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Research Reports

Measuring the Auditory Bubble: How Mobile Music Listening Affects Personal Space

In einer eigenen kleinen Welt: Wie mobiles Musikhören die persönliche Distanzzone beeinflusst

Eva Schurig*[1]

[1] Institute for Music Education Research, Hanover University of Music, Drama and Media, Hanover, Germany.

Abstract

Research on mobile music listening (through headphones while on the move) revealed that people use music to create an imaginary space around themselves that cannot be breached by others. This concept recalls the zone around each person called personal space. Thus, the questions posed in this exploratory study were as follows: How does music listening through headphones influence personal space? Is there a difference between air-conduction and bone-conduction headphones? Thirty people (M_age = 34.6, SD_age = 15.4; 11 male, 19 female) took part in the experiment. They were each approached by either a female or male assistant while listening to self-chosen music and were instructed to ask them to stop at two points: firstly, when an ideal conversation distance had been reached, and secondly, when the assistant should not come any closer. The distances between assistant and participant were measured first without music and then randomly while listening through air-conduction or bone-conduction headphones. Results indicate that listening to music influences personal space: when music was listened to through headphones, the ideal conversation distance was smaller, whereas the second distance measurement was only affected by air-conduction headphones. Apart from music, no other factor was found to influence the size of personal space. The findings of the present study reveal that listening to music and even the kind of headphones used have a measurable influence on personal space. The smaller personal distance required when listening to music can be explained by the fact that the listener is distracted from unpleasant situations and can instead focus on something positive.

Keywords: mobile music listening, headphones, personal space, auditory bubble, bone-conduction headphones, crowdedness

Zusammenfassung

Forschung zum mobilen Musikhören (über Kopfhörer unterwegs) weist darauf hin, dass Personen mit Musik einen imaginären Raum um sich schaffen, in den andere nicht eindringen können. Dieses Konzept erinnert an das der persönlichen Distanzzone, die jeder Mensch um sich hat. Daher sollten in dieser Studie folgende Fragen beantwortet werden: Wie beeinflusst das Musikhören über Kopfhörer die persönliche Distanzzone? Zeigt sich dabei ein Unterschied zwischen verschiedenen Kopfhörerarten? 30 Personen (M_Alter = 34.6, SD = 15.4; 11 männlich, 19 weiblich) nahmen an der exploratorischen Studie teil. Jede von ihnen hörte selbstgewählte Musik während entweder eine weibliche oder männliche Hilfskraft auf sie zukam. Sie sollten diese stoppen, wenn ein idealer Gesprächsabstand erreicht wurde, und nochmal, wenn die Nähe unangenehm wurde. Abstände wurden erst ohne Musik und dann randomisiert mit Knochenleitungs- und Luftleitungskopfhörern gemessen. Im Ergebnis zeigte sich, dass Musikhören die persönliche Distanzzone beeinflusst: wenn Musik über Kopfhörer gehört wurde (egal welche Kopfhörer), dann war der ideale Gesprächsabstand kleiner, während die näheren Abstände nur mit Luftleitungskopfhörern kleiner wurden. Außer der Musik fanden sich keine weiteren Einflussfaktoren auf die persönliche Distanzzone. Die Resultate der Studie weisen darauf hin, dass Musikhören und sogar die Art der Kopfhörer zu einem gewissen Grad die persönliche Distanzzone beeinflussen, was zeigt, dass dies nicht nur auf der Vorstellung der Musikhörer*innen beruht. Dass beim Musikhören weniger Abstand zu anderen benötigt wird, kann u.a. durch die Ablenkung von unangenehmen Situationen und dem Fokus auf positive Eindrücke erklärt werden.

Schlüsselwörter: mobiles Musikhören, Kopfhörer, persönliche Distanzzone, auditory Bubble, Knochenleitungskopfhörer, Gedrängtheit

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Begutachtet von: Mia Kuch; Felix Thiesen.

*Korrespondenzanschrift: Department of Music, Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstraße 69, 26129 Oldenburg, Germany. E-mail: eva.schurig@uni-oldenburg.de

Mobile music listening, defined here as listening to music through headphones while on the move, is ubiquitous and takes place for a range of different reasons (e.g., Greb et al., 2018; Kuch & Wöllner, 2021). One of the reasons listeners engage in this activity is the feeling of space it creates around them. They feel as if they are surrounded by private space even if it is not physically available, for instance in crowded situations. Bull (2005) called this phenomenon the *auditory bubble*. Listeners themselves use the words "my own little world" to describe the experience created through music listening (Schurig, 2019, p. 106), although this refers to more than the physical space around them by suggesting an absence or disembodiment during physical presence (Turkle, 2006, p. 221). While authors have discussed whether or not this bubble is permeable (e.g., Beer, 2012; Prior, 2014) and how this would affect the understanding of research results, the question remains: is this auditory bubble purely subjective or can it be objectively measured?

