CULTURAL DIFFERENCES IN PERCEIVED TRADITIONAL AND SMART INDOOR SOUNDSCAPE OF DOMESTIC SPACES: A FOCUS ON ARAB AND TURKISH RESIDENTS

Abdul Lah AL KAN

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ABSTRACT

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Abdul Lah AL KAN
INTERIOR ARCHITECTURE MASTER'S THESIS

Supervisor: Assoc. Prof. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU
December 2024, 102 pages

The aim of this study is to understand the current acoustic condition of smart houses, evaluate the effect of smart technology on perceived indoor soundscape, and measure cultural differences regarding that perception. Arab and Turkish residents living in Türkiye were the focus of this study. A method to distinguish traditional and smart houses was not found. Thus, an indoor acoustic environment scenario was designed for each house type. Indoor residential soundscape questionnaire was conducted to answer the research questions, participants were asked to listen to the designed traditional and smart house acoustic environment audio samples, and evaluate the audios using an indoor residential soundscape scale found in the literature. English attributes of the scale were translated to Arabic and Turkish with focus group method. It is found that cultural differences do not affect indoor soundscape perception, embedding smart technology into houses increase eventfulness, yet not decrease comfort ratings of the users, and sensitivity to noise had an influence on indoor soundscape perception.

Keywords: Indoor soundscape, listening test, residential building, smart house, cultural difference.

ÖZET

İÇ MEKAN GELENEKSEL VE AKILLI İŞİTSEL PEYZAJ ALGISINDA KÜLTÜREL FARKLILIKLAR: ARAP VE TÜRK SAKİNLER ÜZERİNE BİR ODAK ÇALIŞMASI

Abdul Lah AL KAN
İÇ MİMARLIK YÜKSEK LİSANS TEZİ

Danışman: Doç. Dr. Papatya Nur DÖKMECİ YÖRÜKOĞLU
Aralık 2024, 102 sayfa

Bu çalışmanın amacı, akıllı evlerin mevcut akustik durumunu anlamak, akıllı teknolojinin algılanan iç mekân ses peyzajına etkisini değerlendirmek ve bu algıya yönelik kültürel farklılıkları ölçmektir. Çalışmanın odak noktası, Türkiye'de yaşayan Arap ve Türk sakinlerdir. Geleneksel ve akıllı evleri ayırt etmek için bir yöntem bulunamadığından, her ev tipi için bir iç mekân akustik ortam senaryosu tasarlanmıştır. Araştırma sorularını yanıtlamak amacıyla bir anket yapılmış, katılımcılardan tasarlanmış geleneksel ve akıllı sesleri içeren ev ortamı ses senaryolarını dinlemeleri ve literatürde bulunan iç mekân işitsel peyzaj algısı değerlendirme ölçeğini kullanarak bu sesleri değerlendirmeleri istenmiştir. İngilizce ölçek, odak grup çalışmaları ile Arapça ve Türkçeye çevrilmiştir. Çalışmada, kültürel farklılıkların iç mekân işitsel peyzaj algısını etkilemediği, akıllı teknoloji seslerinin işitsel peyzaj hareketliği algısını artırırken kullanıcıların işitsel konfor düzeyini azaltmadığı ve gürültüye duyarlılığın iç mekân işitsel peyzaj algısı üzerinde belirgin bir etkisi olduğu bulunmuştur.

Anahtar Kelimeler: iç mekân işitsel peyzaj, dinleme testi, konut, akıllı ev, kültürel farklılık.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

dB	: Decibel
HVAC	: Heating, Ventilation, and Air Conditioning
IoT	: Internet of Things
RH	: Research hypothesis
RQ	: Research question

CHAPTER I
INTRODUCTION

Advancement of technology leads to a more luxurious life, especially in households. Since the discovery of electricity, houses have evolved to a new level. Also, the creation of artificial intelligence and internet of things (IoT) technology houses became a hub for multiple advanced devices. Thus, adding more sound sources to the indoor space resulting in an increased overall acoustic environment. Since people spend most of their time in an indoor space, and most of that time at their houses, improvement and enhancement of the acoustic environment in inevitable. Thus, a well-designed indoor environment of a residential space leads to a better quality of life and wellbeing.

One of the main factors regarding indoor environmental quality is acoustics. While sound is unseen it can affect the way users feel and experience an indoor environment and the way they interact with it, which can be referred to as soundscape. Soundscape is the field of study that cares about human perception of the acoustic condition. Studying indoor soundscape of domestic spaces benefits users' comfort and wellbeing. This study's goal is to investigate the acoustic condition of smart houses in literature, the effect of embedding smart technology on the indoor soundscape of houses, and the cultural difference between Arab and Turkish users living in Türkiye regarding indoor soundscape perception in residential setting.

1.1 AIM AND SCOPE OF THE STUDY

The study aims to identify the current situation of smart houses by studying literature and investigating the smart houses market. Furthermore, since cultural differences can have a huge influence on users' perception of the indoor soundscape, exploring smart technology effect on indoor soundscape perception of residents living in Türkiye, focusing on users whose native language is either Arabic or Turkish to distinguish possible cultural differences among the two groups, other demographical factors (e.g., age, gender, education level) are examined to test whether they have an effect on the perception of the indoor soundscape. Residential area or location of cities are not the focus of the study as the participants evaluate digitally created residential sound samples. Furthermore, people whose native language is neither Arabic nor Turkish are not included in the study. Additionally, only the auditory sense is considered in this research, while other senses (e.g., visual, tactile, etc.) are excluded.

1.2 GAP IN THE LITERATURE AND IMPACT OF THE STUDY

The study mainly aims to make a better understanding of smart technology's effect on the indoor residential soundscape perception. The study focus on answering the following questions:

RQ1. What is the current situation of smart houses regarding the acoustic condition?

RQ2. How does smart technology affect the soundscape of indoor domestic spaces?

RQ3. The following sub-questions discuss the relationship between demographic factors and indoor soundscape perception of houses:

- RQ3.1. Do the cultural differences between Arab and Turkish groups have an influence on the perceived indoor soundscape?
- RQ3.2. Do they get affected by smart technology differently?
- RQ3.3. Do other demographic factors influence the perceived indoor soundscape?

PRISMA review was conducted to identify the gap in the literature. Scopus and ScienceDirect data bases are used to conduct the PRISMA review, looking for articles having the following keywords in their title, abstract, and keywords:

(("smart house" OR "smart home" OR "automated home" OR "automated house") AND ("acoustics" OR "acoustic environment" OR "sound environment" OR "soundscape")) OR (("soundscape" OR "acoustic environment" OR "sound perception") AND ("domestic" OR "residential")) OR (("soundscape" OR "acoustic environment") AND ("cultural difference" OR "cross-cultural" OR "cultural variation" OR "sociocultural" OR "cultural influence"))

The compiled articles (e.g., 624 from Scopus, 66 from ScienceDirect, and 29 previously collected articles) were 728, and 649 articles after removing duplicates. Afterwards, 248 articles were retrieved. Then, the remaining articles were screened for eligibility (articles which are not related with indoor soundscape, articles which are not related with smart houses, and articles which are not written in English were excluded), resulting in 43 articles which were reviewed, **Figure 1**.

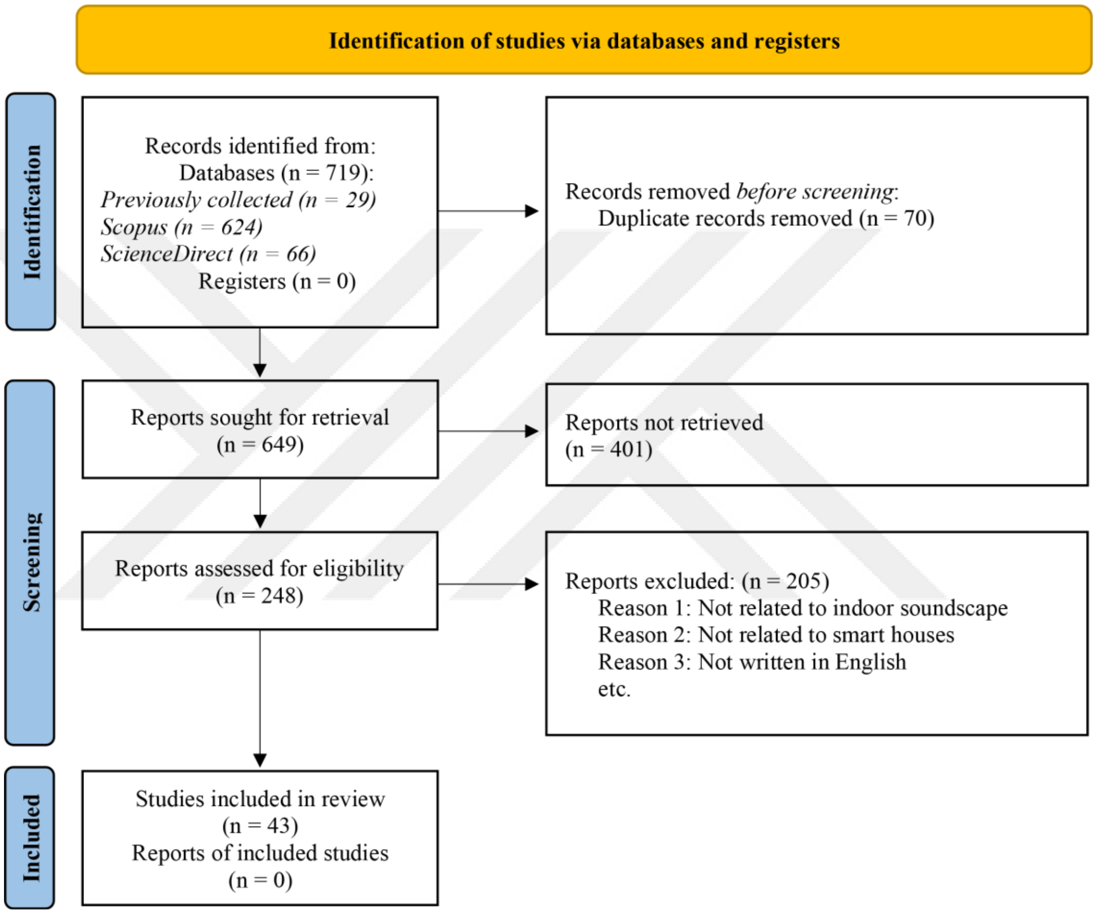

Figure 1: PRISMA review flow digram.

After conducting the PRISMA review, no work in the literature regarding the effect of smart technology on the indoor soundscape of residential buildings was found. Additionally, neither house level of smartness scale, that identifies how smart a house is and can be used as a questionnaire, nor other methods that can be applied to a survey were found. This study contributes to literature by suggesting translations of indoor soundscape scale to both Arabic and Turkish languages, a study of the relationship between embedding smart technology into domestic spaces and the perception of indoor soundscape, and presenting a method to distinguish traditional and smart houses.

1.3 THESIS STRUCTURE

The first chapter of this thesis is the introduction part, it has general information about the importance of this work, its' aim and scope, and the gap in the literature that inspired it. In the second chapter, a literature review is conducted. It has three main focus areas, indoor soundscape, smart houses, and evaluating indoor soundscape of residential buildings. The third chapter discusses the study objectives, the design of the study, data collection and analysis methods, and detailed explanation of the translation phase of the used indoor soundscape scale. Results and discussion are presented in the fourth chapter of this thesis, the chapter provides study results, their description, and statistical analysis. The last chapter of this thesis concludes the research aim, findings, and possible future research areas.

CHAPTER II
LITERATURE REVIEW

Soundscape deals with the human perception of the acoustic environment. It is defined as the acoustic environment as understood, perceived, or experienced by users in a certain context (ISO 2014). Soundscape involves more factors than hearing only, even though it is mainly related to the acoustic environment. Though hearing and memory are the main associations of soundscape, many other psychological, physiological, and sociological aspects affect its' process (Schafer 1993).

Designing soundscapes correctly can improve quality of life and strongly affect the user's experience (Alkan et al. 2023). Lately, indoor soundscape study area has become an important part of research within the field of acoustics. With the advancement of technology and the appearance of smart houses, the indoor residential soundscapes are significantly affected. Thus, considering the concepts of soundscape while designing the indoor built environment can be called an innovative designing approach of the indoor environment (Alkan et al. 2023).

2.1 INDOOR SOUNDSCAPING

Sounds have different types and natures; some are caused naturally and some artificially, certain sounds are beneficial and pleasant to hear or listen to, while others are the opposite. Improving users' quality of life is the task of an architect or designer, which can be achieved by taking into consideration both vision and aural aspects of the designed environment. However, architects nowadays often been called "deaf designers" since they lack consideration of the acoustical principles while designing (Mackrill et al. 2013). Hospitals are a great example of this issue, they are tied with beeping sounds, gurneys wheels in the hallways, sounds of footsteps, and calling vocalizations. These and other examples are considered disturbing and worsen the hospital soundscape, especially if the patient's perspective is considered. They necessitate sleep to properly recover, instead they hear such disturbing sounds day and night, intervening the process of healing (Mackrill et al. 2013). This design issue is not exclusive to hospitals, schools also suffer from poor design leading to less efficient learning outcomes and health problems for teachers and students. Similarly, domestic buildings suffer from poor designed soundscape, causing less comfort and negatively affected overall health for users (Alkan et al. 2023).

Designers must consider that the acoustic design of a space is more crucial and effective than sound design of the sources, since the acoustic properties of space are permanent and harder to modify. Additionally, the properties of a space (e.g., finishing materials) have larger influence on the indoor soundscape relative to the equipment-based sound sources (Alkan et al. 2023). A study made in Italy focused on semantical differences and found significance in flooring material impact over the designed sound of a product on participants. Advising designers to deeply consider materials' acoustical characteristics and assure that spaces have a suitable acoustical condition for the users is crucial in every architectural project and application (Dal Palù et al. 2017).

An initial step into designing the indoor soundscape of a space is understanding the possible sound source types emitted in that space, sound source taxonomy can be created to classify the various audible sounds in a space, this classification can differ according to the usage of the space. According to ISO standard, sound sources in general can be classified into three categories. Sounds emitted from humans, sounds emitted naturally by non-human influence, and sounds emitted by man-made technology (ISO 2018). A sound source taxonomy was proposed by Lindborg for restaurants that classified the sounds according to whether they were designed, a result of the cuisine and the kitchen, or emitted by customers (Lindborg 2016). In some cases, while creating an indoor sound source taxonomy, outdoor sound sources should be considered as well as they affect the indoor soundscape. Another study, which has an initial taxonomy proposal for indoor acoustic environment for shopping centers separated outdoor and indoor sound sources, where outdoor sounds were less audible (Erçakmak and Yörükoğlu 2020).

Soundscape studies which examine indoor acoustic environments consider this classification while asking participants about the sounds they hear in space (Torresin et al. 2023). In Torresin et al study, the participants were asked about the number of sounds they hear and distinguish, where these sounds were divided into sub questions regarding being outdoor or indoor sound sources with respect to their characteristics; natural, human, or technology sounds. Similarly, another study focusing on the indoor soundscape of houses during the Covid-19 pandemic asked participants about the audibility of various sounds. Outdoor and indoor sound sources were divided. However, the division was less complex in general (Peixoto et al. 2023). Sound sources differ according to the space function. A study conducted in Chile found that compared to workplaces, houses have more diversity in the sound sources originated by humans (Gale et al. 2022).

2.1.1 Residential Soundscape

The influence of the soundscape is great on humans, both mental and physical aspects of users' health can be affected. Thus, a poorly designed soundscape can have negative effects upon the health of users in the long term. A study done in the UK investigated the relationship between soundscape and users' physiological measurements found that unpleasant sounds cause participants' heart rate to be increased by a mean of 2 beats per minute while pleasant sounds affected respiration rate, elevating it by one breath per minute (Hume and Ahtamad 2013). Another study was conducted in China suggests that people's psychological and physiological conditions may get directly affected by the soundscape and overall sound environment (Wang et al. 2022).

Regarding residential buildings, sound sources can be sorted into indoor sounds such as TV, human speech, and mechanical noises, and outdoor sounds such as people outside the house, traffic sounds, and weather. Indoor soundscape can be affected by outdoor sounds. A study conducted by Torresin et al found that despite the decrease in level of comfort caused by outside noise, with the presence of noises inside the house, negative effects of noises from outside can be diminished in relation to comfort (Torresin et al. 2020). Another study was conducted in 2021 found that the same indoor acoustic environment can be perceived differently from the same user depending on their activity (Torresin et al. 2021).

Factors such as the elevation of the house, users' behaviors, and social differences have an influence on acoustic environment evaluation (Cheng 2020). In a study conducted in Indonesia found that both motorized sounds and human voice and activity sounds negatively affect the soundscape in residential spaces, while the sounds of animals have the opposite effect (Djimantoro 2022). Moreover, another study found that the presence of other people might affect someone's soundscape perception even though they are living alone (Baharin et al. 2013).

Examining today’s houses, which can be considered as smart, artificial intelligence becomes the main element to be analyzed in future houses, yet still can be speculated. It can be expected that; tonal sound notifications will be mostly replaced by verbal speech generated by machines. Maybe in the near future, humans and machines will have better communication, allowing clearer understanding of the smart house conditions by users, deeper understanding of smart technology and the possible applications of it, and possibly helping users understand themselves better sonically (Alkan et al. 2023).

2.1.2 Cultural Differences in Perceiving Indoor Soundscapes

Cultural differences, experience, and beliefs are known for their influence upon people’s perception, understanding, and the way they give meaning to sounds in the indoor spaces. Thus, considering these differences during the design phase is crucial (Elghadaffi and Dökmeci Yörükoğlu 2020). In a previous work (Alkan et al. 2023), the author discussed different studies on cultural differences while perceiving soundscape and how it’s crucial to consider it. A study was conducted on France, Korean, and Sweden participants found that participants’ background culture affected their perception on sounds, that effect was bigger regarding birdsongs, water sounds, and human sounds (Jeon et al. 2018).

2.2 SMART HOUSES

Smart grids (e.g., smart houses, smart technology, and smart energy) are expected to add $14 trillion of economic value to the global economy by 2030. Such an increase in the use of technology will undoubtedly attract many companies and grab their attention, motivating them to have an investment in the smart houses market, leading to the establishment of new companies in this field. Several leading companies (e.g., Google, Amazon, Apple, and Samsung) are investing in smart houses and the IoT market. Each company has its own smart assistant and works on its own platform. By 2021, 31% of households in the US own smart assistants such as Amazon Echo and Google Nest. The technology of IoT is powerful, it connects and controls multiple devices inside space, making it easier than ever to give orders and modify the connected devices. For instance, through their smart assistant, Google can interact with more than 20,000 devices across 1200 brands (Alkan et al. 2023).

Smart houses can be defined as the technology consisting of different devices, functions, and wireless networks inside the house (Saizmaa and Kim 2008). Others describe them as the application of integrating intelligence into the management of domestic buildings (Mocrii et al. 2018). More recent definitions comprise the existence of IoT technology for a house to be considered smart (Almusaylim and Jhanjhi 2019). Thus, a smart house can be referred to as the living space that contains devices which are using the internet to form a network to remotely execute different functions around the household (Korneeva et al. 2021).

