bir şey yapmak ya da bir şeyleri bozmak düşüncesi beni oldukça endişelendiriyor.				
5. Bilgisayara ilişkin kullanılan kavramlar bana hep karmaşık gelmiştir.				
6. Benim için çok önemli bir dosyada çalışırken kalbimin çok hızlı attığını hissederim.				
7. Bilgisayar beni o kadar gerginleştiriyor ki, yapacağım şeyleri yapamaz duruma geliyorum.				
8. Bilgisayarda bazen bir düğmeye basmak bile beni ürkütür.				
9. Bilgisayardan söz edilmesi bile içimin sıkılmasına yetiyor.				
10.Yanlış bir komutta veya bilgisayarın kilitlenmesinde paniğe kapılıyorum.				
11. Bilgisayarda herhangi bir şey yapmak zorunda kalınca kendimi huzursuz ve rahatsız hissederim.				
12. Düzeltilmesi mümkün çok ufak hatalarda bile eteklerim tutuşur.				
13. Bilgisayarı öğrenmek zorunda kalmak gözümü korkutuyor.				

14. Bilgisayarda çalışmak bana işkence gibi geliyor.				
15. Bilgisayarı öğrenemeyeceğim endişesini yaşıyorum.				
16. Bilgisayarı kullanırken sinirlerimin çok gerildiğini hissediyorum.				
17. Bir bilgisayar programlama dilini rahatlıkla öğrenebileceğime inanıyorum.				
18. Her şeyi yapabilirim ama işe bilgisayara gelince elim ayağım dolaşır.				
19. Bilgisayar klavyesindeki tüm özel tuşları anlamak için dahi olmak lazım…				
20. Bilgisayarın teknik konularını anlamakta güçlük çekiyorum.				
21. Bilgisayar becerilerini kolaylıkla öğrenebileceğim konusunda kendime güveniyorum.				
22. Bilgisayardan olabildiğince uzak duruyorum. Çünkü ona kendimi yakın hissetmiyorum.				
23. Bilgisayarın bozulabileceğini düşünmekten dolayı bilgisayar kullanırken kendimi rahat hissetmiyorum.				
24. Bilgisayarda yanlış bir komut verildiğinde çok miktarda bilginin kaybolmasına neden olabileceğini düşünmek paniğe kapılmama neden oluyor.				
25. Yanlış yapma düşüncesi, bilgisayarda çalışmalarımı olumsuz yönde etkiliyor.				
26. Bilgisayarda çalışırken neşeli ve keyifliyimdir.				
27. Bilgisayarda çalışmaya can atarım.				
28. Bilgisayarda benim için çok önemli bir konu üzerinde çalışırken çok huzursuz ve gergin olurum.				

Appendix 4: Informed Consent Form (Study 2)

Bilgilendirilmiş Onam Formu

Bu çalışma, Başkent Üniversitesi Psikoloji Bölümü öğretim üyelerinden Doç. Dr. Burcu TEKEŞ TOLUNGÜÇ danışmanlığında, Psikoloji Bölümü Sosyal Psikoloji Yüksek Lisans öğrencisi Psk. Ece KEMALLARLI tarafından yürütülmektedir.

Bu araştırmanın amacı, 18-70 yaş aralığındaki bireylerin trafikteki yaya davranışlarını ve bu davranışlarla ilişkili bazı psikolojik ve teknolojik faktörleri incelemektir. Sanal bir yaya geçidi ortamında karşıdan karşıya geçme görevini yerine getirmeniz beklenmektedir. Elde edilecek veriler, yaya güvenliğini artırmaya yönelik çevresel düzenlemelere katkı sağlayabilecek bilimsel sonuçlar üretmeyi amaçlamaktadır.

Çalışmaya katılım tamamıyla gönüllülük temelinde olmalıdır. Çalışma süresince sizden kimlik belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayınlarda kullanılacaktır. Çalışma sırasında doldurulması talep edilecek anket, genel olarak kişisel rahatsızlık verecek herhangi bir ayrıntı içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz çalışmayı yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmada sorumlu olan kişiye, çalışmadan ayrılmak istediğinizi söylemek yeterli olacaktır. Çalışmanın veri toplama aşamasının sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Çalışmaya katılımınız için şimdiden teşekkür ederiz.

Çalışma hakkında daha fazla bilgi almak için Psikoloji Bölümü Yüksek Lisans öğrencilerinden Psk. Ece Kemallarlı, Psikoloji Bölümü öğretim üyelerinden Doç. Dr. Burcu TEKEŞ TOLUNGÜÇ ile iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayınlarda kullanılmasını kabul ediyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Tarih: ……………………….   İmza: ……………………….