The auditory bubble is a vague and fuzzy concept that applies to acoustic separation from the environment—which is the perspective most often found in research on mobile music listening (e.g., Bull, 2014; Watson & Drakeford-Allen, 2016)—while it also affects the perception of space. On the one hand, it can change the experience of the environment (e.g., listeners can create "aestheticized spaces," Bull, 2004, p. 177; Weber, 2008); on the other hand, as implied by the definition of the concept provided above, it influences (the perception of) distance to surrounding people.

Within the field of proxemics, academics from different research areas, such as sociology, psychology and anthropology, address the distances people keep to each other and how this affects communication, social interaction in general, and individual well-being (Ferri et al., 2015; Layden et al., 2018; Ruggiero et al., 2017). Holahan (1982) defines *personal space* as "the *zone around an individual into which other persons may not trespass*" (p. 275, emphasis in original). Interestingly, the word "bubble" is also used to describe the effect of personal space on the individual, namely that it creates a "protective 'bubble' around the body" (Hunley & Lourenco, 2018, p. 10). Since listeners report that requirements of space around them are influenced by music, it could be said that the auditory bubble and personal space effectively become synonymous, which implies that measuring personal space during music listening also automatically means measuring the auditory bubble. Thus, this article will first describe personal space and its effects before examining it in the context of music listening. As the present study was carried out during the pandemic, a specific section will address research on personal space during this time.

Theoretical Background

The Concept of Personal Space

Personal space is a well-explored phenomenon that has been the focus of a variety of studies, particularly in the 1960s and 1970s. An invasion of personal space leads to a range of reactions, for instance going away, anger, discomfort (Altman, 1975, p. 88), aggression, excess motor activity (Dean et al., 1976), defensive gestures or change of posture (Sommer, 1969, p. 37), and this reaction can be different for different people. All these responses support the preservation of personal space and therefore help to regulate interactions with other people and to establish a preferred amount of privacy (Altman, 1975, p. 54). They also serve to protect the individual by keeping stress to a minimum (Holahan, 1982, p. 285) but foster communication as well—the closer someone is, the more information is available about them (Holahan, 1982, p. 294).

Hall (1966) defined four different dimensions of personal space: intimate distance (0–18 in. = 0–45 cm), personal distance (1.5–4 ft = 0.45–1.22 m), social distance (4–12 ft = 1.22–3.66 m) and public distance (12–25 ft = 3.66–7.6 m), each of which have different functions and can be found in various social situations. Personal distance, for example, can be observed in conversations between two people, social distance is the distance between two strangers who pass each other in the street, while public distance is the space between a performer and their audience.

There is some dispute about the shape of personal space. Research from the 1970s claims that it is shaped like an hourglass, with less space required at the sides than at the front and back, and less space in front than at the back (Sommer, 1974, p. 205). These results were corroborated by Adams and Zuckerman (1991) who discovered that a person needs more space when someone approaches from the back as opposed to the front. In contrast, more recent studies utilising virtual reality and live experiments found that personal space is round (Hecht et al., 2019). Since a variety of different factors were identified as influences on personal space (as will be discussed below), it is likely that this is the reason the mentioned studies came to different conclusions about the shape of personal space.

While studies from the 1970s and 1980s were concerned with personal space, current studies differentiate between peripersonal and interpersonal space (D'Angelo et al., 2019), where interpersonal space is the equivalent to personal space as defined above, whereas peripersonal space is the space around the body in which potential interactions between the person and the surroundings are perceived and motor action is generated. Other researchers define personal space as part of the peripersonal space—again as the preferred distance for interaction—but peripersonal space is also the defence zone around the body, the space where actions towards the surroundings are coordinated (Hunley & Lourenco, 2018, p. 14). All these definitions have in common that the space surrounding a person—be it peripersonal, interpersonal or personal space—organizes interactions with other people as well as the surroundings. Due to the confusing and contrasting definitions of peripersonal and interpersonal space and ambiguity about whether personal space is part of the former or the latter, the term "personal space" will be used here according to the definition provided by Holahan (1982) above.