In contemporary times, communication between humans and devices mainly relies on a predefined keyword, usually followed by the request, and ends with the smart devices providing feedback. Signals, notes, or tones may sometimes support this communication process, which can be designable sonic objects. This communication process has number of requirements (i.e., advanced speech coding, high level of speech intelligibility, low level of background noise, and high sound intensity of speech) (Alkan et al. 2023).

Smart houses mainly have four functions: alerting, monitoring, controlling, and intelligence. The first and simplest function is alerting, it gives users the information, this information can be transmitted either through sound notifications or digital text on screens. Alerting notifications are highly customizable in smart houses, making them one of the dominant sound marks of smart houses that can be designed. Monitoring is the second function of smart houses. It is crucial to have graphical and aural interfaces while creating smart houses. The role of these interfaces is to present information regarding smart devices installed throughout the household such as air conditioner temperature, a vital alert, live footage of a security camera, etc. The third fundamental of smart houses is control. While observing the state of their houses, users can modify and arrange the environment of their houses using IoT technology of smart devices multiple ways (e.g., monitoring screens, voice commands, smart switches, and phone applications). scheduling future events and organizing smart devices to act automatically can be achieved leading to reduced wasted time for the users. The most complex function of smart houses, intelligence, is the fourth function. Past smart houses devoid actual smartness. Smart devices in the past were called smart, though they lacked smart functionality even while listening to sounds and executing specific tasks. However, their applications were mostly a combination of several machines and their functions or by including electricity for essential duties in the early stages (Alkan et al. 2023).

Current smart houses include artificial intelligence and machine learning mechanisms which by accomplishing a higher level of smartness. A great example of this is smart assistants: they acquire the ability to listen to users' voice commands, process them, control the devices around the household, do a search on the internet, and learn the users' habits, and act upon them. Monitoring and control functions affect the indoor soundscape of smart houses in a different way compared to alerting function. Monitoring and control functions require two-way communication methods among the user and the device. Thus, the need for speech intelligibility increases a lot (Alkan et al. 2023).

2.2.1 Internet of Things (IoT)

IoT technology is the heart of a smart house; most recent definitions use IoT as a condition for a house to be called smart. The definition of IoT differs according to the intended field. However, according to literature, describing the definition of IoT can be categorized into four categories (Aagaard et al. 2018):

1. As intelligent objects,
2. As an extension of the Internet,
3. As a global network infrastructure and
4. As an interaction of information.

Regarding smart houses, IoT can be referred to as the number of devices that form a connection among each other via global network to a communication system (Mamatnabiyev and Suliyev 2018). Another way to define IoT is as the system of different devices, appliances, and machines in the house that are interconnected and inserted with hardware and software and have the ability of transforming data over the network without the need for human-human or human-machine interaction (Ayan and Turkay 2020).

2.2.2 From Traditional to Smart Houses

The early smart house systems were used by wealthy individuals between 1960s and 1980s, these systems were not affordable for the public, and they were focusing on lighting and heating control mainly. Home automation started to emerge between the 1990s and early 2000s, smart house concept became more widely available to the public, and more features were included in them regarding security, entertainment, and other aspects. In the mid-2000s the IoT era started, the advancement of IoT technology led to the concept of smart houses improving and becoming more available. IoT made it possible to integrate different devices and appliances, which created seamless and more connected house environment (Alkan et al. 2023).

Between the 2010s until the present day, smart houses became more advanced, installed with more complex systems (i.e., machine learning and artificial intelligence), giving smart houses the ability to learn the behaviors of users and adapt to them, making it more comfortable and increasing energy efficiency. Future inspections of smart houses are associated with 5G advancement, edge computing, and other aspects which are expected to improve smart houses making them more connected and aware of the needs of users. Augmented and virtual reality is a promising technology that can also help smart houses become more engaging, while data exchange with higher security can be achieved with blockchains (Alkan et al. 2023).

2.2.3 Indoor Soundscape of Smart Houses

Space design and positioning smart devices inside it, both are significant aspects of the quality of smart house indoor soundscape. Acoustic characteristics and designing smart devices positions are unavoidably connected, and the importance of smart houses acoustical design is rendered through this relationship (Alkan et al. 2023). The integration of sounds making the acoustic environment of space is called indoor soundscape. This integration covers both intentional sounds and unintentional sounds (e.g., human speech, appliances, music, and background noises). Smart houses have multiple sound sources (e.g., smart speakers, smart TVs, and other smart appliances), all these sound sources play a rule in forming the indoor soundscape since they are intentionally designed to emit sounds to be heard (Alkan et al. 2023). This integration of sounds must be considered while designing the indoor space and the smart devices implemented in it. Having a large number of sound sources inside the space can affect the voice commanded devices in that space. Which requires processing steps to aid the devices understanding the speech instructions (Alshammri 2023).

2.2.4 Sound Sources in Smart Houses

Sound sources in traditional houses (e.g., TV, radio, and music) are limited compared to smart houses. They are usually designed separately rather than having a correlation, and they are manually controlled by users. Moreover, since they are designed separately instead of working seamlessly together, their quality of sound depends on the individual effort put into it by the brand. Meanwhile, the interconnected grid of sound sources in smart houses (e.g., smart speaker, smart thermostat, smart TV, smart security system, smart doorbell, and other smart appliances) create the possibility of a better controlled system via smart apps or with voice commands.

Smart speakers are the heart of smart house, it is the most owned smart device among users, it can control most functions around the house, it can provide information regarding multiple aspects of the house, and it can verbally interact with the users. An investigation of the smart house market was conducted by (Alkan et al. 2024), the study reviewed the most purchased smart devices, as shown in **Figure 2**.

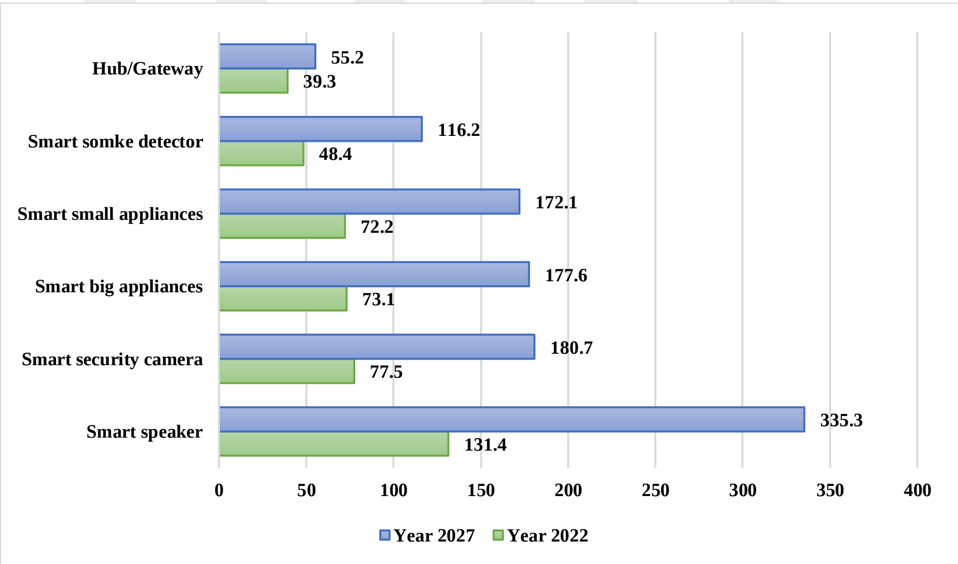

Figure 2: Numbers of owned smart devices in millions (Statista 2022).

The study found that smart speaker was the leading among most owned smart devices in 2022 in US (Alkan et al. 2024). Thus, the study proceeded with investigating the available sound notification files of different smart speaker companies of free access since the study wasn't funded, acquiring 316 Verbal sounds & 14 Tonal sounds found Amazon Echo on official developers' pages (Speechcon Reference n.d.; Voice

Service n.d.). And 55 Verbal sounds & 17 Tonal sounds found for Apple HomePod on unofficial sites (*HomePod Sounds* n.d.).

The found audio files were categorized according to the four smart house functions (i.e., Alerting, Monitoring, Controlling, and Intelligence) while classifying whether they are Verbal or Tonal sound notifications. In result, most emitted sounds were verbal generally and for the intelligence function, alerting and monitoring functions showed variety in the type of emitted sounds, and tonal sounds were dominant for the control function (Alkan et al. 2024).

2.3 EVALUATING SOUNDSCAPES

Multiple approaches can lead to collecting, analyzing, and visualization of soundscape data. The debate on collecting and analyzing data regarding the way people perceive and understand the acoustic environment is recent compared to the time where the field of soundscape appeared as it's known today (Mitchell et al. 2022). It is hard to assume the existence of a perfect method in collecting and representing soundscape data. However, well designed models can be enough to use while integrating multiple methods can lead to more sufficient results. Axelsson et al demonstrate the importance of discussing current soundscape study models to review their effectiveness, while considering the possibility of integrating different models to achieve a better understanding of that soundscape (Axelsson et al. 2019). A study conducted by Aletta et al compared two soundscape measuring methods which was proposed by ISO standard (Aletta et al. 2019). The study compared soundwalk and questionnaire methods and found strong statistical significance among the two methods. The study suggested that both methods can categorize different soundscapes.

2.3.1 Soundscape Evaluation Scale

Soundscape evaluation scale has been previously published within ISO standards in 2018, which consists of two main dimensions (Pleasantness and Eventfulness) and two sub dimensions rotated 45o as shown in **Figure 3**. The scale can be adapted into the questionnaire, giving five possible values for each attribute ranging from *Totally agree* to *Totally disagree*, and asking participants to choose which answer suits them best for each attribute. While the two main dimensions are independent, the two sub dimension values affect them using triangle equations allowing results to be plotted into a 2-D plane (ISO 2018).

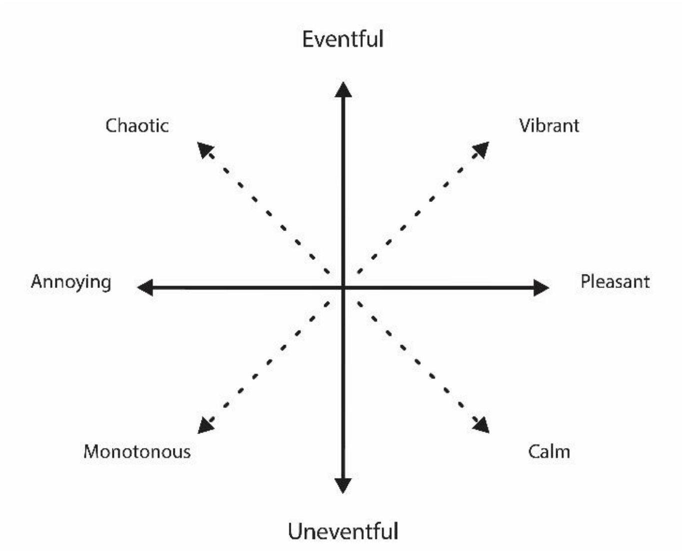

Figure 3: Urban soundscape evaluation scale (ISO 2018).

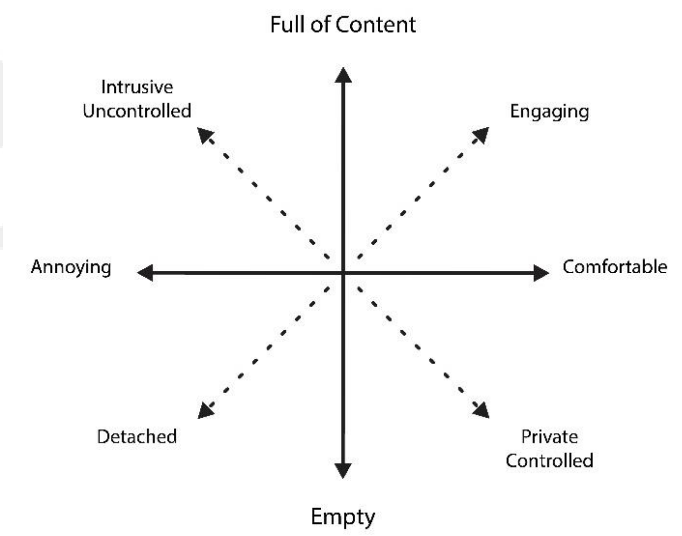

Figure 4: Indoor residential soundscape evaluation scale (Torresin et al. 2020).

An indoor soundscape evaluation scale specified for residential usage was adapted by Torresin et al. The study considers three main dimensions (Comfort 58%, Content 25%, and Familiarity 7%) focusing on indoor soundscape evaluation. Thus, the study proposed an evaluation scale consisting of two main dimensions (Comfort and Content). The scale is represented on a 2-D plane as shown in **Figure 4** where the two dimensions are defined as main axes with two sub-axes (Engagement and Privacy/Control) rotated 45° (Torresin et al. 2020).

Comfort dimension is associated with the level of comfort a user feels within the indoor acoustic environment of a space, while the Content dimension is focused on the number of acoustic events occurring in that indoor space from the user's perspective. Another soundscape dimension consisting of 7 factors (e.g., Pleasant, Calmness, Vibrant, Eventful, Softness, Relaxing, and Variant) on a 2D plane that was used to evaluate indoor residential soundscape in different cities in Indonesia (Djimantoro and Sakina 2021) is also present in the literature.

2.3.2 Translating & Adapting Soundscape Attributes

Though the soundscape scale can be applied regardless of the participant's cultural background, a translated version of the scale is more effective and suitable for covering larger sample of the targeted cultural groups, allowing for more accurate representation. A guideline article suggests two translation methods as most popular: translating an instrument and then back-translating it to the original language, and two or more independent translations of an instrument then comparing them to provide one alternative to be evaluated by a bilingual as third party (Gudmundsson 2009). When translators in the focus group know that a back translation method will be used to evaluate their translation, they will purposely choose words that can be translated back to the original language correctly rather than focusing on the optimal possible translation (Geisinger 1994). Therefore, relying on independent translation methods can be recommended. However, a study conducted by Epstein et al compared different methods and stated that there is no golden standard for cross cultural translation methods (Epstein et al. 2015).

Previous works provided translations of the eight soundscape attributes given by ISO standard (ISO 2018). Karn et al made a focus group translation method for soundscape scale, where five linguistics proposed a set of translation for each of the eight soundscape attributes. The proposed translation alternatives were validated using an online survey among bilingual Thai and English participants (Watcharasupat et al. 2022). In Anugrah et al research, the participants in the translation phase provided several alternatives to represent each one of the English attributes. The alternatives provided must be formal terms indexed in the official dictionary. Then, the participants selected one term to represent each English attribute considering the naïve people to understand it easily (Sudarsono et al. 2022). In the research conducted by Dokmeci Yorukoglu et al, a focus group method was used as well. However, participants of the focused group were provided a word pool of the Turkish equivalents for each English attribute prepared by the author. Participants of the focus group voted for 1st and 2nd

preference translation (Dökmeci Yörükoğlu et al. 2023). Another study by Nikolaos et al relied on independent translations from bilinguals, then the translations were compared and back translated to English in for evaluation (Papadakis et al., 2022).

A validation phase of the translated attributes is mandatory, proper method must be used to ensure the end translation and make it reliable in surveys for different cultures (International Test Commission 2018). Several methods can be used to validate the proposed soundscape attributes translations (e.g., online survey, listening tests in lab, sound walk in situ, applying questionnaire). In Dokmeci Yorukoglu et al article, to validate the soundscape attributes translation a listening test method was conducted. Participants were given 27 audio scenarios to listen to and asked to answer a Turkish questionnaire, the same audio scenarios were given one week later with an English questionnaire to eliminate any memory effects on participants' answers (Dökmeci Yörükoğlu et al. 2023).

CHAPTER III
DESIGN OF THE STUDY

The main goal of this study is to understand the varying effects of traditional and smart technology related sounds on indoor soundscape perception in residential settings of different cultural groups. The study has three main concerns, current situation of smart houses, the effect of smart devices on indoor soundscape, and cultural differences between Arab and Turkish people in perceiving indoor soundscape of both traditional and smart domestic spaces. Both a method of distinguishing traditional and smart houses and a method to evaluate indoor soundscape were needed. Thus, the study design consisted of solving these two requirements individually before proceeding in answering the research questions.

3.1 OBJECTIVES AND RESEARCH QUESTIONS

The research aims to focus on indoor residential soundscapes. Moreover, the study aims to analyse the effect of smart technology on Arab and Turkish people living in Türkiye in perceiving indoor soundscape and the cultural differences among the two groups. The study has three main questions:

RQ1. What is the current situation of smart houses regarding acoustic conditions?

RQ2. How does smart technology affect residential indoor soundscapes?

RQ3. The following sub-questions discuss the relationship between demographic factors and indoor soundscape perception of houses:

- RQ3.1. Do the cultural differences between Arab and Turkish groups have an influence on the perceived indoor soundscape?
- RQ3.2. Do they get affected by smart technology differently?
- RQ3.3. Do other demographic factors influence the perceived indoor soundscape?

3.2 HYPOTHESIS

The focus of this research is to understand the effect of smart technology on indoor residential soundscapes. The current acoustic condition of smart houses is more chaotic compared to traditional houses since they have increased sound sources. The study has three hypotheses:

RH1. Smart technologies are mostly designed individually and a grid design coordinating all sound sources yet to exist.

RH2. Increasing the number of sound sources in houses will lead to overall less acoustic comfort while being more eventful for users.

RH3. The following sub-hypotheses discuss the relationship between demographic factors and indoor soundscape perception of houses:

- RH3.1. The two cultural groups perceive the indoor soundscape differently.
- RH3.2. Smart technology influences Arab and Turkish residents in a different way.
- RH3.3. Other demographic factors (e.g., education, age, gender, and sensitivity to noise) have an influence on the perceived indoor soundscape.

3.3 DATA COLLECTION METHODS

To answer the first research question, an extensive study of the literature, which most of was published as a book chapter titled: *Indoor Soundscapes of the Future: Listening to Smart Houses,* and an investigating of the smart technology market which was published as a conference paper titled: *An investigation of sound sources in smart houses for improved machine-to-human communication*. Both are original works done by the author and his supervisor and were cited in the literature review section in this thesis. Regarding the second and third research questions, a questionnaire was designed to measure the effect of smart technology on perceived indoor soundscape and the cultural differences among Arab and Turkish people living in Türkiye regarding that perception. The questionnaire is targeting Arab and Turkish people living in Türkiye. Thus, translating the soundscape scale used in the questionnaire will aid participants in understanding it easily. Participants were asked about their native language (English, Turkish, Arabic, or other), to determine the two cultural groups which are the focus of this study. Responses from English or other language natives will not be included in the analysis, rather it is in the questionnaire to eliminate any possible answers from outside of the targeted groups.