Appendix 5: Sociodemographic Information Form

Demografik Bilgi Formu

1. Cinsiyetiniz: ____________

2. Yaşınız: ________________

3. Son 5 yıldır hangi ilde ikamet ediyorsunuz?

____

4. Yaşamınızın büyük bir kısmını nerede geçirdiniz?

☐ Köy ☐ Kasaba ☐ İlçe ☐ Şehir ☐ Büyükşehir

5. Eğitim durumunuz:

☐ İlkokul

☐ Lise

☐ Üniversite

☐ Yüksek Lisans

☐ Doktora

6. Günlük ulaşımınızı nasıl sağlarsınız? Aşağıdaki ulaşım çeşitlerinin altında bulunan şeritten kullanım yüzdenizi işaretleyiniz. Her bir ulaşım çeşidine verdiğiniz değerlerin toplamının 100 olmasına özen gösterin. (Örnek: Yürüyerek-40, Araba-60)

Yürüyerek (Yaya)

Araba

Toplu taşıma (Otobüs, Dolmuş, Metro)

Elektrikli Scooter/ Bisiklet

7. Sokakta <u>yaya olarak</u> ulaşımınızı sağlarken hiç kaza yaşadınız mı?

☐ **Evet** ☐ **Hayır**

12. Tanısını almış olduğunuz bir fiziksel engeliniz var mı?

☐ **Var** ☐ **Yok**

Varsa nedir?

____

13. Tanısını almış olduğunuz bir nörolojik rahatsızlığınız (Vertigo, epilepsi vb.) var mı?

☐ **Var** ☐ **Yok**

Varsa nedir?

____

14. Son bir hafta içerisinde fiziksel bir ağrı sebebiyle yürümekte zorluk çektiğiniz oldu mu?

☐ **Evet** ☐ **Hayır**

Evet ise; yürüme zorluğunu hala devam ediyor mu? ☐ **Evet** ☐ **Hayır**

Appendix 6: Identifier

İsim ve soyadınızın <u>ilk iki harfini</u> ve <u>doğum yılınızın son iki hanesini</u> aşağıya kodlayınız (Eğer birden fazla isme sahipseniz yalnızca ilk isminizin harflerini kodlayınız).

Örnek:

Appendix 7: Ethics Committee Approval

Evrak Tarih ve Sayısı: 08.05.2025-459324

T.C.
BAŞKENT ÜNİVERSİTESİ REKTÖRLÜĞÜ
Akademik Değerlendirme Koordinatörlüğü

1993

Sayı : E-62310886-605-459324
Konu : Ece Kemallarlı'nın Etik Onayı

08.05.2025

SOSYAL BİLİMLER ENSTİTÜSÜ MÜDÜRLÜĞÜNE

İlgi : 14.04.2025 tarih ve 451419 sayılı yazınız.

Enstitünüz Sosyal Psikoloji (Tezli) Yüksek Lisans Programı öğrencisi Ece Kemallarlı'nın, Doç. Dr. Burcu Tekeş Tolungüç danışmanlığında yürüteceği, "The Effect of Technology and Age on Pedestrian Crossing: The Role of Auditory Signals" başlıklı tez çalışması değerlendirilmiş ve bilgilerinize ekte sunulmuştur.

Prof. Dr. Sadegül AKBABA ALTUN
Kurul Başkanı

Ek: Değerlendirme Formu

Evrak Tarih ve Sayısı: 08.05.2025-459324

Sayı : 17162298.600-131
Konu : Tez Çalışması

24 Nisan 2025

İlgili Makama

Üniversitemiz Sosyal Bilimler Enstitüsü Sosyal Psikoloji (Tezli) Yüksek Lisans Programı öğrencisi Ece Kemallarlı'nın, Doç. Dr. Burcu Tekeş Tolungüç danışmanlığında yürüteceği, "The Effect of Technology and Age on Pedestrian Crossing: The Role of Auditory Signals" başlıklı tez çalışması değerlendirilmiş ve yapılmasında bir sakınca olmadığı tespit edilmiştir.

Bilgilerinize saygılarımızla sunarız.

Başkent Üniversitesi Sosyal ve Beşeri Bilimler ve Sanat Alan Araştırma Kurulu

Ad, Soyad	Değerlendirme	İmza
Prof. Dr. Gözen Güner Aktaş	Olumlu/~~Olumsuz~~	
Prof. Dr. Sadegül Akbaba Altun	Olumlu/~~Olumsuz~~	
Prof. Dr. Fatih Çetin	Olumlu/~~Olumsuz~~	
Prof. Dr. Hasan Tahsin Fendoğlu	Olumlu/Olumsuz	
Prof. Dr. Filiz Kalelioğlu	Olumlu/~~Olumsuz~~	
Prof. Dr. Hidayet Hale Künüçen	Olumlu/~~Olumsuz~~	
Prof. Dr. Özcan Yağcı	Olumlu/~~Olumsuz~~	