Influences on Size of Personal Space

Environmental Factors

The size of personal space is dependent on a range of different influences (for a summary of the presented influential factors, see Figure 1), one of them being the physical environment. White (1975) discovered that less personal space is required in bigger rooms, while small rooms cause a need for more personal space. Leventhal et al. (1978), however,

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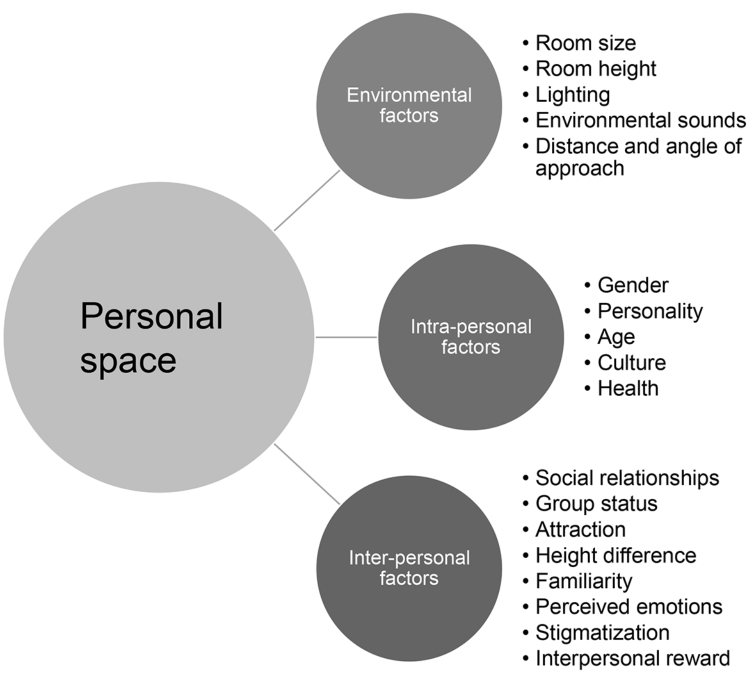
state that room size is not that influential but that it is more important to measure the distance at which someone is approaching, because this could be connected with feelings towards the invader. Conversely, this means that room size is important, because a bigger room allows people to approach from further away. Apart from the distance someone approaches from, the angle of approach is relevant when studying personal space, as well as the general situation, e.g., if it is private or public and the appearance of the physical surroundings (Altman, 1975, p. 66). The height of the room was also found to influence personal space, particularly that higher rooms lead to less required personal space in both men and women (Cochran & Urbanczyk, 1982). Lighting is an additional part of the physical surroundings and if it is low people feel uncomfortable more rapidly when someone approaches (Adams & Zuckerman, 1991). Moreover, the sounds of the environment lead to differing sizes of personal space. Negative sounds in the environment suggest danger and therefore lead to an increase of personal space (Ferri et al., 2015). Ferri et al. therefore suggest that personal space serves as a safe space. This is corroborated by Vagnoni et al. (2018) who discovered that people stay further away from aggressive interactions that do not involve them, thus increasing their personal space, i.e., safety zone in the face of potential danger.

Figure 1

Factors Influencing Size of Personal Space



Note. Summary of influential factors on personal space and examples.

Person-Specific Factors

Apart from the physical environment, person-specific characteristics change the size of personal space: Age, gender and personality all affect personal space (Altman, 1975, p. 66). In a study by Dean et al. (1976) children were asked to approach adults, and the results indicate that age was more important than gender or skin colour with regard to the size of personal space. Other research also found that children need less personal space than adults (Aiello et al., 1981; Holahan, 1982, p. 280).

Regarding gender, men were found to need more personal distance than women (Hecht et al., 2019; Layden et al., 2018), and people of all genders keep further away from an approaching man than from an approaching woman (Krail & Leventhal, 1976, p. 172). These results were confirmed by more recent studies that also discovered that people keep more distance to older individuals (Iachini et al., 2016, 2021). Results of an experiment in a virtual environment showed that the participants of all genders kept further away from a male avatar than a female one but that there was no difference in preferred distances for male and female participants, which might be ascribed to the avatar seeming more gender neutral than intended (Hecht et al., 2019).

The personality of the person being approached also makes a difference in the personal space required. Introverts, for instance, tend to need more personal space than extraverts (Sommer, 1969, p. 30), Heightened anxiousness also leads to a larger personal space (Altman, 1975, p. 72; Iachini et al., 2021), and higher scores in loneliness correlate with a preference for more personal space (Layden et al., 2018).

Additionally, personal space seems to depend on the functioning of certain parts of the brain. Kennedy et al. (2009) examined the personal space of a person with a damaged amygdala and discovered that they did not require any personal space apart from the space that is needed to fully perceive the approaching person. Interestingly, the participant was fully aware that while she did not mind if someone came close to her, this might be different for other people (p. 2).