To conduct the questionnaire successfully and to achieve the desired study goals both a method to distinguish traditional houses and smart houses and a soundscape scale were required, **Figure 5**. An indoor soundscape scale for residential buildings found in the literature was used in the questionnaire. However, the scale is in English and needs to be translated to Arabic and Turkish languages to make it easier for participants to understand it. Regarding distinguishing smart houses, no measuring scale was found in the literature. Moreover, according to the literature, distinguishing or defining a house's level of smartness precisely isn't an easy task and the transition from traditional house to smart house isn't in a perspicuous way. In result, recording for an indoor residential space were taken using "ZOOM H6 Handy Recorder" to represent a traditional household environment. For the smart environment, the same recording was adapted by adding smart devices' voices to represent the smart house environment in the questionnaire.

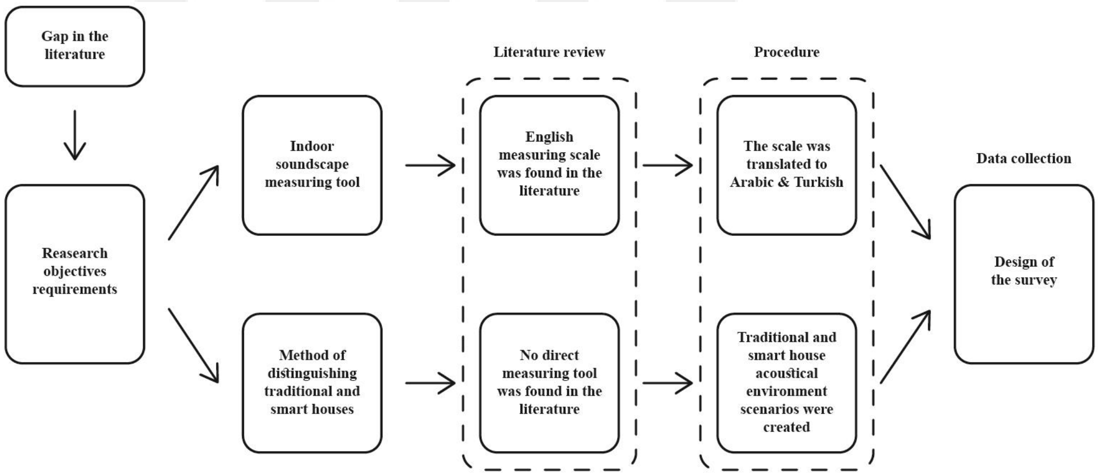

Figure 5: Indoor soundscape evaluation questionnaire design requirements.

3.3.1 Distinguishing Traditional Houses from Smart Houses

Initially, the selected approach was to ask participants about the soundscape of their houses and to measure the effect of smart technology on different groups' perception in that matter. Literature review was made to find a measuring scale to distinguish between traditional and smart houses, no direct measuring tool that can be used in the questionnaire was found. However, literature has some key elements that can be used to create a scale to be used in a questionnaire. For instance, smart sensor system to determine users' existence and activities, smart management system to coordinate the functions around the house according to users' needs, smart control system which consisting of smart speaker with machine-to-human communication system, and smart appliances (e.g., smart refrigerator, smart TV, smart oven) are the conditions for a house to be called smart (Diegel et al. 2005).

Utilizing this knowledge, the author created a house level of smartness measuring scale to be used as questionnaire in the questionnaire. The scale consists of several questions to whether the house of the participant acquire certain smart devices or not, according to the amount of available smart devices in the participant's house, a numerical grade is addressed representing the level of smartness of that house. However, it's not promising to easily find enough number of households that satisfy a high score in the created scale in Türkiye with the available tools of the author. Thus, a completely different approach was used. Participants will be given certain audios representing traditional and smart house indoor acoustic environments which will be designed by the author. Participants will be asked to listen to these audios and rate the acoustic environment of them using the soundscape scale.

At first, the author decided to create the intended audios synthetically using AI sound generating models. AudioBox AI model was used, since it's higher performance compared to baselines (Vyas et al. 2023), to generate the intended acoustic environments audios. Prompt for generating the sounds were written using ChatGPT AI model to get more accurate results, since an AI model will better communicate to an AI model. Yet, the generated sounds did not match an indoor soundscape of a house rather the model can design individual sounds and merging them, noting that the generated sounds have a distinct background noise for each. Thus, the house indoor soundscapes were created using an actual house acoustic environment in Ankara.

Recordings using "ZOOM H6 Handy Recorder" were performed at the author's house. The recordings were performed in the living room of the author's house representing the traditional house acoustic environment. Later, the sounds of smart devices were added to the performed recording to create the smart house acoustic environment. See **Figure 6**.

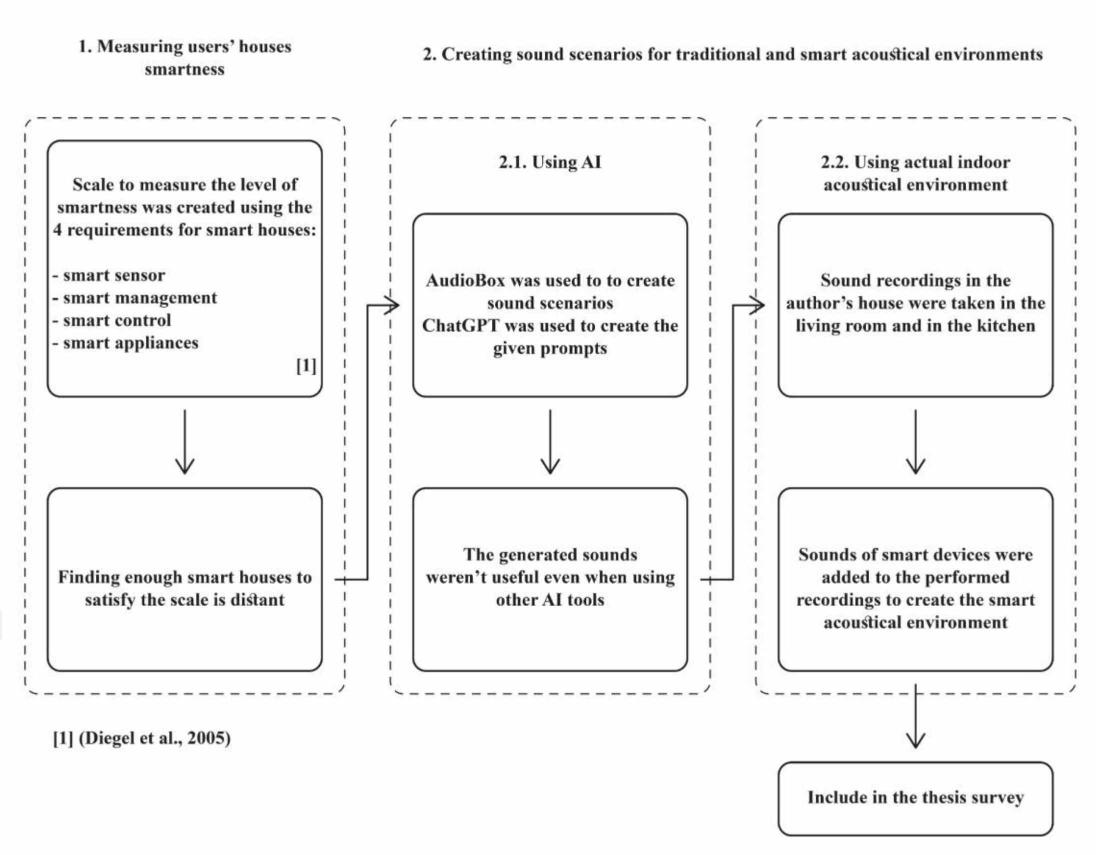

Figure 6: Choosing a method to distinguish traditional and smart houses.

Prior to conducting the recording session, the author prepared a sound sources taxonomy of the indoor spaces of houses regardless of their smartness level. The taxonomy divides the hearable sounds in houses to indoor and outdoor sound sources, each divided to either natural, human, or technological caused sound as shown in **Figure 7**.

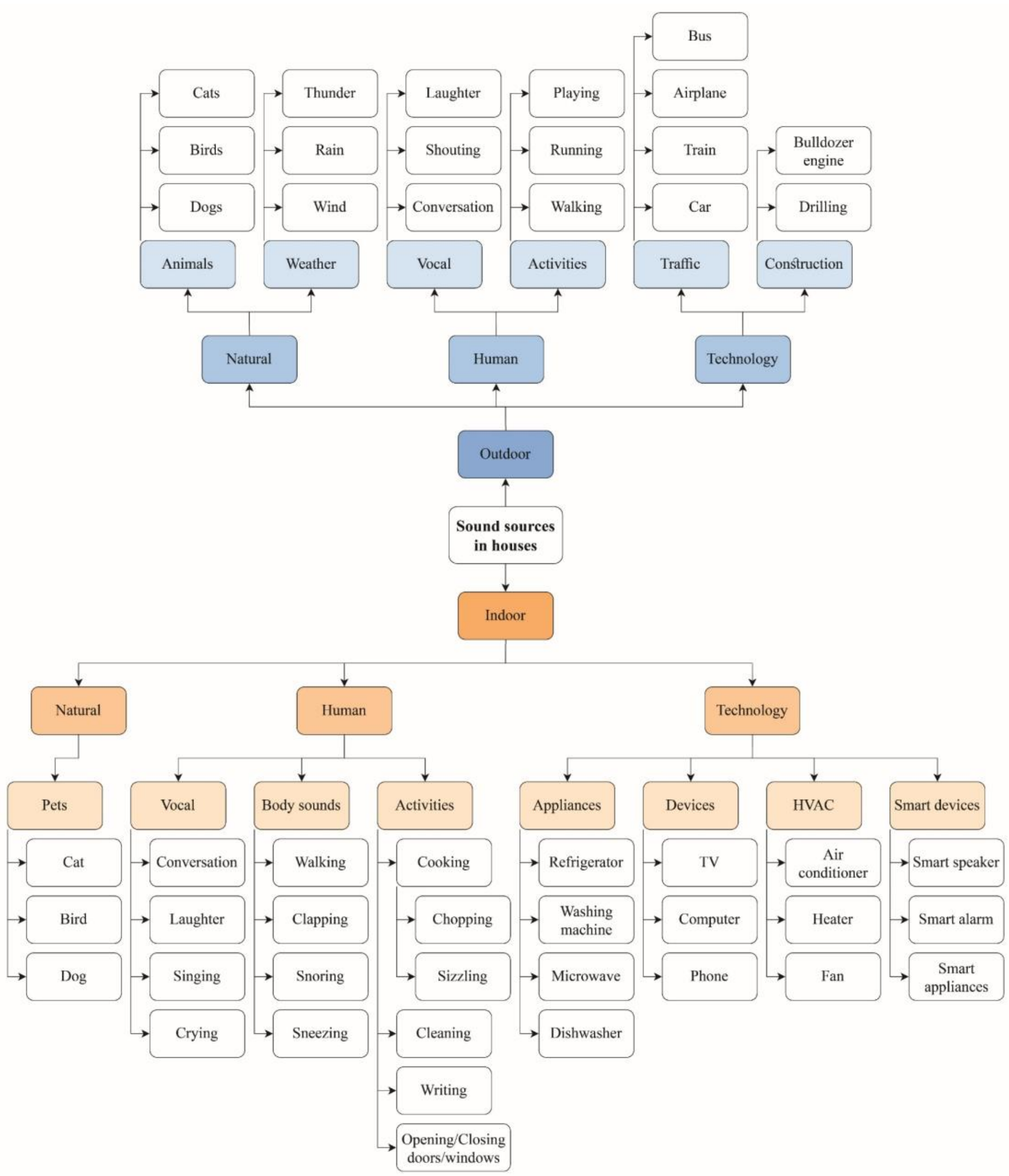

Figure 7: Sound sources taxonomy in houses.

Indoor recording of the living room was conducted using “ZOOM H6 Handy Recorder”, for technical specifications see **Appendix 1**. The device was set in front of the sofa as shown in **Figure 8**. The room window was closed to eliminate the dominance of outdoor noises over the recording. During the recording, the author created sounds mimicking an activity of someone eating at the dining table, receiving a phone notification, standing up, turning off the fan, and leaving the room. The recording session intended to create a scenario of a user sitting in the living room eating their food, receiving a phone message, then turning off the fan while leaving the room. See **Figure 9** for sound sources positions in the traditional house sound scenario.

Figure 8: Recording session of the living room acoustic environment.

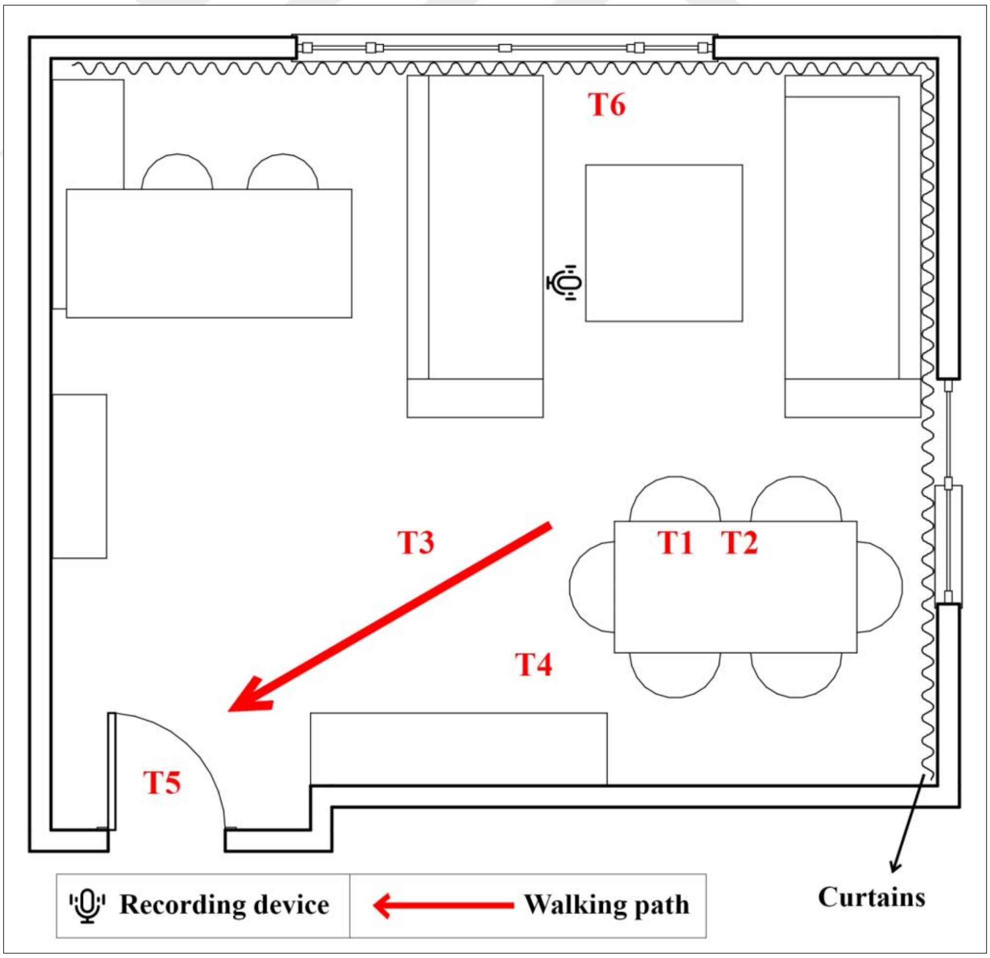

Figure 9: Sound source positions of the traditional house scenario.

Table 1: Typical sounds included in the traditional house scenario.

Sound No	Sound context	Time started/ended (seconds)
Sound T1	Eating (Plate and spoon sounds)	0 – 13
Sound T2	Phone notification	9 – 10
Sound T3	Walking (With home shoes on)	20 – 28
Sound T4	Fan	0 – 22
Sound T5	Door opening and closing	28 – 30
Sound T6	Outdoor noises (Cars and people)	Uncontrolled

Table 1 shows the included typical sounds for creating the traditional house sound scenario and the time during the recording which they start or end, sound source for each one and the microphone positions are shown in **Figure 9**. The recording was then adjusted using Audacity software to increase the overall decibel (dB) by 25 to make it easier to hear. Also, the door closing sound at the end of the recording was reduced to avoid any possible distortion. The resultant audio file was chosen to represent the traditional house acoustic environment.

For the smart house acoustic environment and to make the smartness measuring factor fair, the traditional representing recording was adapted using Audacity software, implementing smart devices' notification voices. The sound files of smart devices were taken from developers' site (Speechcon Reference n.d.; Voice Service n.d.). The used sounds, represented in **Table 2**, intended to create a scenario of a user sitting in their living room eating, a smart assistant waking up S1 and saying "Good afternoon" S2, then the user receives a phone notification which activates a smart notification as well S3, the user which is a girl speaks to the smart assistant commanding it to set all notifications as read S4, the smart assistant wakes up again S1 and replies with confirmation S5, then the user stands up, turns the fan off which activates a smart notification S6 then leaves the room while the smart assistant wakes up S1 and says "Good bye" S7.

In total, there is one traditional living room and one smart living room indoor acoustic environment audios which were used in the thesis questionnaire, see **Appendix 2** for both traditional and smart house scenario audios links.

Table 2: Sounds added to create the smart scenario.

Sound No	Sound context	Time inserted (seconds)
Sound S1	Device wake sound	1.05 + 15.95 + 23.15
Sound S2	Device saying “Good afternoon”	1.7
Sound S3	Notification alarm	8.7
Sound S4	Girl speech commanding Alexa	9.5
Sound S5	Device saying “Alrighty”	16.6
Sound S6	Notification sound of device getting off	22.45
Sound S7	Device saying “Goodbye”	23.8

Concisely, sound recording of a living room in a traditional house was conducted, dB levels were adjusted, and the audio was used to represent the traditional house scenario. Also, external sounds were added to the resultant audio to create the smart house scenario. Then, both scenarios were uploaded to SoundCloud and embedded as links into SurveyMonkey online platform so that the questionnaire participants can hear them without the need of leaving the survey page. Within the survey platform, participants were asked to listen to the audios and rate them while asking them to use headphones, see **Figure 10**.

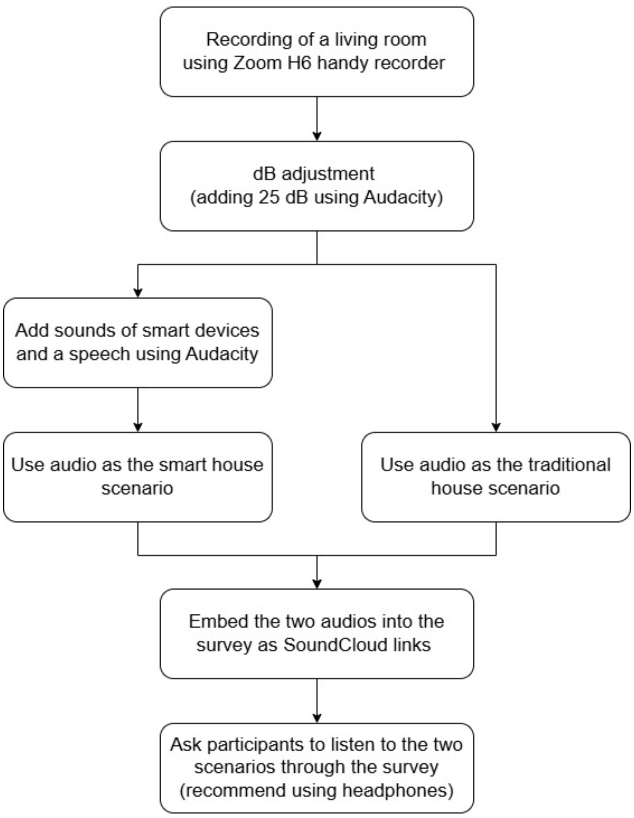

Figure 10: Sound design phase and listening session.

SPL level measurements for the traditional and smart house audios were done using MATLAB software as shown in **Figure 11**, also SPL measurements for the added smart sounds, from **Table 2**, were made as shown in **Figures 12** and **13**, the separation is due to the major time difference in one of the smart sounds. Both SPL measurements used real-time SPL with A-weighting and fast time weighting measuring tool. Furthermore, psychoacoustics measurements were performed using MATLAB software, Loudness shown in **Figure 14**, Sharpness in **Figure 15**, Fluctuation strength in **Figure 16**, and Roughness in **Figure 17**.

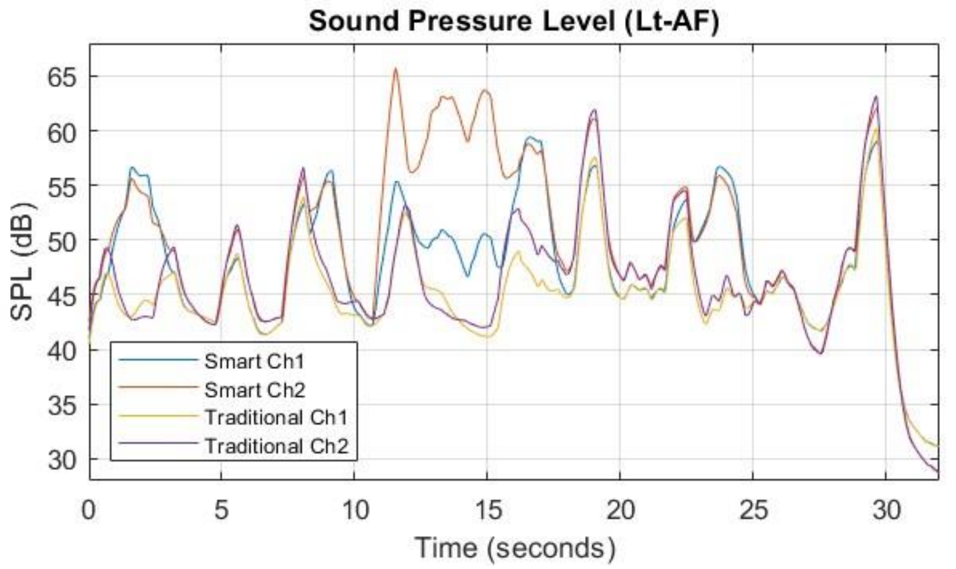

Figure 11: Real-time SPL with A-weighting and fast time weighting measurement for traditional and smart house audios (Smoothing set to 0.3).

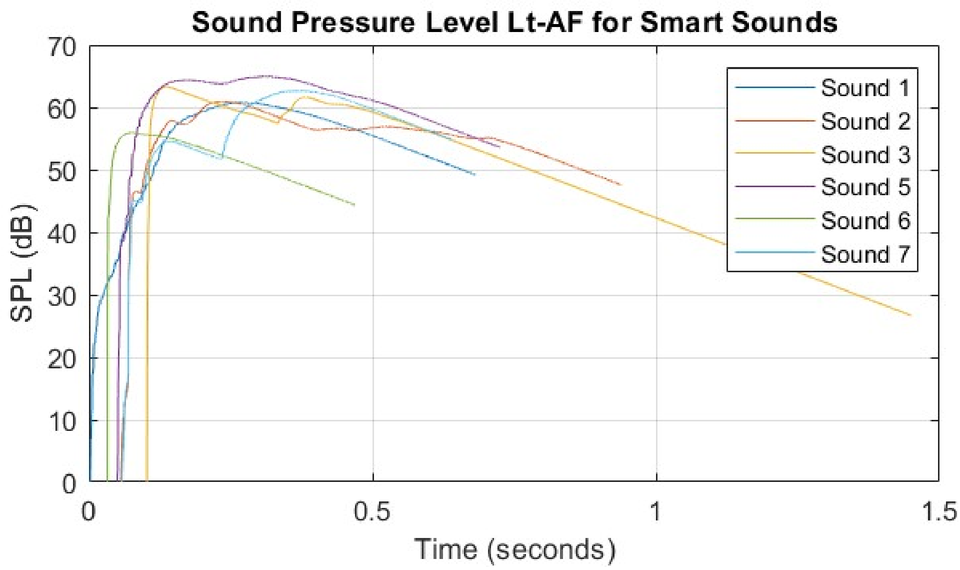

Figure 12: Real-time SPL with A-weighting and fast time weighting measurement for the added short smart sounds, mean measured for stereo (Smoothing set to 0.5).

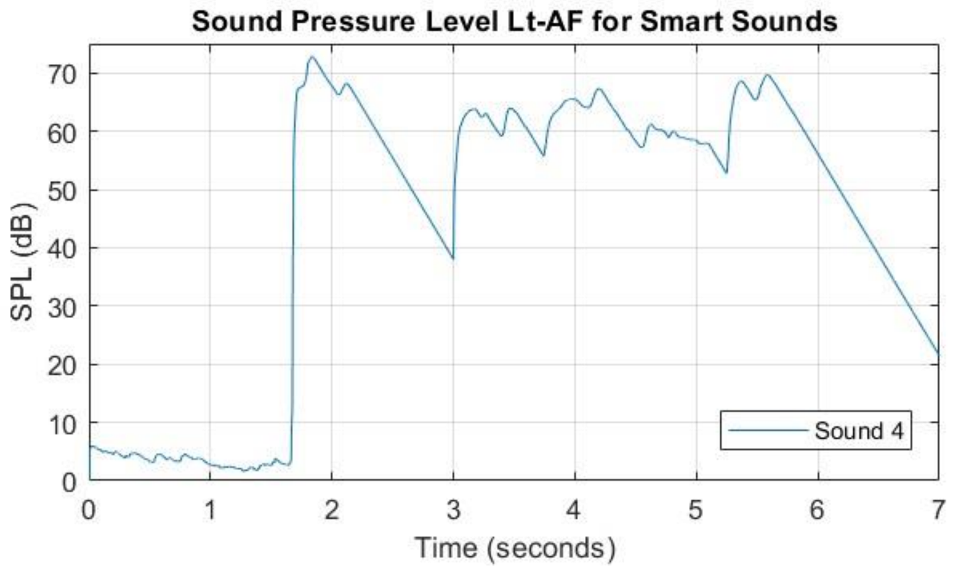

Figure 13: Real-time SPL with A-weighting and fast time weighting measurement for the added long smart sound, mean was measured for stereo (Smoothing set to 0.5).

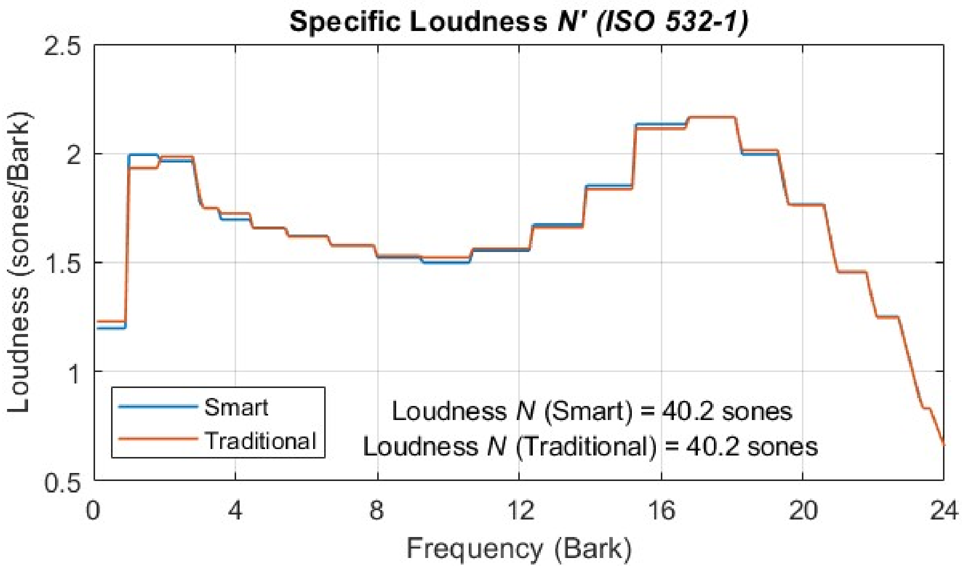

Figure 14: Perceived loudness of acoustic signal.

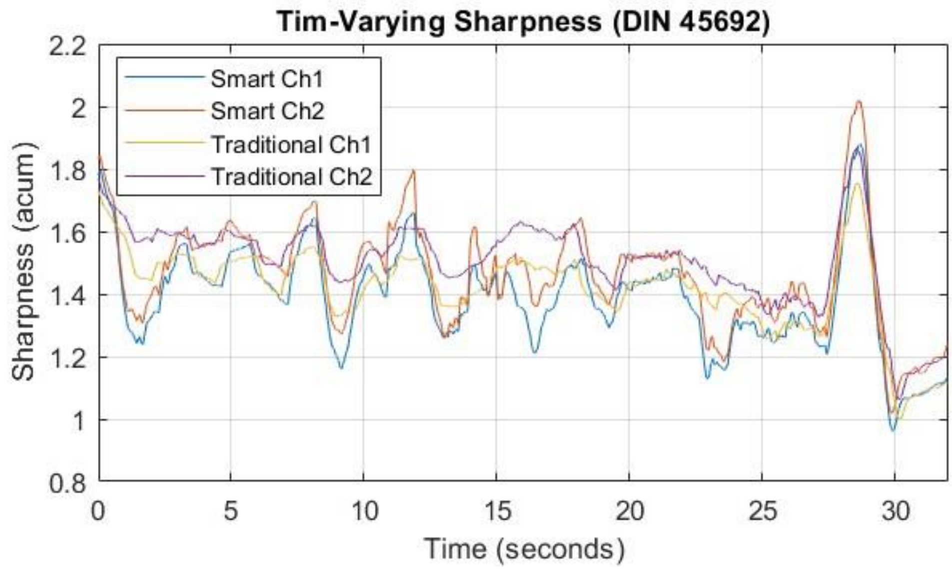

Figure 15: Perceived sharpness of acoustic signal (Smoothing set to 0.7).

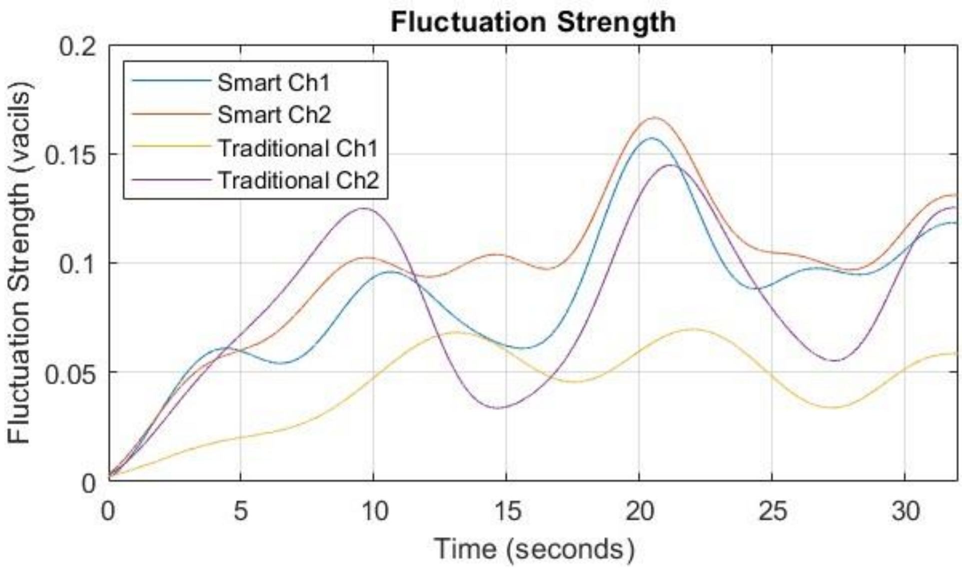

Figure 16: Perceived fluctuation strength of acoustic signal.

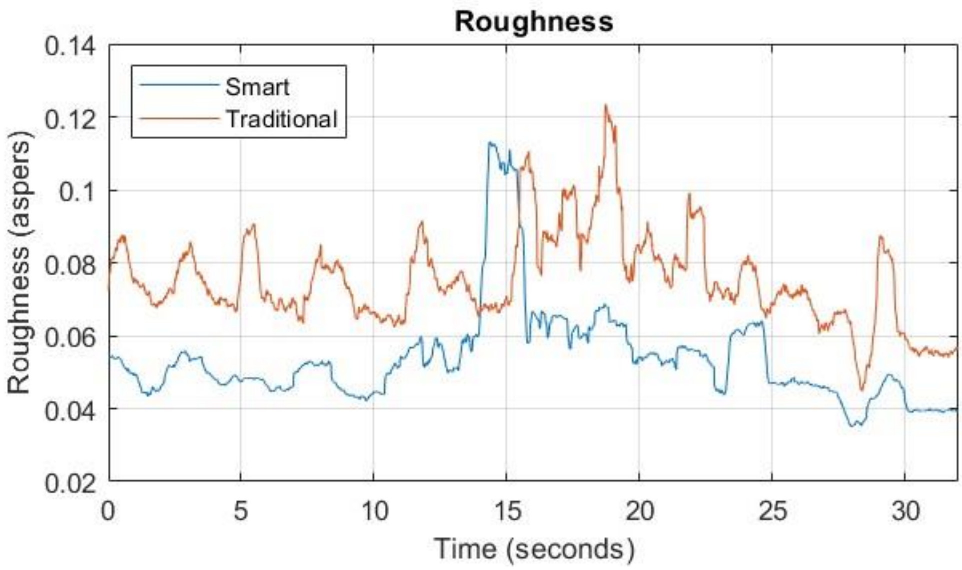

Figure 17: Perceived roughness of acoustic signal (Smoothing set to 0.9).

3.3.2 Translation of the English Indoor Soundscape Attributes

After studying the literature for translation methods, a focus group method for the translation phase and a listening test were used. Establishing a team with the desired language as their native language with good knowledge of English shown in **Figure 18**, see **Appendix 3** for Arabic, **Appendix 4** for Turkish teams' information.

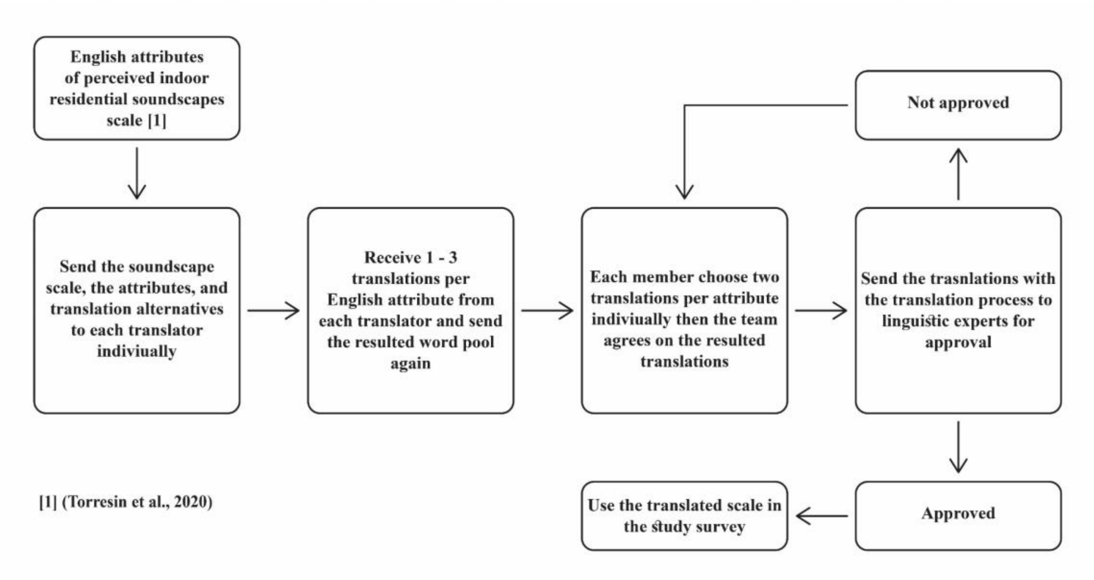

Figure 18: Translation process of the indoor soundscape attributes.

English attributes including an explanation of the two main axes and the function of the sub-axes in the soundscape scale, according to Torresin's paper (Torresin et al. 2020), were prepared by the author in an Excel file and provided to the two translation teams members individually to eliminate any potential mutual influence among team members. Each translator was asked to read the English attributes and provide one to three possible translations for each attribute. Subsequently, translation alternatives were collected while removing any duplications and organized as a word pool in another Excel file. Afterwards, the author created an online communication group gathering team members of an intended language and sent the new file to the chat group. This time, translators were asked to pick one or two translation alternatives from the pool for each English attribute and send the files to the author privately. Then, the author counted the most repeatedly voted translation alternatives and made a new file containing all members' preferences and sent it to the group. Translators had an open discussion on the chat group agreeing or disagreeing on the voting results.

Table 3: English soundscape attributes translation results to Turkish and Arabic.

English attribute	Turkish translation	Arabic translation
Full of Content	Zengin içerikli	غنية بالمحتوى Ghaniya bil-muhtawa
Empty	Boş	خالية Khalia
Comfortable	Rahat	مريحة Muriha
Annoying	Rahatsız edici	مزعجة Muz'ija
Engaging	Etkileşimli	متفاعلة Mutafa'ila
Detached	Bağımsız	منفصلة Munfasila
Private	Özel	خاصة Khassa
Controlled	Kontrollü	مسيطر عليها Musaytar alayha
Intrusive	Araya karışan	تداخلية Tadakhuliya
Uncontrolled	Kontrolsüz	غير مسيطر عليها Ghayr musaytar alayha

Lastly and after getting consent of most translation members, the resulted translation with explanation of the whole translation process and the soundscape scale main function were sent to linguistic expert, whose mother language is the intended language for translation and their profession is English language and literature or English translation, for their approval, see **Table 3**. The mentioned translation process was performed for both the Arabic translation team and the Turkish translation team separately, see **Appendices 5**, **6**, and **7** for Arabic translation process and **Appendices 8**, **9**, and **10** for Turkish translation process.