Inter-Personal Factors

Besides personal characteristics, inter-personal factors influence the size of the required personal space. Indeed, Altman (1975, p. 66) found that social relationships, group status and attraction change the size of the personal space. If people like and understand each other, then less personal space is required (Altman, 1975, p. 80; Layden et al., 2018). In 1982 researchers carried out several studies to test the conversational distance of salespeople in different conditions and observed that a promised interpersonal reward (e.g., expertise, attractiveness, purchasing power) led to a closer conversational distance (Burgoon & Aho, 1982).

Room size and height were mentioned as influential factors above, and next to these, the height of the people involved is also of importance. The height of a person negatively correlates with their need for space, this, however, is only the case if the people involved feel tall or small in comparison to the person approaching. This was discovered in an experiment that provided the illusion of being tall or small (D'Angelo et al., 2019). If both people are of the same height, then there should be no difference in personal space (Hecht et al., 2019)—apart from other factors that could possibly influence the required space.

In a study applying skin-conductance measures, higher levels were measured when an unfamiliar person was approaching (Candini et al., 2021), meaning that knowing the person who is approaching decreases the required personal space. Apart from familiarity, emotions tend to keep people at different distances. If someone appears angry (as opposed to happy or neutral), the other person's personal space is larger (Ruggiero et al., 2017). Here, again, personal space functions as a safe space that keeps potential conflict at bay. In experiments where two people are asked to interact, personal space depends on the conversation style of the approaching person (Burgoon & Aho, 1982). A bigger distance is kept around socially stigmatized people, such as people with visible disabilities or mental illness (Holahan, 1982, p. 294; Martin et al., 2000).

The required or socially acceptable distance between two people is also dependent on culture—in some cultures people tend to be very close to each other in conversations, while people in other cultures tend to keep their distance from each other (Coelho & Stein, 1977; Hall, 1974). Thus, the distances defined by Hall (1966) for the USA might not be as clearly defined for other cultures and might also have changed over time. A more recent, global study by Sorokowska et al. (2017) provides evidence, that intimate, personal and public distances vary significantly across different cultures, and while the personal distances adhere to the definitions by Hall, the intimate and social distances are smaller and larger respectively. Therefore, while the differentiation into different distance zones according to Hall is still relevant today, the specific numbers are not as fixed.

Personal Space During the Pandemic

During the pandemic, governments all over the world called on their citizens to practice social distancing to prevent Covid-19 from spreading. Additionally, people wore masks to prevent contagion. All of these measures could have influenced personal space. Two studies addressed this topic: through an online questionnaire during the pandemic, it was discovered that people wearing masks were allowed to come closer, which shows more trust in the person opposite if they wore a mask (Cartaud et al., 2020). Additionally, people who had already had Covid needed less personal space, which might also be connected to their reduced fear of being re-infected with Covid. This was corroborated by a different study (Iachini et al., 2021), where the authors concluded that personal space depends on the perceived and not the actual risk. They used a scale to measure personal space in an online study with virtual representations of the self and a person opposite and found that this space was reduced when a face mask was worn. Additionally, the authors compared data from before and during the pandemic and discovered, unsurprisingly, that personal space was dramatically larger during Covid than pre-Covid.

Influence of Music on Personal Space

The influence of music on personal space has been the subject of only one study to date (Tajadura-Jiménez et al., 2011). In two experiments (the first with 32 and the second with 38 participants) the researchers measured the influence of different experimenter-chosen music (positive and negative) and different hearing conditions (loudspeakers and headphones) on personal space, including either a female or male experimenter and either the participant or the experimenter approaching the other person. Their results indicate that less personal space is required when participants listen to positive music through headphones, while personal space increases when negative music is played through loudspeakers. The authors explain this through the increased perception of threat when negative music is part of the surroundings, which leads to an increased private space, while “positive emotion signals a safe environment” (p. 5). When the participant was in control (i.e. approaching), then no effect of emotional valence of the music was found, as opposed to the condition where the experimenter approached the participant.

Bone-Conduction Headphones

Bone-conduction headphones are headphones that sit on the jawbone and transmit the sound through the bone directly into the inner ear. As opposed to air-conduction headphones (e.g., in-ear and over-ear headphones) they do not cover the ears but allow the listener to be open to auditory stimuli from the environment (Shokz, 2021). While the listening experience might give the impression that the sound is coming from the environment, it is still subject to the listeners' choice and only audible to them (unless played very loudly).