3.3.3 Questionnaire Design

The indoor residential soundscape questionnaire consists of four sections. The first section ask participants about their mother language (Q1), country of origin (Q2), gender (Q3), age (Q4), education level (Q5), and whether the participant lives in Türkiye (Q6), then participants are asked to identify to what extent they disagree/agree with the following sentences: “I am sensitive to noise” (Q7), “I find it difficult to relax in a place that’s noisy” (Q8), “I get mad at people who make noise that keeps me from falling asleep or getting work done” (Q9), “I get annoyed when my neighbors are noisy” (Q10), “I get used to most noises without much difficulty” (Q11), which are (Q7 to Q11) to represent the noise sensitivity of participants (Torresin et al. 2023).

In the second section of the questionnaire, participants are asked to listen to the traditional house indoor acoustic environment and rate it using the indoor residential soundscape scale; Arabic and Turkish translation of the indoor soundscape attributes which are results of the translation process are given alongside the English attributes (Q12), additionally participants are asked to listen to the smart house indoor acoustic environment and rate it using the same scale (Q13). In both questions, participants were not told which indoor acoustic environment is traditional or smart, nor the purpose of this comparison to eliminate any possible bias.

The third section asks participants whether each indoor soundscape attribute is relatable to be used in sound evaluation or not (Q14).

Finally, the fourth section asks participants to determine whether each English indoor soundscape attribute has a good or bad translation to the participant’s mother language; only Arabic and Turkish translations are given (Q15). See **Appendix 11**.

3.3.4 Data Gathering Protocol

The indoor residential soundscape questionnaire was designed and conducted using a paid version of Survey Monkey online platform. The questionnaire was shared on October 15th, 2024, primarily as a link through online communication students' groups of different universities in Ankara, Türkiye. The link was shared publicly as well with people who are not students while asking all participants to share the questionnaire as well. Afterwards, the data was collected from the survey platform on November 5th, 2024, for the data analysis phase.

3.4 DATA ANALYSIS

Initially, 272 responses were collected on November 5th, 2024. However, irrelevant responses which are out of the study scope and the inefficient responses (e.g., Participants with English or Other as native language, Participants with Turkish as native language but from a country other than Türkiye, participants with Arabic as native language but from a non-Arab country, and participants who only answered the demographical section or part of it and quit) were eliminated. Exclusively, participants with Turkish as a native language who are from Türkiye and participants with Arabic as a native language who are from an Arab country are the focus sample of this study and were included. In result, 75 responses from Turkish group and 95 responses from Arab group were included in the analysis phase. Demographic data of each group was analyzed to represent the distribution of each cultural group. **Figures 19**, **20**, and **21** represent the gender distribution of the participants generally, Arab participants, and Turkish participants.

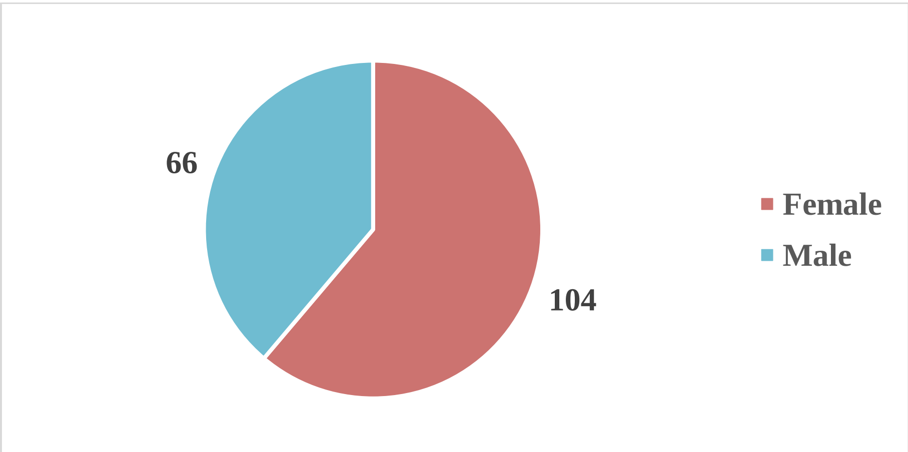

Figure 19: Gender distribution of both cultural groups.

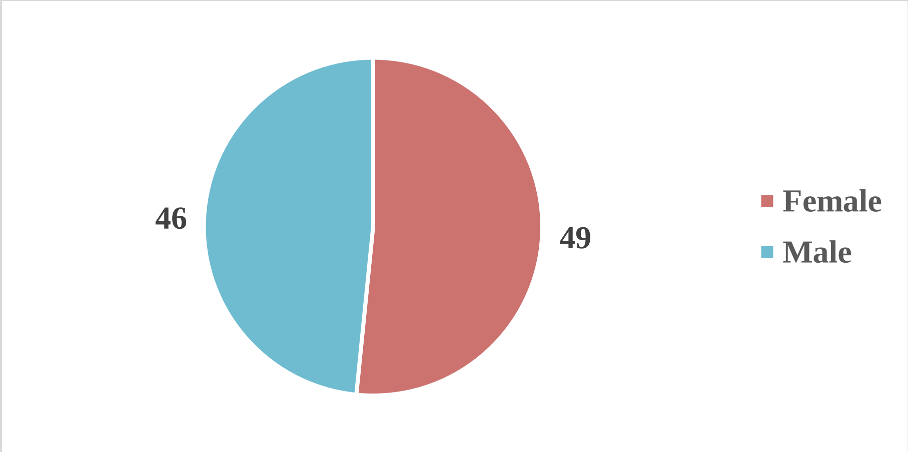

Figure 20: Gender distribution of the Arab participants.

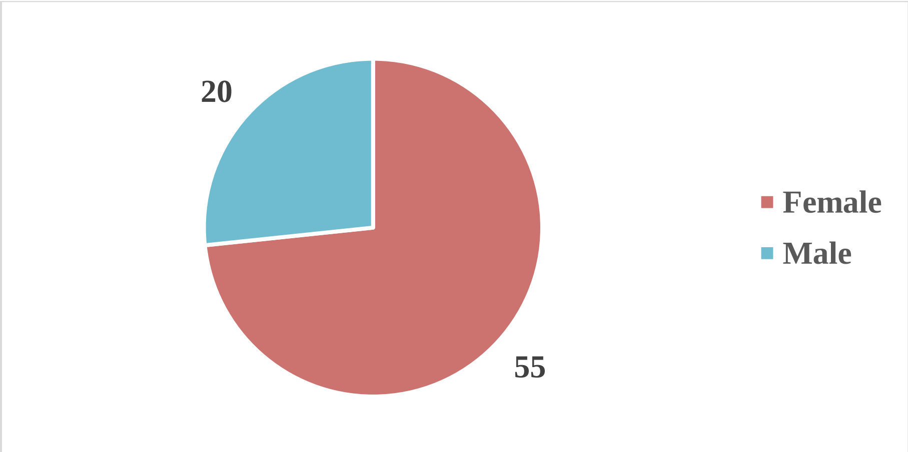

Figure 21: Gender distribution of the Turkish participants.

In both cultural groups (Arab and Turkish) combined, 63.2% of participants were between 18 years old and 24 years old as shown in **Figure 22** and 70% of participants were undergraduate students as shown in **Figure 23**.

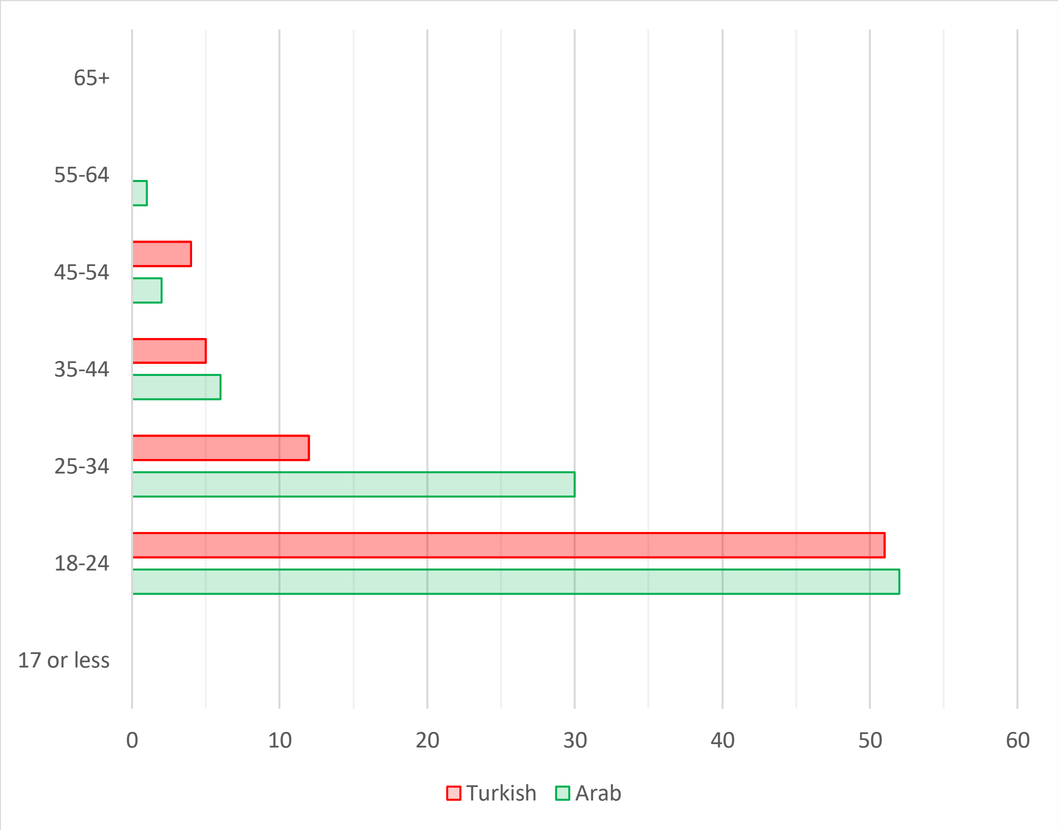

Figure 22: Age distribution of the two cultural groups.

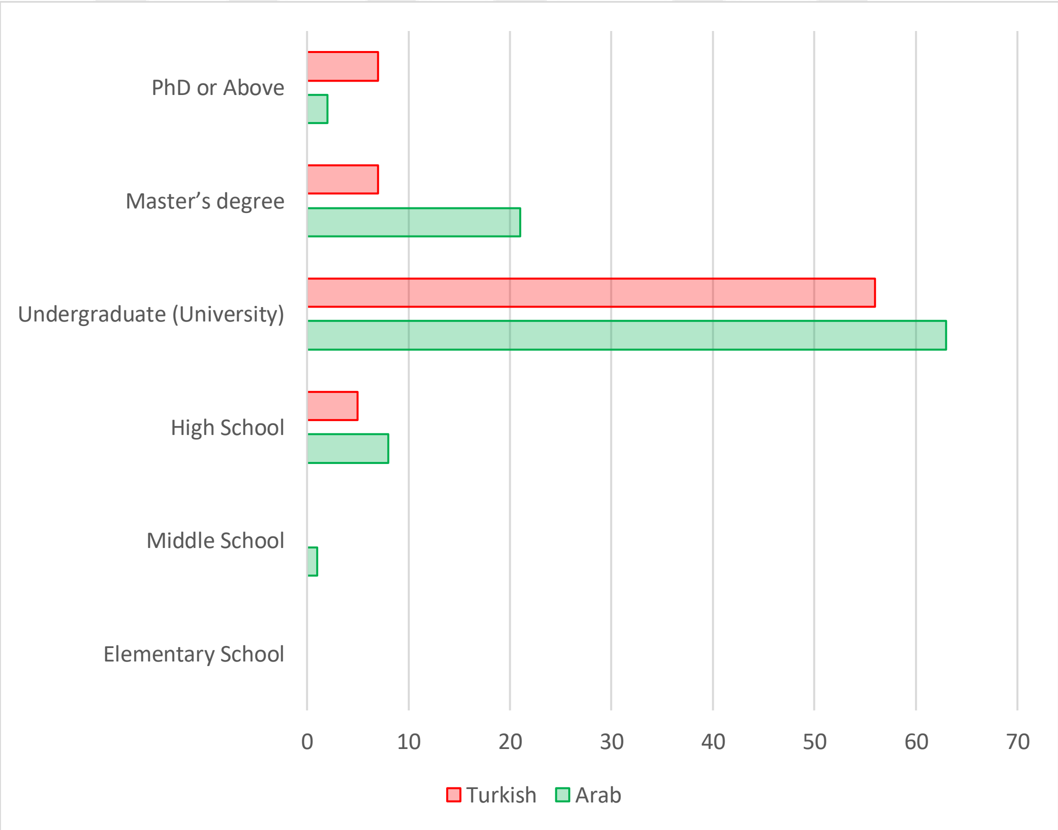

Figure 23: Level of education of the two cultural groups.

CHAPTER IV
RESULTS AND DISCUSSION

The study aim was to investigate the current smart houses situation regarding their acoustic condition, hypothesizing that a grid design of coordinated sound sources yet to exist as a Research Hypothesis 1 (**RH_1**).

Aiming also to measure the effect of embedding smart technology into an indoor space on the perceived soundscape of that space, hypothesizing that process will lead to decreasing acoustic comfort (**$RH_{2.1}$**) and increase eventfulness for users (**$RH_{2.2}$**).

Furthermore, the study aimed to measure the cultural differences between Arab and Turkish people in indoor soundscape perception, hypothesizing that there are significant differences among the two groups (**$RH_{3.1}$**), whether their perception get affected by adding smart technology differently, hypothesizing that the two groups get affected differently (**$RH_{3.2}$**), and the possible influence of other demographical factors (i.e., education, age, gender, and sensitivity to noise) on participants soundscape perception regardless of their native language, hypothesizing that the mentioned factors have an influence on the perceived indoor soundscape (**$RH_{3.3}$**).

Aiming to test (**RH_1**), both extensive study of literature and investigation of the smart houses market were conducted to get an understanding of the current situation of smart houses regarding the acoustic condition. Both previous studies were published as a book chapter titled: *Indoor Soundscapes of the Future: Listening to Smart Houses*, and a conference paper titled: *An investigation of sound sources in smart houses for improved machine-to-human communication*.

The questionnaire conducted is intended to test the remaining (**RH**). The questionnaire asks participants about their educational level, age, gender, noise sensitivity, indoor perceived soundscape of two given sound environments, and their opinion on the used attributes whether they are relatable to describe an indoor sound environment and if each English attribute had a good translation to their native languages (Arabic/Turkish) or not.

The indoor residential soundscape scale is designed by Likert scale; Strongly disagree (1 point), Disagree (2 points), Neither agree nor disagree (3 points), Agree (4 points), Strongly agree (5 points) evaluated for each of the eight indoor soundscape attributes (i.e., Full of Content (f), Empty (em), Comfortable (c), Annoying (a), Engaging (en), Detached (d), Private/Controlled (pc), Intrusive/Uncontrolled (iu)). Participants answered the scale for both the traditional and smart indoor acoustic environment audio scenarios. X and Y coordinates were created for each response using **Equation 1** to calculate the X axis (Comfort axis) and **Equation 2** to calculate the Y axis (Comfort axis). Then, 2-D plane scatter plots were created using the calculated coordinates, where each response is represented as a point in the created scatter plot.

Equation 1: $Comfort = [(c - a) + cos45(pc - iu) + cos45(en - d)]\frac{1}{4+\sqrt{32}}$

Equation 2: $Content = [(f - em) + cos45(iu - pc) + cos45(en - d)]\frac{1}{4+\sqrt{32}}$

4.1 DESCRIPTIVE FINDINGS

The performed investigation and literature study, which are sited in the literature review section of this thesis, show that smart devices are being designed individually rather than a grid design for coordinated acoustic system and smart houses are being designed as a system of devices or singular device to be implemented into a traditional house to make it more smart, which will lead to an unexpected acoustic condition resulting in a less acoustic comfort and worst perceived indoor soundscape. Thus, (**RH_1**) can be accepted.

Transforming from traditional house, **Figure 24**, to smart house, **Figure 25**, had no significant effect on the comfort axis, as shown in **Table 4**, meaning that (**$RH_{2.1}$**) can be rejected. However, the transformation had a significant increase in the content axis, as shown in **Table 5**, meaning that (**$RH_{2.2}$**) is true.

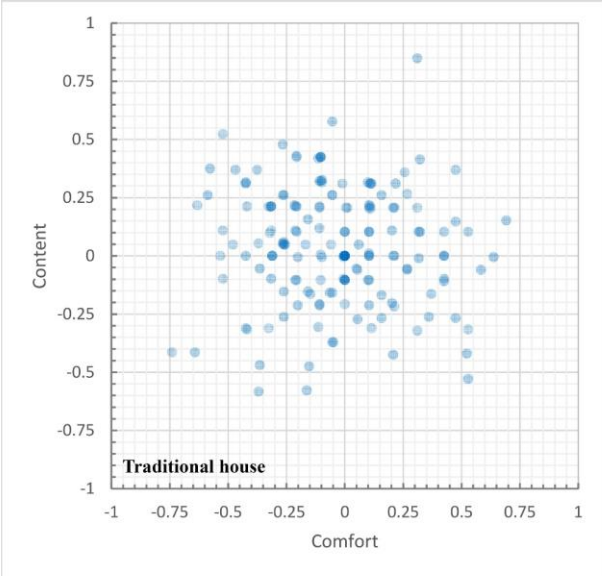

Figure 24: Responses for traditional house acoustic environment.

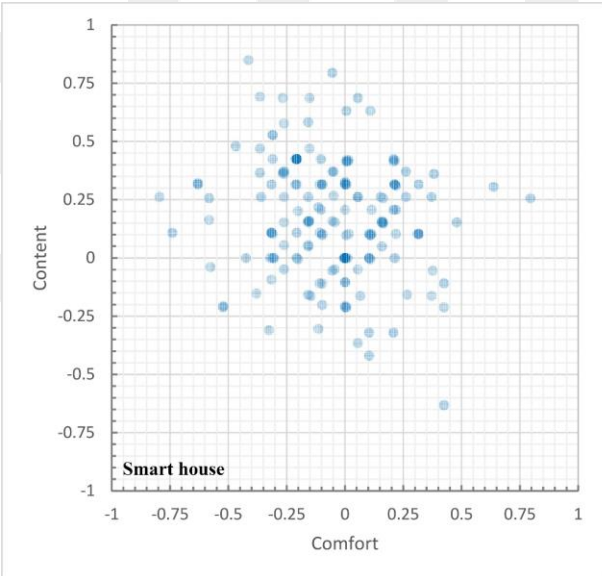

Figure 25: Responses for smart house acoustic environment.

Arab and Turkish responses were compared in both the traditional house case, as shown in **Figure 26**, and smart houses cases, as shown in **Figure 27**. Both cases were statistically analyzed to inspect the cultural differences regarding indoor soundscape. The results in **Tables 6**, **7**, **8**, and **9** show no significant difference in either case. Meaning that (**RH$_{3.1}$**) can be rejected.