Aims and Research Question

Qualitative research tends to confirm the existence of an auditory bubble (e.g., Dibben & Haake, 2013; Krause et al., 2015; Schurig, 2019). However, with the exception of Tajadura-Jiménez et al. (2011) there is paucity of work to quantify this bubble. That study used experimenter-chosen music, which may have different effects as compared to music that is listened to according to personal preferences (Cassidy & MacDonald, 2009). Thus, the present study explored the following questions: How does listening to music through headphones influence personal space? Is there a difference between air-conduction and bone-conduction headphones? And are there other factors that impact personal space during mobile music listening?

The auditory bubble comes into existence when people listen to music through headphones (in public). According to research related to mobile music listening—as mentioned above—this auditory bubble leads listeners to mind less if people come closer to them than they would normally accept. Thus, the required personal space shrinks when listening to music (through the auditory bubble). The hypothesis explored in this research was therefore as shown below:

Hypothesis: With music, the required personal space shrinks.

A subsidiary aim of the study was to discover whether there is a difference in the size of personal space when over-ear air-conduction headphones are used as compared to bone-conduction headphones. Bone-conduction headphones have not yet been explored with regard to music listening experiences, so including them in this study proved particularly interesting. Their impact on the personal space of the listener compared to the effect of air-conduction headphones might be in either of two directions.

On the one hand, personal space might decrease with over-ear headphones compared to bone-conduction headphones, since the former cover the ears and therefore prevent the participant from hearing the other person approaching, which in turn would be less stressful and lead to a smaller required personal space. On the other hand, since over-ear headphones cover the ears and block out surrounding sounds, the participant does not have all the information necessary to decide on the size of their personal space. They could feel cut off from their surroundings and hence stop the approaching person more quickly.

Method

Ethical Approval

The study was carried out in accordance with relevant institutional and national guidelines and regulations (Deutsche Gesellschaft für Psychologie, 2022; Hanover University of Music, Drama and Media, 2017) and with the principles outlined in the Declaration of Helsinki. Formal approval of the study by the ethics committee of the Hanover University of Music, Drama and Media was not mandatory, as the study adhered to all required regulations. Informed consent was provided by all participants, and they had the option to cease participating in the study at any time without any negative consequences.

Participants

The experiment was carried out with 30 participants[1] aged 19–71 (M = 34.6; SD = 15.41), 19 female, 11 male and no nonbinary. They had all lived mainly in Germany for the last 3 years. They were recruited through leaflets at the university, public bulletin boards, the author's choir, word of mouth and advertisements in seminars. As the study was exploratory, the aim was to use a convenience sample.

Material

The questionnaire consisted of three parts: questions about the approaching person, a personality questionnaire and demographic questions. First, the participants were asked to indicate their impression of the approaching person on 6-point Likert scales, stating whether they respected them, knew them, and found them likeable or attractive. They then specified whether they knew the approaching person or not. The second part included the Big Five Inventory-SOEP (BFI-S; Schupp & Gerlitz, 2008). Lastly, there were questions about the participants' age, gender, height, and country of residence for the last 3 years. They also had the opportunity to provide additional information that they thought had influenced their behaviour during the experiment.

The over-ear headphones used were Sennheiser HD25 Light and the bone-conduction headphones were OpenMove by AfterShokz (now Shokz). Distances were measured with a Brandson Laser distance meter and music was provided via Spotify on either a laptop or tablet.

Procedure

At the start of the study, each participant was introduced to the procedure, signed the consent form and was told that the aim of the experiment was to discover whether music listening led to sociable behaviour. Thus, they were asked to imagine being in a less-crowded part of a city and being approached by someone who wants to ask for directions[2]. With this in mind, each participant stood in an indicated spot in a room (the room size was either 9.59 m × 6.16 m or 9.57 m × 5.76 m) where all the furniture was moved aside.

Each participant was either approached by a male or a female assistant throughout their participation in the study, since the gender of the approaching person was found to significantly influence the size of personal space (e.g., Altman, 1975, p. 75). The assistant approached slowly and straight on from about 4.6 metres away and the participant indicated when the ideal distance for a conversation with a stranger was reached (i.e., a social distance according to Hall, 1966, pp. 121–123). Then the distance was measured between the feet of the participant and the assistant. Subsequently, the approaching person came even closer very slowly and the participant had to indicate when they started to feel uncomfortable (i.e., the threshold to intimate distance according to Hall, 1966, p. 120). Here the distance was measured again. A stop-distance task was preferred to an approach-distance task because mobile music listening would normally take place in public places where the listener would have limited control over their personal space in crowded surroundings.

Each participant was approached under three different conditions, the first always being without music, so that measure could be used as a baseline for comparison. The other two conditions were listening to music over either bone-conduction or air-conduction (i.e., over-ear) headphones—these conditions were randomised so that each participant experienced both kinds of headphones (see Figure 2). The participants chose their music from Spotify and made sure

1) The number of participants was predetermined through G*Power (V3.1.9.6) with a large effect size of $d_Z = 0.5$, power of $1-\beta = .80$, and an α error of 0.05, and then rounded up.

2) The cover story was adapted from that of Hecht et al. (2019), which they used for one of their experiments. The cover story itself was received via personal correspondence. As opposed to Hecht et al.'s studies where participants were the ones asking for directions, in the present study, the approaching person was imagined to do the asking.

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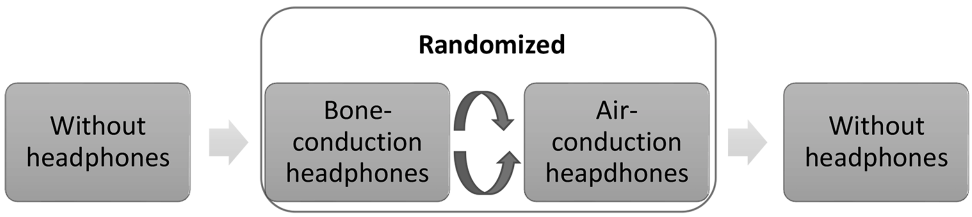
that the volume levels were comfortable. Each condition included three approaches by the assistant and at the end there was another measurement without music. A video camera was set up to record the behaviour of the participant while being approached.

Figure 2

Order of Conditions Presented to Each Participant



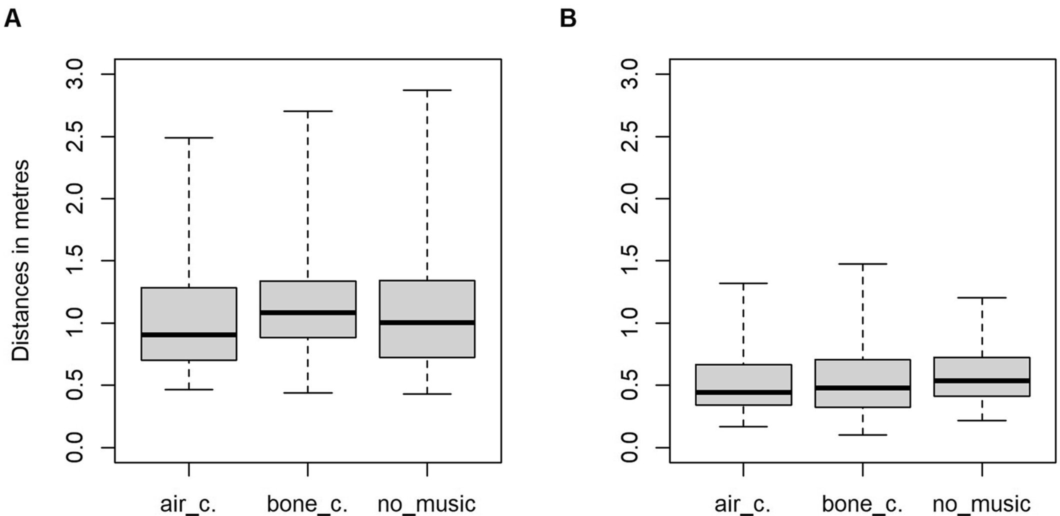
Following the experiment, the participants were asked to complete the questionnaire and then told about the actual purpose of the study. Because this purpose was very difficult to conceal, none of the participants were particularly surprised that the aim was to discover connections between music listening and personal space. Since the study was carried out during the pandemic, all the people involved used at-home Covid tests before the experiment, and the experimenter and assistant wore masks at all times. The participants were asked not to wear masks in order to observe possible (facial) reactions.