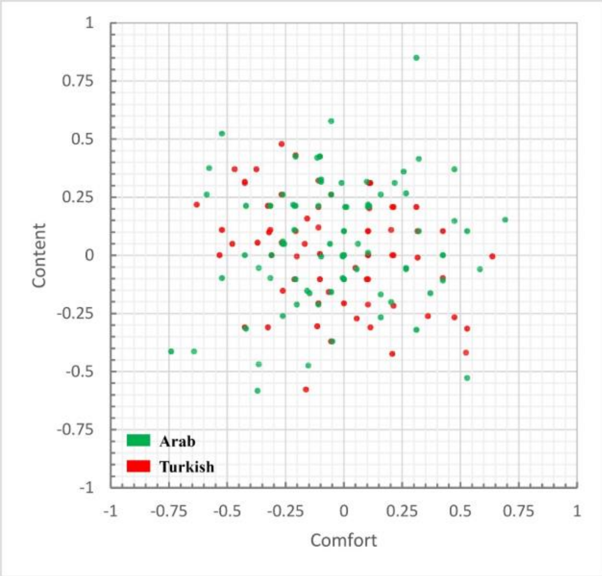

Figure 26: Arab and Turkish responses for the traditional house.

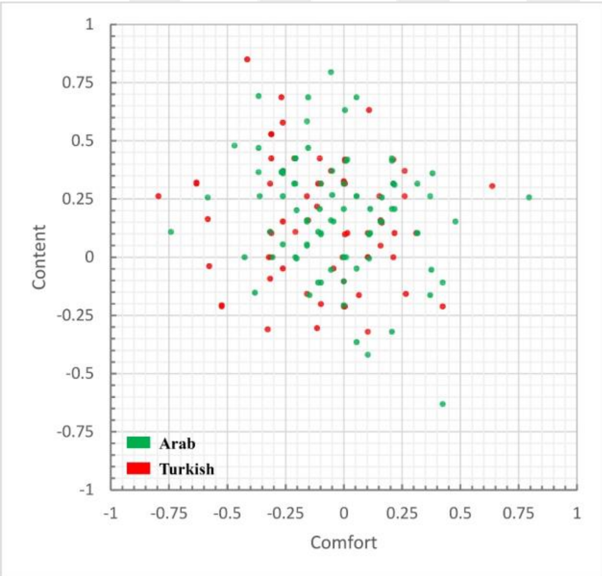

Figure 27: Arab and Turkish responses for the smart house.

Arab and Turkish responses were then analyzed separately to inspect whether transforming to smart house affected each group differently. The results in **Tables 10**, **11**, **12**, and **13** show that regarding the comfort axis both groups showed no significant differences when transforming into smart house, and both groups had significant increase in the content axis. Meaning that (**RH**$_{3.2}$) can be rejected.

The questionnaire asked participants about their education level, age, gender, and noise sensitivity level. These factors were used to inspect a possible effect on the perception of indoor soundscape regardless of participants' native language.

The results in **Tables 14**, **15**, **16**, and **17** show that education level had no influence on the perception of indoor soundscape, except for the content axis in the smart house, where participants with higher education had significantly higher mean values.

The results in **Tables 18**, **19**, **20**, and **21** show that there is no significant difference between low and high age groups in terms of perceived indoor soundscape. The results in **Tables 22**, **23**, **24**, and **25** show that there is no significant difference between female and male groups in terms of perceived indoor soundscape.

Lastly, the results in **Tables 26**, **27**, **28**, and **29** show that participants with high noise sensitivity levels were significantly less comfort mean values in both the traditional and the smart house cases. Also, this group had higher content mean value in the smart house case, while having no significant differences between the two groups for the content axis in the traditional house case. Meaning that (**$RH_{3.3}$**) can be rejected for education level, age, and gender factors while accepting the hypothesis regarding the noise sensitivity as an influence on the perception of indoor soundscape.

The questionnaire asked participants to identify which English attribute is relatable to describe an indoor acoustic environment and which is not in their opinion. For both Arab and Turkish participants' cases, Empty, Detached, and Private attributes had more voting as unrelatable as shown in **Figures 28**, and **29**.

The questionnaire asked participants to identify whether each English attribute has a good translation to their native language or not in their opinion. In both Arab and Turkish participant cases, most votes for all English attributes were good translation as shown in **Figures 30**, and **31**.

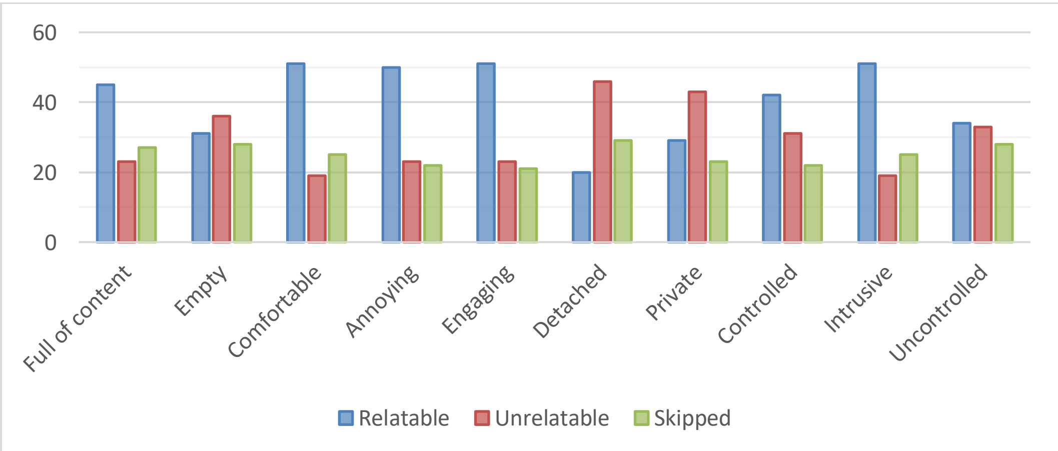

Figure 28: Arab responses on attributes relatability.

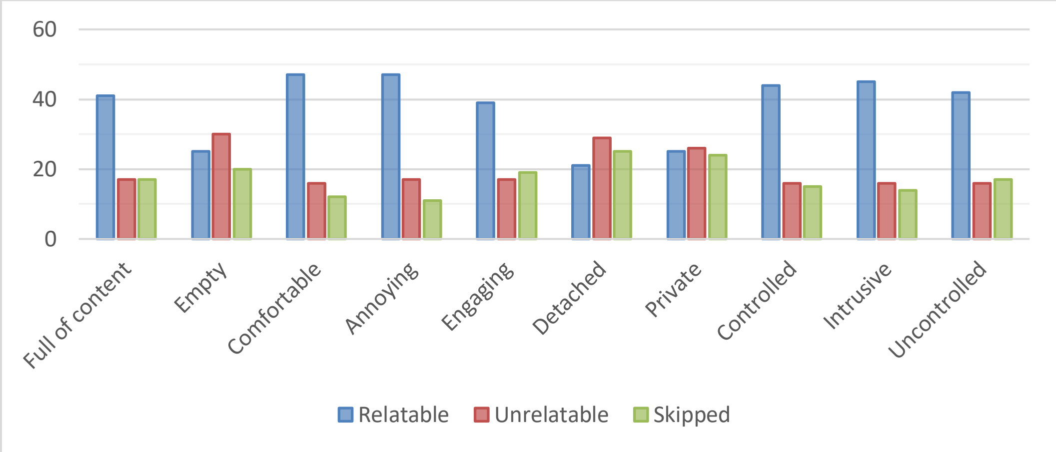

Figure 29: Turkish responses on attributes relatability.

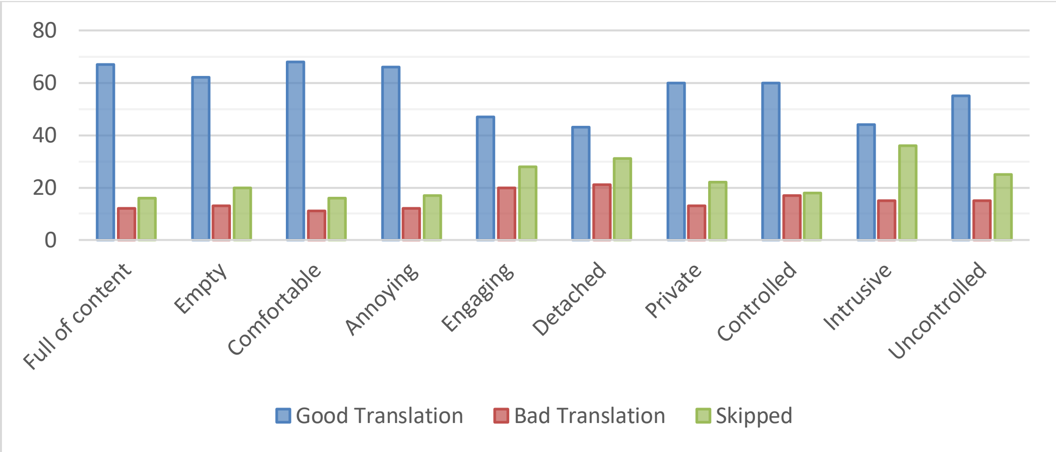

Figure 30: Arab responses on translation quality.

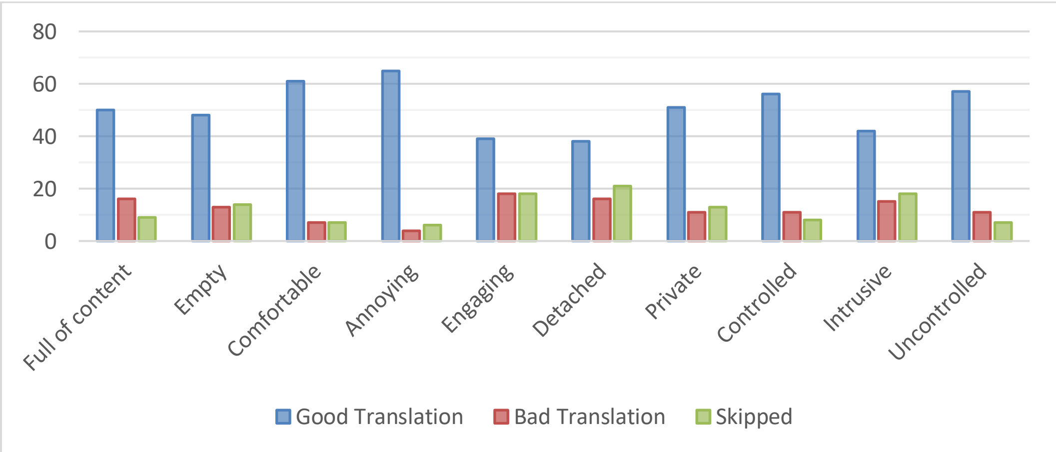

Figure 31: Turkish responses on translation quality.

4.2 STATISTICAL ANALYSIS

The coordinates resulted from the indoor soundscape scale were used as values for statistical analysis. Both X (Comfort) and Y (Content) axis values were treated separately during the analysis phase. Z-test for two sample means statistical analysis method was applied using data analysis tool in Excel software. The null hypothesis statement was that the mean difference between the two tested variables is zero, while the alternative hypothesis suggested that there was a significant difference between the two tested variables.

To test (**$RH_{2.1}$**) and (**$RH_{2.2}$**), comfort axis of values of the traditional house were compared to comfort axis values of the smart house, and content axis values of the traditional house were compared to content axis values of the smart house, without cultural or demographic classifications, the results are presented in **Tables 4** and **5**.

To test (**$RH_{3.1}$**), Arab and Turkish responses of the comfort axis of the traditional house were compared to inspect any possible cultural differences in perceived indoor soundscape. Similarly, Arab and Turkish responses were compared for the content axis of the traditional house, for the comfort axis of the smart house, and for the content axis of the smart house, the results are presented in **Tables 6**, **7**, **8**, and **9**. To test (**$RH_{3.2}$**) and measure whether embedding smart technology affect the two cultural groups' soundscape differently, comfort axis of the traditional and the smart house of Arab responses were compared. Similarly, content axis of the traditional and the smart house of Arab responses, comfort axis of the traditional and the smart house of Turkish responses, and content axis of the traditional and the smart house of Turkish responses were compared, the results are presented in **Tables 10**, **11**, **12**, and **13**.

To test (**$RH_{3.3}$**), responses of each factor were divided into two sections A & B to compare the effect of that factor on indoor soundscape perception, other factors and native language of the respondent were ignored during this process. Level of education of participants was divided into undergraduate or lower (Low) and master's degree or above (High), age was divided into 24 years or lower (Low) and 25 years or older (High), gender was divided into (Female) and (Male), noise sensitivity was divided into 50 scores on the noise sensitivity scale or lower (Low) and more 50 scores (High). Afterwards and for each factor, section A & B of that factor was compared for the comfort axis of the traditional house, the content axis of the traditional house, the comfort axis of the smart house, and the content axis of the smart house. Results for education level analysis are presented in **Tables 14**, **15**, **16**, and **17**. Results for age analysis are presented in **Tables 18**, **19**, **20**, and **21**. Results for gender analysis are presented in **Tables 22**, **23**, **24**, and **25**. Results for noise sensitivity analysis are presented in **Tables 26**, **27**, **28**, and **29**.

4.2.1 Testing Smart Technology Effect

While comparing the traditional and the smart house cases for all responses, no significant mean difference between the two cases was found in the comfort axis, as shown in **Table 4.** While having a significant increase in the content axis, as shown in **Table 5.**

Table 4: Analysis comparing traditional and smart houses (Comfort axis).

	Traditional	*Smart*
Mean	-0.037061189	-0.05777918
Known Variance	0.0798424	0.0653266
Observations	170	170
Hypothesized Mean Difference	0	
z	0.708981917	
P(Z<=z) one-tail	0.239167849	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.478335699	
z Critical two-tail	1.959963985	

Table 5: Analysis comparing traditional and smart houses (Content axis).

	Traditional	*Smart*
Mean	0.039312645	0.170239065
Known Variance	0.0595257	0.0619843
Observations	170	170
Hypothesized Mean Difference	0	
z	-4.897176353	
P(Z<=z) one-tail	4.86118E-07	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	9.72236E-07	
z Critical two-tail	1.959963985	

4.2.2 Testing Cultural Differences Effect

While comparing Arab and Turkish responses in the traditional house case, no significant mean difference was found in the comfort axis, as shown in **Table 6.** Also, no significant mean difference between Arab and Turkish responses in the traditional house case was found in the content axis, as shown in **Table 7.**

Table 6: Analysis of traditional house, comparing Arab and Turkish participants (Comfort axis).

	Arab	*Turkish*
Mean	-0.033218487	-0.041928612
Known Variance	0.0812245	0.0780493
Observations	95	75
Hypothesized Mean Difference	0	
z	-0.200053018	
P(Z<=z) one-tail	0.420719558	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.841439117	
z Critical two-tail	1.959963985	

Table 7: Analysis of traditional house, comparing Arab and Turkish participants (Content axis).

	Arab	*Turkish*
Mean	0.053611982	0.021200151
Known Variance	0.0652612	0.0516736
Observations	95	75
Hypothesized Mean Difference	0	
z	-0.873783011	
P(Z<=z) one-tail	0.191118217	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.382236434	
z Critical two-tail	1.959963985	

While comparing Arab and Turkish responses in the smart house case, no significant mean difference was found in the comfort axis, as shown in **Table 8.** Also, no significant mean difference between Arab and Turkish responses in the smart house case was found in the content axis, as shown in **Table 9.**

Table 8: Analysis of smart house, comparing Arab and Turkish participants (Comfort axis).

	Arab	*Turkish*
Mean	-0.025208354	-0.09903556
Known Variance	0.0601011	0.0688998
Observations	95	75
Hypothesized Mean Difference	0	
z	-1.874422713	
P(Z<=z) one-tail	0.030436093	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.060872185	
z Critical two-tail	1.959963985	

Table 9: Analysis of smart house, comparing Arab and Turkish participants (Content axis).

	Arab	*Turkish*
Mean	0.172681308	0.167145557
Known Variance	0.0607941	0.0634747
Observations	95	75
Hypothesized Mean Difference	0	
z	-0.143591306	
P(Z<=z) one-tail	0.442911603	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.885823206	
z Critical two-tail	1.959963985	

While comparing the traditional and the smart house cases for the Arabic responses, no significant mean difference was found in the comfort axis, as shown in **Table 10.** However, a significant increase in the smart house case was found in the content axis, as shown in **Table 11.**

Table 10: Analysis of Arab participants, comparing traditional and smart houses (Comfort axis).

	Traditional	*Smart*
Mean	-0.033218487	-0.025208354
Known Variance	0.0812245	0.0601011
Observations	95	95
Hypothesized Mean Difference	0	
z	-0.207678294	
P(Z<=z) one-tail	0.417740084	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.835480167	
z Critical two-tail	1.959963985	

Table 11: Analysis of Arab participants, comparing traditional and smart houses (Content axis).

	Traditional	*Smart*
Mean	0.053611982	0.172681308
Known Variance	0.0652612	0.0607941
Observations	95	95
Hypothesized Mean Difference	0	
z	-3.268745778	
P(Z<=z) one-tail	0.000540127	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.001080253	
z Critical two-tail	1.959963985	

While comparing the traditional and the smart house cases for the Turkish responses, no significant mean difference was found in the comfort axis, as shown in **Table 12.** However, a significant increase in the smart house case was found in the content axis, as shown in **Table 13.**

Table 12: Analysis of Turkish participants, comparing traditional and smart houses (Comfort axis).

	Traditional	*Smart*
Mean	-0.041928612	-0.09903556
Known Variance	0.078049	0.0689
Observations	75	75
Hypothesized Mean Difference	0	
z	1.290138289	
P(Z<=z) one-tail	0.098501324	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.197002648	
z Critical two-tail	1.959963985	

Table 13: Analysis of Turkish participants, comparing traditional and smart houses (Content axis).

	Traditional	*Smart*
Mean	0.021200151	0.167145557
Known Variance	0.0516736	0.0634747
Observations	75	75
Hypothesized Mean Difference	0	
z	-3.724708527	
P(Z<=z) one-tail	9.77705E-05	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.000195541	
z Critical two-tail	1.959963985	

4.2.3 Testing Level of Education Effect

While comparing the low education level group (undergraduate or lower) and the high education level group (master's or higher) in the traditional house case, no significant mean difference was found in the comfort axis, as shown in **Table 14.** Also, no significant mean difference was found in the content axis, as shown in **Table 15.**

Table 14: Analysis of traditional house, comparing low (undergraduate or lower) and high (master's or higher) education levels (Comfort axis).

	Low	*High*
Mean	-0.038121846	-0.033248558
Known Variance	0.0755116	0.095391
Observations	133	37
Hypothesized Mean Difference	0	
z	-0.086886073	
P(Z<=z) one-tail	0.465381035	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.93076207	
z Critical two-tail	1.959963985	

Table 15: Analysis of traditional house, comparing low (undergraduate or lower) and high (master's or higher) education levels (Content axis).

	Low	*High*
Mean	0.047425578	0.010149939
Known Variance	0.0591592	0.0597562
Observations	133	37
Hypothesized Mean Difference	0	
z	0.821312646	
P(Z<=z) one-tail	0.205734103	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.411468207	
z Critical two-tail	1.959963985	

While comparing the low education level group (undergraduate or lower) and the high education level group (master's or higher) in the smart house case, no significant mean difference was found in the comfort axis, as shown in **Table 16.** However, a significant increase in the smart house case was found in the content axis, as shown in **Table 17.**

Table 16: Analysis of smart house, comparing low (undergraduate or lower) and high (master's or higher) education levels (Comfort axis).

	Low	*High*
Mean	-0.065840559	-0.028801792
Known Variance	0.0573366	0.0929741
Observations	133	37
Hypothesized Mean Difference	0	
z	-0.682643287	
P(Z<=z) one-tail	0.247416137	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.494832274	
z Critical two-tail	1.959963985	

Table 17: Analysis of smart house, comparing low (undergraduate or lower) and high (master's or higher) education levels (Content axis).

	Low	*High*
Mean	0.145721272	0.258370589
Known Variance	0.0649887	0.0412567
Observations	133	37
Hypothesized Mean Difference	0	
z	-2.812997375	
P(Z<=z) one-tail	0.002454103	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.004908205	
z Critical two-tail	1.959963985	

4.2.4 Testing Age Effect

While comparing the low age group (24 or lower) and the high age group (25 or higher) in the traditional house case, no significant mean difference was found in the comfort axis, as shown in **Table 18.** Also, no significant mean difference was found in the content axis, as shown in **Table 19.**

Table 18: Analysis of traditional house, comparing low (24 or lower) and high (25 or higher) age groups (Comfort axis).

	Low	*High*
Mean	-0.054708355	-0.004708051
Known Variance	0.081911	0.074432
Observations	110	60
Hypothesized Mean Difference	0	
z	-1.122206636	
P(Z<=z) one-tail	0.130887296	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.261774592	
z Critical two-tail	1.959963985	

Table 19: Analysis of traditional house, comparing low (24 or lower) and high (25 or higher) age groups (Content axis).

	Low	*High*
Mean	0.059415328	0.002457726
Known Variance	0.056724	0.062564
Observations	110	60
Hypothesized Mean Difference	0	
z	1.442817431	
P(Z<=z) one-tail	0.074535954	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.149071908	
z Critical two-tail	1.959963985	

While comparing the low age group (24 or lower) and the high age group (25 or higher) in the smart house case, no significant mean difference was found in the comfort axis, as shown in **Table 20.** Also, no significant mean difference was found in the content axis, as shown in **Table 21.**

Table 20: Analysis of smart house, comparing low (24 or lower) and high (25 or higher) age groups (Comfort axis).

	Low	*High*
Mean	-0.072219093	-0.031306006
Known Variance	0.061505	0.071249
Observations	110	60
Hypothesized Mean Difference	0	
z	-0.978955775	
P(Z<=z) one-tail	0.163800916	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.327601832	
z Critical two-tail	1.959963985	

Table 21: Analysis of smart house, comparing low (24 or lower) and high (25 or higher) age groups (Content axis).

	Low	*High*
Mean	0.153167715	0.201536539
Known Variance	0.060953	0.062361
Observations	110	60
Hypothesized Mean Difference	0	
z	-1.211696444	
P(Z<=z) one-tail	0.1128143	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.225628601	
z Critical two-tail	1.959963985	

4.2.5 Testing Gender Effect

While comparing female and male responses in the traditional house case, no significant mean difference was found in the comfort axis, as shown in **Table 22.** Also, no significant mean difference was found in the content axis, as shown in **Table 23.**

Table 22: Analysis of traditional house, comparing female and male gender groups (Comfort axis).

	Female	*Male*
Mean	-0.049747682	-0.017070353
Known Variance	0.07762	0.082691
Observations	104	66
Hypothesized Mean Difference	0	
z	-0.730826146	
P(Z<=z) one-tail	0.232442676	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.464885351	
z Critical two-tail	1.959963985	

Table 23: Analysis of traditional house, comparing female and male gender groups (Content axis).

	Female	*Male*
Mean	0.04316833	0.03323702
Known Variance	0.0637406	0.0528237
Observations	104	66
Hypothesized Mean Difference	0	
z	0.264178284	
P(Z<=z) one-tail	0.395821272	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.791642544	
z Critical two-tail	1.959963985	

While comparing female and male responses in the smart house case, no significant mean difference was found in the comfort axis, as shown in **Table 24.** Also, no significant mean difference was found in the content axis, as shown in **Table 25.**

Table 24: Analysis of smart house, comparing female and male gender groups (Comfort axis).

	Female	*Male*
Mean	-0.082864078	-0.018251462
Known Variance	0.0653796	0.062689
Observations	104	66
Hypothesized Mean Difference	0	
z	-1.626287519	
P(Z<=z) one-tail	0.051944253	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.103888506	
z Critical two-tail	1.959963985	

Table 25: Analysis of smart house, comparing female and male gender groups (Content axis).

	Female	*Male*
Mean	0.183670531	0.149074331
Known Variance	0.0585497	0.0666641
Observations	104	66
Hypothesized Mean Difference	0	
z	0.872285223	
P(Z<=z) one-tail	0.191526399	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.383052797	
z Critical two-tail	1.959963985	

4.2.6 Testing Noise Sensitivity Effect

While comparing the low noise sensitivity level group (50 or lower) and the high noise sensitivity level group (51 or higher) in the traditional house case, a significant decrease for the high noise sensitivity level group was found in the comfort axis, as shown in **Table 26.** However, no significant mean difference was found in the content axis, as shown in **Table 27.**

Table 26: Analysis of traditional house, comparing low and high noise sensitivity groups (Comfort axis).

	Low	*High*
Mean	0.070856131	-0.057437187
Known Variance	0.060984	0.080789
Observations	27	143
Hypothesized Mean Difference	0	
z	2.414351794	
P(Z<=z) one-tail	0.007881617	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.015763234	
z Critical two-tail	1.959963985	

Table 27: Analysis of traditional house, comparing low and high noise sensitivity groups (Content axis).

	Low	*High*
Mean	-0.032697259	0.05290892
Known Variance	0.047522	0.060628
Observations	27	143
Hypothesized Mean Difference	0	
z	-1.831783801	
P(Z<=z) one-tail	0.033491819	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.066983638	
z Critical two-tail	1.959963985	

While comparing the low noise sensitivity level group (50 or lower) and the high noise sensitivity level group (51 or higher) in the smart house case, a significant decrease for the high noise sensitivity level group was found in the comfort axis, as shown in **Table 28.** However, a significant increase for the high noise sensitivity level group was found in the content axis, as shown in **Table 29.**

Table 28: Analysis of smart house, comparing low and high noise sensitivity groups (Comfort axis).

	Low	*High*
Mean	0.057068772	-0.079463759
Known Variance	0.041581	0.066849
Observations	27	143
Hypothesized Mean Difference	0	
z	3.047242398	
P(Z<=z) one-tail	0.001154757	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.002309514	
z Critical two-tail	1.959963985	

Table 29: Analysis of smart house, comparing low and high noise sensitivity groups (Content axis).

	Low	*High*
Mean	0.039785175	0.194870219
Known Variance	0.06498	0.057599
Observations	27	143
Hypothesized Mean Difference	0	
z	-2.925894979	
P(Z<=z) one-tail	0.001717334	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.003434669	
z Critical two-tail	1.959963985	

4.3 DISCUSSION

Studying smart house acoustic condition shows no grid design connecting and coordinating the different smart devices around the house in terms of acoustics. Each smart device is designed without correlating it within a sound source system. This approach leads to an overall more chaotic indoor acoustic environment, resulting in less acoustic comfort and worse soundscape perception for users. Results of the questionnaire conducted in this study showed that embedding smart technology into space did not affect the level of comfort for participants generally, but this process increased the perceived content level for them. Integrating smart technology can lead to a better understanding of the events occurring inside the house with the help of the verbal communication system they are constructed with, making it easier for users to monitor and control the indoor environment of their houses. This advantage can be achieved sometimes without losing much of users' comfortability if the number of sound sources are controlled.

No cultural differences were detected when comparing Arab and Turkish respondents, both groups had similar indoor soundscape perception in traditional and smart house acoustic environment. Furthermore, both groups got affected by smart technology likewise. It can be that the place someone lives in has a bigger influence on their acoustic perception than the cultural background they are coming from. Elghadaffi and Yorukoglu found significant differences between Arab and Turkish residents living in Ankara in terms of perceived soundscape (Elghadaffi and Dökmeci Yörükoğlu 2020). However, in their study 80% of participants were from Libya and Iraq. While in this study, 55% of participants are from Syria and 11% from Palestine. This varying in results can be due to the fact that Levantine people, and Syrians specially, are geographically and culturally close to Turkish people. Specifically, Syrian culture is closer to Turkish culture than it is to another culture from an Arab country in north Africa. For instance, "Buz" is a Turkish word refers to ice, "Buz" is used in some regions in Syria to demonstrate that something is so cold or to refer to ice. Also, "Buza" is used in some Syrian regions to refer to ice-cream. Furthermore, some dishes are common among the two cultures. Thus, treating all Arab cultures as one group can be imprecise due to the diversity among the different Arab countries cultural wise.

Lastly, education, age, and gender had no role in indoor soundscape perception, neither in traditional house nor in smart one. A study conducted by Cao & Kang on companion factors effects on perceived soundscape, the study found that age factor had a great influence on noticing speaking sounds (Cao and Kang 2021). This study showed no relationship between age and the perceived indoor soundscape in residential spaces, this can be since 63% of participants were between the age ranges 18 and 24, and 25% were between 25 and 34 age range. This suggests that an effect of age upon indoor soundscape might be found with a more diverse age range and with a larger sample size.

On the other hand, the level of noise sensitivity had a major role in affecting indoor soundscape perception. Participants with high levels of noise sensitivity had less acoustic comfort perception, and higher perceived content in the smart house case. It can be suggested that people with higher noise sensitivity are more likely to notice and care about every sound event occurring within the indoor space and give more attention to it.

CHAPTER V
CONCLUSION

Residential spaces, especially houses play crucial role in human life, as most of the time is spent inside houses. The acoustic environment has a major impact on users' health and wellbeing as well. Thus, designing the indoor acoustic environment is very important to ensure a better quality of life. This thesis studied the relationship between smart technology within the scope of indoor residential soundscapes. Cultural and demographical differences of the participants are also examined through the indoor residential soundscape questionnaire that was designed and conducted to measure the effect of smart technology on perceived indoor residential soundscapes. The results indicate that:

1. Smart devices are not designed as one sound system, no grid design coordinating all sound sources was found in literature.
2. Transforming into smart house affects the perceived eventfulness for users while not having significant effect on the comfortability for them.
3. Cultural differences among the two targeted groups (Arab and Turkish participants) had no influence on the indoor soundscape perception or the effect of smart technology.
4. Education level, age, and gender had no measurable influence on the perceived indoor soundscape.
5. Noise sensitivity level had a clear effect on participant's responses, suggesting a strong relationship between noise sensitivity and acoustic comfort of users.

Table 30 summarizes the Z-test for two sample means analysis results, showing the mean changes for the latter compared factor in each tested sample.

Table 30: Z-test for two sample means analysis results summary.

Comparison factor	Sample	Comfort axis	Content axis
Traditional vs Smart	All	No	**Increase**
Arab vs Turkish	Traditional house	No	No
	Smart house	No	No
Traditional vs Smart	Arab responses	No	**Increase**
	Turkish responses	No	**Increase**
Education (low vs high)	Traditional house	No	No
	Smart house	No	**Increase**
Age (low vs high)	Traditional house	No	No
	Smart house	No	No
Gender (female vs male)	Traditional house	No	No
	Smart house	No	No
Noise sensitivity (low vs high)	Traditional house	**Decrease**	No
	Smart house	**Decrease**	**Increase**

5.1 FUTURE RESEARCH

This research examined the current smart house trends in the literature, identified the effect of smart technology on indoor soundscape of residential spaces, and cultural differences in perceived traditional and smart acoustic environments among Arab and Turkish people living in Türkiye. Future research can be done on validating the indoor residential soundscape attributes and scale used in this study to achieve a larger number of responses from the two intended groups. Also, future work can be done on improving the indoor soundscape attributes, focusing on identifying simpler attributes to make it easier for participants to understand how the attributes should describe the indoor acoustic environment, leading to more accurate responses. Further research can also involve acoustic measurements and identifying level of smartness in residential spaces. Future research can be done on investigating the relationship between noise sensitivity and indoor soundscape perception. Additionally, cultural differences among different Arab groups regarding indoor soundscape and smart technology perception can also be integrated to the aforementioned future research topics.

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APPENDICES

APPENDIX 1: TECHNICAL SPECIFICATIONS OF THE RECORDER

Recording Media	
SD Card:	16MB to 2GB
SDHC Card:	4GB to 32GB
SDXC Card:	64GB to 1TB
Inputs	
XYH-6 X/Y mic:	Mic type: Unidirectional
	Sensitivity: -41 dB, 1 kHz at 1 Pa
	Input gain: -∞ to 46.5 dB
	Max sound pressure input: 136 dB SPL
XYH-6 MIC/LINE IN:	Connector: 1/8" stereo mini jack
	Input level: - ∞ to 46.5 dB
	Input impedance: 2 k Ω
	Plug-in power: 2.5V supported
MSH-6 MS mic:	Mic types: Unidirectional and bi-directional
	Sensitivity: -37 dB, 1 kHz at 1 Pa (unidirectional)
	-39 dB, 1 kHz at 1 Pa (bi-directional)
	Input gain: -∞ to 42.5 dB
	Max sound pressure input: 120 dB SPL (unidirectional)
	122 dB SPL (bi-directional)
INPUTS 1 to 4:	Connectors: XLR / TRS combo jacks
	(XLR: Pin 2 hot / TRS: Tip hot)
	Input gain: (PAD OFF) -∞ to 55.5 dB
	Input gain: (PAD ON) -∞ to 35.5 dB
	Input impedance: 1.8kΩ or more
	Max input level: +22 dBu (PAD ON)
	Phantom power: +12V /+24V /+48V

	(Phantom power can be turned on/off independently for Inputs 1 - 4)
	Equivalent Input Noise (EIN): -120 dBu or less
Outputs	
LINE OUT:	Jack type: 1/8" stereo mini jack
	Rated Output Level: -10 dBu when output load impedance is 10k Ω or more
PHONE OUT:	Jack type: 1/8" stereo mini jack
	Output Level: 20 mW +20 mW into 32 Ω load
Built-in speaker:	400mw 8 Ω mono speaker
Recording Formats	
WAV:	Sampling frequency: 44.1/48/96 kHz
	Bit rate: 16/24
	(Mono/Stereo, BWF-compliant)
	Maximum simultaneous recording tracks: 8 (L/R + INPUT 1 to 4 + L/R backup)
	(Backup recording: -12dB lower than set L/R input ga
MP3:	Sampling frequency: 44.1kHz
	Bit Rate: 48/56/64/80/96/112/128/160/192/224/256/320kbps
	Maximum simultaneous recording tracks: 2
Display	
LCD Screen:	2.0-inch full color LCD (320 x 240 pixels)
USB	
Mass Storage Class operation:	Class: USB2.0 High Speed
Audio Interface operation: Multi-track mode:	Class: USB2.0 High Speed
	Inputs / Outputs: 6 / 2
	Sampling frequency: 44.1/48kHz/96kHz
	Bit rate: 16/24 bit
	USB bus powered operation possible
Power Requirements	
	AA size (LR6) battery x 4
	Alkaline or NiMH type

	AC adapter: AD-17 (DC5V/1A/USB-type) (optional)
	USB bus power
Battery Life	
	Battery life (with alkaline battery, continuous recording) Over 20 hours
Dimensions and Weight	
	H6: 77.8mm (W) x 152.8mm (D) x 47.8mm (H), 280g
	XYH-6: 78.9mm (W) x 60.2mm (D) x 45.2mm (H), 130g
	MSH-6: 58.0mm (W) x 67.6mm (D) x 42.1mm (H), 85g

APPENDIX 2: HOUSE ACOUSTIC ENVIRONMENT RECORDING FILES

https://drive.google.com/drive/folders/1yT_YdZ2kWL1F1Qo0i9tDrI0P5PG1mekm?usp=sharing

APPENDIX 3: ARABIC TRANSLATION TEAM INFO (PART 1/2)

P	Name	Surname	Institution	Faculty / Department	Field of Study	Position	English Proficiency Proof	EQ. in TOEFL	Role in the team
1	Abduallah	Damash	Middle East Technical University	Electric and Electronic Engineering	Biomedical Engineering	Master's Student	METU EPE (85)	106	Translator
2	Abdullah	Alkan	Çankaya University	Interior Architecture	Acoustics	Master's Student	TOEFL IBT (82)	82	Translator, Coordinator
3	Feras	Alsheikh	UT Austin	Engineering	Petroleum Engineering	Master's Student	TOEFL IBT (113)	113	Translator
4	Hazem	Kholosi	Middle East Technical University	Aerospace Engneering	Control	Master's Student	METU EPE (91.5)	112	Translator
5	Mohamed	Al Husrom	Middle East Technical University	Civil Engneering	Traffic Engineering	Master's Student	METU EPE (80)	102	Translator

APPENDIX 3: ARABIC TRANSLATION TEAM INFO (PART 2/2)

P	Name	Surname	Institution	Faculty / Department	Field of Study	Position	English Proficiency Proof	EQ. in TOEFL	Role in the team
6	Nada	Saber	Çankaya University	Interior Architecture	Environmental psychology	Master's Student	CU EPE (80)	96	Translator
7	Yara	Murad	Çankaya University	Interior Architecture	Way Finding	Master's Student	CU EPE (93)	112	Translator
8	Zinah	Al-bayyar	Çankaya University	Interior Architecture	Acoustics	PhD Student	TOEFL IBT (90)	90	Translator
	Papatya	Dökmeci Yörükoğlu	Çankaya University	Interior Architecture	Acoustics	Assoc. Prof. Dr. Head of Department , Director	YÖKDİL (100)	120	Observer
	Tayseer	Abdulhafed	Atilim University		Eglish language and literature	PhD Student			Linguistic expert

APPENDIX 4: TURKISH TRANSLATION TEAM INFO (PART 1/2)

P	Name	Surname	Institution	Faculty / Department	Field of Study	Position	English Proficiency Proof	EQ. in TOEFL	Role in the team
1	Ayça	ŞENTOP	Norwegian university of science and technology	Faculty of engineering	Acoustics	Postdoc	Yökdil (98.75)	119	Translator
2	Beyza	ERÇAKMAK OSMA	Çankaya University	Interior Architecture	Acoustics	PhD Student	Yökdil (86.25)	104	Translator
3	Konca	ŞAHER	Kadir Has University	Art and Design Faculty	Acoustics	Assoc. Prof. Dr. and Chair at Interior Arch and Env. Design	YDS (88)	106	Translator
4	Merve	ÖZGÜNER	Çankaya University	Interior Architecture	Acoustics	Master's degree graduate	YDS (65)	78	Translator
5	Nilgün	AKBULUT ÇOBAN	Antalya Provincial Directorate of Environment, Urbanization and	Environment Management and Audit	Acoustics	Environmental Engineer /Technical Expert	YDS (92)	110	Translator