Results

The first step was to calculate means from the three measurements for each of the conditions, that is, one for no music, one for bone-conduction headphones and one for air-conduction headphones. These provided the basis for further calculations. To test the hypothesis, comparisons were made between the distances kept under the different conditions. Since the data were not normally distributed and a within-participants design was used to compare (non-)headphone conditions, Friedman Tests (rstatix package in R; Kassambara, 2023) were calculated. They indicated significant differences, $\chi^2(2) = 22.504$, $p < .001$, Kendall's $W = 0.375$, for the conversation distance (from now on called talk distance) as well as the line between personal and intimate distance (henceforth called inner distance), $\chi^2(2) = 20.467$, $p < .001$, Kendall's $W = 0.341$. Post-hoc-tests (Bonferroni-Dunn) showed no difference between the music conditions, but significant differences ($p < .001$) between air-conduction ($M = 1.04$ m, $SD = 0.47$ m) and no music ($M = 1.26$ m, $SD = 0.59$ m) as well as bone-conduction ($M = 1.13$ m, $SD = 0.56$ m) and no music ($p = .049$) for the talk distance. For the inner distance there was no longer a difference ($p = .085$) between bone-conduction ($M = 0.55$ m, $SD = 0.30$ m) and no music ($M = 0.61$ m, $SD = 0.28$ m), but air-conduction ($M = 0.51$ m, $SD = 0.26$ m) and no music varied significantly ($p < .001$; see also Figure 3 for boxplots of the comparisons). Therefore, the hypothesis was confirmed because there were always differences between music and non-music conditions. In answer to the subsidiary question, the air-conduction headphones always led to a significantly smaller personal space, while bone-conduction headphones only led to a significant decrease of personal space during the talk and not the inner distance in contrast to no music. Comparing both headphones did not show a significant difference of required personal space between the two headphone conditions.

Figure 3

Comparison of Talk and Inner Distances



Note. Panel A: Boxplots of talk distances. Panel B: Boxplots of inner distances. Bone-c. = bone-conduction headphones; air-c. = air-conduction headphones. Whiskers represent the range of data.
*$p < .05$. **$p < .01$. ***$p < .001$.

To test whether there was an order effect, the measures without headphones at the beginning and at the end were compared. A Wilcoxon signed-rank test showed no difference between talk distances before (*Mdn* = 1.13) and after (*Mdn* = 1.10), $T = 131$, $p = .101$, $r = -0.22$; nor between the inner distances before (*Mdn* = 0.55) and after (*Mdn* = 0.52), $T = 208$, $p = .909$, $r = 0.015$. An effect of presenting the condition without headphones first can therefore be excluded.

Other Influencing Factors

The research also aimed to discover possible influences on personal space during music listening. One of these influences in question was the gender of the assistant. Due to the between-participants design regarding the gender of the assistant (one participant was only approached by one assistant) and the non-normally distributed data, Mann-Whitney-U-Tests were carried out. The calculations revealed no significant differences in the distances (both talk distance and inner distance) kept from the male ($n = 21$) and the female assistant ($n = 9$; see Table 1).

Similarly, Mann-Whitney-U-tests were calculated to detect influences of familiarity with the assistant, that is, whether the participant knew the assistant or not. Again, no difference was found in talk and inner distances between those who knew the assistant ($n = 10$) and those who did not ($n = 20$; see Table 2).

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Table 1

Effect of Assistant's Gender

	Male		Female			
Variable	***M***	***SD***	***M***	***SD***	***p***	***W***
Talk bone-c.	1.129	0.63	1.139	0.39	.42	76
Talk air-c.	0.099	0.49	1.127	0.44	.35	73
Talk no music	1.204	0.62	1.375	0.52	.21	66
Inner bone-c.	0.559	0.35	0.539	0.15	.54	81
Inner air-c.	0.512	0.29	0.499	0.15	.59	82
Inner no music	0.601	0.32	0.624	0.21	.66	84

Note. Differences in distances (in metres) kept from male and female assistant calculated with Mann-Whitney-U-Test. The critical *p*-value after Bonferroni adjustments for multiple comparisons was .0083. Bone-c. = bone-conduction headphones; air-c. = air-conduction headphones.

Table 2

Effect of Knowing Assistant

	Unknown		Known			
Variable	***M***	***SD***	***M***	***SD***	***p***	***W***
Talk bone-c.	1.201	0.61	0.982	0.44	.29	125
Talk air-c.	1.061	0.48	0.989	0.49	.53	115
Talk no music	1.301	0.58	1.163	0.62	.45	118
Inner bone-c.	0.579	0.34	0.501	0.20	.72	108
Inner air-c.	0.520	0.29	0.485	0.18	.93	102
Inner no music	0.623	0.31	0.578	0.25	.95	102

Note. Differences in distances (in metres) kept from assistants depending on familiarity. Calculated with Mann-Whitney-U-test. The critical p-value after Bonferroni adjustments for multiple comparisons was .0083. Bone-c. = bone-conduction headphones; air-c. = air-conduction headphones.

Other possible influencing factors, such as assistant attributes, i.e. attractiveness, liking and respect, personality, age, and height differences between participant and assistant were computed with correlations (Spearman) and displayed in Table 3. Similarly, Mann-Whitney-U-tests were calculated to compare distances between male and female participants, with *W*-values ranging from 84 to 101 and *p*-values from .39 to .89. None of the factors were found to influence either talk or inner distances.