APPENDIX 4: TURKISH TRANSLATION TEAM INFO (PART 2/2)

P	Name	Surname	Institution	Faculty / Department	Field of Study	Position	English Proficiency Proof	EQ. in TOEFL	Role in the team
6	Özlem	TÜRKER BAYRAK	Çankaya University	Industrial Engineering	Statistics	Assoc prof	KPDS (84)	101	Translator
7	Papatya Nur	DÖKMECİ YÖRÜKOĞLU	Çankaya University	Interior Architecture	Acoustics	Assoc. Prof. Dr. Head of Department , Director	YÖKDİL (100)	120	Translator
8	Zühre Sü	GÜL	Ted university	Architecture	Acoustics	Assoc prof	Yokdil (98)	118	Translator
	Abdullah	ALKAN	Çankaya University	Interior Architecture	Acoustics	Master's degree student	TOEFL IBT (82)	82	Coordinator, Observer
	Sakibe Nalan	BÜYÜKKANTARCIOĞLU	Çankaya University		English translation and interpreting studies				Linguistic expert

APPENDIX 5: TRANSLATION MATRIX: ARABIC TEAM (PART 1/2)

English Attribute	Translation by:					
	Collins	**Longman**	**Cambridge**	**Chat GPT AI**	**Copilot AI**	**Google translate**
Full of content	مليء بالمحتوى	مليء بالمحتوى	مليء بالمحتوى	مليء بالمحتوى ,متميز بالمحتوى	مليئة بالمحتوى	مليئة بالمحتوى
Empty	أجوف	أجوف	فارغ	فارغ ,خالي	فارغة	فارغ
Comfortable	مريح	مريح	مريح	مريح ,مريحة ,ملائم	مريحة	مريح
Annoying	مزعج	مزعج	مزعج	مزعج ,مزعجة ,متضايق	مزعجة	مزعج
Engaging	جذاب	جذاب	جذاب	جذاب ,مشوق ,مفعم بالحيوية	مشوقة	جذابة

APPENDIX 5: TRANSLATION MATRIX: ARABIC TEAM (PART 2/2)

English Attribute	Translation by:					
	Collins	Longman	Cambridge	Chat GPT AI	Copilot AI	Google translate
Detached	منفصل	منفصل	منفصل	مستقل ,منعزل ,غير متصل ,منغمس	منفصلة	منفصل
Private	خاص	خاص	خاص	خاص ,سري ,خصوصي	خاصة	خاص
Controlled	متحكم فيه	متحكم فيه	متحكم فيه	متحكم فيه ,مسيطر عليه ,منظم	مسيطرة	خاضع للسيطرة
Intrusive	تدخلي	تدخلي	تدخلي	متطفل ,متدخل ,متطفل	متطفلة	تطفلي
Uncontrolled	غير المنضبط	غير منضبط	غير منضبط	غير مسيطر عليه ,غير متحكم فيه ,غير منضبط	غير مسيطرة	غير منضبط

APPENDIX 6: WORD POOL FOR THE ARABIC TRANSLATION

English Attribute	Translation alternatives											
Full of Content	ثرية بالمحتوى	حيوية	ذات محتوى	غنية بالمحتوى	غنية بالمضمون	مفعمة بالحيوية	مليئة المحتوى	مليئة بالأصوات	مليئة بالمحتوى	ممتلئة	ممتلئة بالمحتوى	
Empty	خالية	خالية من الأصوات	خالية من المحتوى	راكدة	فارغة							
Comfortable	باعثة على الراحة	مريحة	مناسبة	مهدئة	وثيرة							
Annoying	ضوضاء	غير مريحة	مزعجة	مضايقة	مقلقة							
Engaging	جذابة	فعالة	متفاعلة	مثيرة للانتباه	مثيرة للاهتمام	محفزة	مدمجة	مشاركة	مشوقة	ملفتة	ملفتة للنظر	ممتعة
Detached	غير مثيرة للانتباه	غير مثيرة للاهتمام	مستقلة	معزولة	مقطوعة	منعزلة	منفصلة					
Private	خاصة	خصوصية	ذاتية	سرية	شخصية	محددة	منفردة					
Controlled	متحكم بها	متحكم فيها	محكمة	مسيطر عليها	مسيطرة	مضبوطة	منسقة	منضبطة	منظمة			
Intrusive	تداخلية	تداخلية	تطفلية	غريبة	غير مرغوبة	غير ملائمة	فضولية	متداخلة	متدخلة	متطفلة		
Uncontrolled	غير متحكم بها	غير متحكم فيها	غير محكمة	غير مسيطر عليها	غير مضبوطة	غير منضبطة	غير منظمة	فوضوية				

APPENDIX 7: VOTING RESULTS OF THE ARABIC TEAM (PART 1/2)

	P1	P2	P3	P4	P5	P6	P7	P8	Most voted	Votes
Full of Content	حيوية	مليئة بالمحتوى	مليئة بالمحتوى	غنية بالمحتوى	ثرية بالمحتوى	مليئة بالاصوات	غنية بالمحتوى	حيوية	غنية بالمحتوى	4
	مفعمة بالحيوية	غنية بالمحتوى	ممتلئة بالمحتوى	غنية بالمضمون	مفعمة بالحيوية	غنية بالمحتوى	مليئة بالمحتوى	مليئة المحتوى	مليئة بالمحتوى	3
Empty	فارغة	خالية	خالية	خالية	خالية	خالية من الاصوات	خالية	خالية	خالية	6
	خالية من الأصوات	خالية من المحتوى	فارغة	فارغة	فارغة	خالية من المحتوى	فارغة	راكدة	فارغة	5
Comfortable	مريحة	مريحة	مريحة	مريحة	مريحة	مريحة	مريحة	مريحة	مريحة	8
	مهدئة	باعثة على الراحة	باعثة على الراحة	مناسبة	مهدئة	باعثة على الراحة	وثيرة	مناسبة	باعثة على الراحة	3
Annoying	مزعجة	مزعجة	مزعجة	مزعجة	مزعجة	غير مريحة	مزعجة	ضوضاء	مزعجة	8
	غير مريحة	غير مريحة	مضايقة	مضايقة	غير مريحة	مزعجة	مضايقة	مزعجة	غير مريحة	4
Engaging	متفاعلة	جذابة	متفاعلة	متفاعلة	جذابة	متفاعلة	جذابة	محفزة	متفاعلة	6
	محفزة	متفاعلة	مثيرة للانتباه	مشاركة	متفاعلة	مثيرة للانتباه	مثيرة للاهتمام	ممتعة	جذابة	3

APPENDIX 7: VOTING RESULTS OF THE ARABIC TEAM (PART 2/2)

	P1	P2	P3	P4	P5	P6	P7	P8	Most voted	Votes
Detached	منعزلة	منعزلة	منفصلة	مستقلة	معزولة	معزولة	غير مثيرة للاهتمام	معزولة	معزولة	6
	منفصلة	منفصلة	معزولة	معزولة	منفصلة	غير مثيرة للانتباه	معزولة	منفصلة	منفصلة	5
Private	خاصة	خاصة	خصوصية	خاصة	خاصة	خاصة	خاصة	محددة	خاصة	7
	شخصية	شخصية	خاصة	سرية	شخصية	شخصية	شخصية	منفردة	شخصية	5
Controlled	مضبوطة	متحكم بها	متحكم بها	متحكم بها	محكمة	منضبطة	متحكم بها	منضبطة	مسيطر عليها	5
	مسيطر عليها	متحكم فيها	مسيطر عليها	مسيطر عليها	منضبطة	مسيطر عليها	مسيطر عليها	منظمة	متحكم بها	4
Intrusive	غير ملائمة	تطفلية	تداخلية	تداخلية	تطفلية	تداخلية	تداخلية	غير ملائمة	تداخلية	6
	متداخلة	تداخلية	تطفلية	تطفلية	تداخلية	غير مرغوبة	تطفلية	متدخلة	تطفلية	5
Uncontrolled	غير متحكم بها	غير متحكم فيها	غير متحكم بها	غير متحكم بها	غير محكمة	غير منضبطة	غير متحكم بها	غير منظمة	غير مسيطر عليها	5
	غير مسيطر عليها	غير منظمة	غير مسيطر عليها	غير مسيطر عليها	غير منضبطة	غير مسيطر عليها	غير مسيطر عليها	فوضوية	غير متحكم بها	4

APPENDIX 8: TRANSLATION MATRIX: TURKISH TEAM (PART 1/2)

English Attribute	Translation by:					
	Collins	Longman	Cambridge	Chat GPT AI	Copilot AI	Google translate
Full of content	İçerik Dolu	İçerik Dolu	İçerik dolu	İçerik dolu, Dolu dolu, Zengin içerikli	Dolu içerik	İçerik Dolu
Empty	Boş	Boş	Boş	Boş, Dolusuz, İçi boş	Boş	Boş
Comfortable	Rahat	Rahat	Rahat	Rahat, Konforlu, Huzurlu	Rahat	Rahat
Annoying	Can sıkıcı	Can sıkıcı	Can sıkıcı	Rahatsız edici, Sıkıcı, Sinir bozucu	Rahatsız edici	Sinir bozucu
Engaging	Ilgi çekici	İlgi çekici	İlgi çekici	İlgili, Etkileyici, Çekici	Çekici	ilgi çekici

APPENDIX 8: TRANSLATION MATRIX: TURKISH TEAM (PART 2/2)

English Attribute	Translation by:					
	Collins	**Longman**	**Cambridge**	**Chat GPT AI**	**Copilot AI**	**Google translate**
Detached	Müstakil	Müstakil	Müstakil	Bağımsız, Kopuk, Ayrı	Bağımsız	Müstakil
Private	Özel	Özel	Özel	Özel, Gizli, Mahrem	Özel	Özel
Controlled	Kontrollü	Kontrollü	Kontrollü	Kontrollü, Denetim altında, İdareli	Kontrollü	Kontrollü
Intrusive	Tacizkar	Müdahaleci	Müdahaleci	Müdahaleci, Sızan, Saldırgan	Müdahaleci	Müdahaleci
Uncontrolled	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz, Denetimsiz, İdare edilemeyen	Kontrolsüz	Kontrolsüz

APPENDIX 9: WORD POOL FOR THE TURKISH TRANSLATION

English Attribute	Translation alternatives										
Full of Content	Anlamlı	Bol içerikli	Cümbüşlü	Dolu dolu	Dolu içerikli	Dolu içerik	İçerikli	İçeriği zengin	İçerik dolu	Mekana özgü seslerle dolu	Zengin	Zengin içerikli
Empty	Anlamsız	Boş	İçeriği boş	Sessiz								
Comfortable	Konforlu	Rahat	Rahatlatıcı									
Annoying	Can sıkıcı	Rahatsız edici	Sinir bozucu									
Engaging	Cezbedici	Çekici	Etkileyici	Etkileşimli	Hoş	İlgi çekici	Merak Uyandıran					
Detached	Alakasız	Ayrık	Bağımsız	Bağlantısız	İzole	Kopuk	Müstakil	Ortamdan Bağımsız	Ortamdan Kopuk	Uyumsuz		
Private	Mahrem	Özel	Özerk									
Controlled	Kontrollü	Kontrol altında										
Intrusive	Araya giren	Araya karışan	Arka Plan Sesleri	Dış Gürültülü	Müdahaleci	Sınır tanımayan	Sınırları aşan	Zorla içeri giren				
Uncontrolled	Kontrolsüz											

APPENDIX 10: VOTING RESULTS OF THE TURKISH TEAM (PART 1/2)

	P1	P2	P3	P4	P5	P6	P7	P8	Most voted	Votes
Full of Content	Zengin içerikli	Dolu dolu	Dolu dolu	Anlamlı	Dolu içerikli	Zengin içerikli	İçeriği zengin	Zengin içerikli	Zengin içerikli	4
		Zengin	Dolu içerikli	Zengin içerikli	Dolu dolu			İçeriği zengin	Dolu dolu	3
Empty	Boş	Anlamsız	Boş	Anlamsız	Boş	Sessiz	Boş	Boş	Boş	6
		Boş	Anlamsız	Sessiz	İçeriği boş				Anlamsız	3
Comfortable	Rahat	Rahat	Rahat	Rahat	Rahat	Rahatlatıcı	Rahat	Konforlu	Rahat	6
		Konforlu		Konforlu	Rahatlatıcı				Konforlu	3
Annoying	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	Rahatsız edici	8
		Can sıkıcı	Sinir bozucu	Sinir bozucu	Can sıkıcı	Sinir bozucu			Sinir bozucu	3
Engaging	Etkileşimli	Çekici	Cezbedici	Cezbedici	İlgi çekici	Cezbedici	İlgi çekici	Etkileşimli	Etkileşimli Cezbedici İlgi çekici	3
		Etkileyici	Etkileşimli	İlgi çekici	Çekici	Etkileyici			Çekici Etkileyici	2

APPENDIX 10: VOTING RESULTS OF THE TURKISH TEAM (PART 2/2)

	P1	P2	P3	P4	P5	P6	P7	P8	Most voted	Votes
Detached	Kopuk	Alakasız	Ayrık	Bağımsız	Ayrık	uyumusz	Alakasız	Kopuk	Alakasız Bağımsız	4
		Ortamdan kopuk	Bağımsız	Alakasız	Bağımsız	alakasız		Ortamdan Bağımsız	Kopuk Ayrık	2
Private	Özerk	Mahrem	Mahrem	Mahrem	Özel	Özel	Özel	Özel	Özel	7
		Özel	Özel	Özel	Mahrem				Mahrem	5
Controlled	Kontrollü	Kontrollü	Kontrollü	Kontrollü	Kontrollü	Kontrollü	Kontrollü	Kontrollü	Kontrollü	8
		Kontrol altında		Kontrol altında	Kontrol altında				Kontrol altında	3
Intrusive	Sınır tanımayan	Müdahaleci	Müdahaleci	Arka Plan Sesleri	Araya karışan	Dış Gürültülü	Araya giren	Araya karışan	Araya karışan	4
		Araya giren	Sınır tanımayan	Araya karışan	Araya giren	Arka Plan Sesleri			Araya giren	3
Uncontrolled	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	Kontrolsüz	8

APPENDIX 11: INDOOR SOUNDSCAPE EVALUATION QUESTIONNAIRE FOR RESIDENTIAL SPACES (PART 1/3)

	Question	**Answers**
1	What is your mother language?	English / Arabic / Turkish / Other (please specify)
2	What is the country of your origin?	List of countries
3	What is your gender?	Female / Male
4	What is your age?	Under 18 / 18-24 / 25-34 / 35-44 / 45-54 / 55-64 / 65 or more
5	What is your education level?	Elementary / Middle School / High School / Undergraduate (University) / Master's degree / PhD or Above
6	Do you live in Türkiye?	Yes / No
Please state to what extent you disagree/agree with the following sentences:		
7	I am sensitive to noise.	0 (Strongly disagree) – 100 (Strongly agree)
8	I find it difficult to relax in a place that's noisy.	0 (Strongly disagree) – 100 (Strongly agree)
9	I get mad at people who make noise that keeps me from falling asleep or getting work done.	0 (Strongly disagree) – 100 (Strongly agree)
10	I get annoyed when my neighbors are noisy.	0 (Strongly disagree) – 100 (Strongly agree)
11	I get used to most noises without much difficulty.	0 (Strongly disagree) – 100 (Strongly agree)

APPENDIX 11: INDOOR SOUNDSCAPE EVALUATION QUESTIONNAIRE FOR RESIDENTIAL SPACES (PART 2/3)

	Question	Answers
Please listen to the following 2 audios and rate them (better to use headphones). There are 8 scales under each audio, to what extent do you agree or disagree that the given living room sound environment in the audio is ... (the 8 scales).		
12	**The sound environment in the audio is...** Q12.1 Full of content/Zengin içerikli/غنية بالمحتوى; Q12.2 Empty/Boş/خالية; Q12.3 Comfortable/Rahat/مريحة; Q12.4 Annoying/Rahatsız edici/مزعجة; Q12.5 Engaging/Etkileşimli/متفاعلة; Q12.6 Detached/Bağımsız/منفصلة; Q12.7 Private, Controlled/Özel, Kontrollü/ خاصة، مسيطر عليها; Q12.8 Intrusive, Uncontrolled/Araya karışan, Kontrolsüz/تداخلية، غير مسيطر عليها;	Strongly disagree (1 point) Disagree (2 points) Neither agree nor disagree (3 points) Agree (4 points) Strongly agree (5 points)
13	**The sound environment in the audio is...** Q13.1 Full of content/Zengin içerikli/غنية بالمحتوى; Q13.2 Empty/Boş/خالية; Q13.3 Comfortable/Rahat/مريحة; Q13.4 Annoying/Rahatsız edici/مزعجة; Q13.5 Engaging/Etkileşimli/متفاعلة; Q13.6 Detached/Bağımsız/منفصلة; Q13.7 Private, Controlled/Özel, Kontrollü/ خاصة، مسيطر عليها; Q13.8 Intrusive, Uncontrolled/Araya karışan, Kontrolsüz/تداخلية، غير مسيطر عليها;	Strongly disagree (1 point) Disagree (2 points) Neither agree nor disagree (3 points) Agree (4 points) Strongly agree (5 points)

APPENDIX 11: INDOOR SOUNDSCAPE EVALUATION QUESTIONNAIRE FOR RESIDENTIAL SPACES (PART 3/3)

	Question	Answers
14	**In your opinion, which words are relatable to sound evaluation? and which are not?** Q14.1 Full of content/Zengin içerikli/غنية بالمحتوى; Q14.2 Empty/Boş/خالية; Q14.3 Comfortable/Rahat/مريحة; Q14.4 Annoying/Rahatsız edici/مزعجة; Q14.5 Engaging/Etkileşimli/متفاعلة; Q14.6 Detached/Bağımsız/منفصلة; Q14.7 Private/Özel/خاصة; Q14.8 Controlled/Kontrollü/مسيطر عليها; Q14.9 Intrusive/Araya karışan/تداخلية; Q14.10 Uncontrolled/Kontrolsüz/غير مسيطر عليها;	Relatable Unrelatable Can't decide
15	**In your opinion, which English words have a good translation to your language, and which don't?** Q15.1 Full of content/Zengin içerikli/غنية بالمحتوى; Q15.2 Empty/Boş/خالية; Q15.3 Comfortable/Rahat/مريحة; Q15.4 Annoying/Rahatsız edici/مزعجة; Q15.5 Engaging/Etkileşimli/متفاعلة; Q15.6 Detached/Bağımsız/منفصلة; Q15.7 Private/Özel/خاصة; Q15.8 Controlled/Kontrollü/مسيطر عليها; Q15.9 Intrusive/Araya karışan/تداخلية; Q15.10 Uncontrolled/Kontrolsüz/غير مسيطر عليها;	Good translation Bad translation Can't decide