Table 3

Correlation Matrix With Other Factors

Variable	Attractiveness	Liking	Respect	Age	Conscientiousness	Extraversion	Openness	Agreeableness	Neuroticism	Height difference
Talk bone-c.										
ρ	.165	−.091	−.164	−.085	−.140	−.104	−.275	−.015	−.074	.071
p-value	.39	.63	.39	.65	.46	.58	.14	.94	.69	.71
Talk no music										
ρ	.207	−.179	−.144	−.071	−.028	−.059	−.225	−.017	.063	.18
p-value	.27	.35	.45	.71	.88	.76	.23	.93	.74	.25
Talk air-c.										
ρ	.244	−.123	−.036	−.011	−.044	−.072	−.247	−.008	−.036	.57
p-value	.19	.52	.85	.96	.82	.71	.19	.97	.85	.41
Inner no music										
ρ	.130	−.201	−.103	.050	−.157	−.036	.007	−.035	.091	.115
p-value	.49	.29	.59	.79	.41	.85	.97	.86	.63	.55
Inner bone-c.										
ρ	.218	−.113	−.046	.066	−.314	−.006	−.053	−.030	.041	.060
p-value	.25	.55	.81	.73	.09	.98	.78	.87	.83	.75
Inner air-c.										
ρ	.269	−.190	.036	.082	−.246	−.015	.024	−.002	.133	.155
p-value	.15	.31	.85	.67	.19	.94	.90	.99	.49	.42

Note. Results of the correlations (Spearman) of assistant attributes with distances. Bone-c = bone-conduction headphones; air-c = air-conduction headphones.

Discussion

The central aim of this exploratory study was to assess, how listening to music through headphones would affect the perception of distance to an approaching person. When comparing ideal conversation (talk) distances with the inner boundaries of the personal (inner) distance, it was found that the talk distance was significantly smaller with both air-conduction and bone-conduction headphones. The inner distance was only influenced by the over-ear air-conduction headphones and not the bone-conduction headphones. These observations point towards a confirmation of the hypothesis that the required personal space shrinks when listening to music. In addition, we asked whether any other factors might be found to affect the size of personal space during music listening. However, neither the attributes of the assistant nor those of the participants were relevant for the size of the talk or inner distance.

These results expand the findings of Tajadura-Jiménez et al. (2011), who discovered that positive music through earphones decreases personal space. Although the authors also revealed that negative music through earphones did not lead to a difference in personal space, the present study showed that—without controlling for valence—generally listening to music through over-ear headphones led to a reduced personal space. This agrees with findings from qualitative studies, where participants reported feeling less crowded when listening to mobile music of their own choice (e.g., Bull, 2010, p. 56; Skånland, 2011, p. 11). One explanation could be that participants might choose music whose valence is rather more positive than negative, which would therefore corroborate the effects found by Tajadura-Jiménez et al. (2011). Since preferences for music with a certain valence were found to be associated with personality—in fact, liking for negative valence music was linked with higher scores in neuroticism (Greenberg et al., 2016, p. 602), and the participants of the present study had lower scores in neuroticism, $M = 3.68$, $SD = 1.25$, than the other personality traits, with means ranging from 4.32 to 4.90 and standard deviations ranging from 0.77 to 1.01—this explanation pertains to the present results. Nevertheless, further research into the seeming discrepancy between the effects of music overall and the effects of only positive music is necessary, for instance, by analysing the music that mobile listeners listen to in crowded situations.

Generally, listening to music has been found to be relaxing (e.g., Skånland, 2011), which might explain why the usual stress reaction from a breach of personal space came later in the headphone conditions. Additionally, music might also have distracted the listener from the stress or even the task at hand, which could have caused relaxation and a later reaction time to the approaching assistant. Nevertheless, as neither the relaxation nor stress reaction were measured in this experiment, the causes for the impact of music on personal space will need to be explored in further studies.

The findings encourage the use of bone-conduction headphones alongside other devices to investigate the effects of music delivered through different systems on human behaviour. While answering the subsidiary question, a comparison between bone-conduction and air-conduction headphones (over-ear) showed that different kinds of earphones influence personal space differently: both talk distance and inner distance were smaller when over-ear headphones were used, while music listened to through bone-conduction headphones only affected conversation distance—and these results were barely significant.

One of the main functions of mobile music listening is masking unwanted environmental sounds (e.g., Kuch & Wöllner, 2021) and thus dissociating from the environment (Bull, 2000). Since bone-conduction headphones do not cover the ears, the masking effect and distraction is less prominent and available and auditory stimuli from the environment are able to reach the listener. Thus, if the listener hears the steps from the approaching person, the combination of sensory information might lead them to stop the assistant earlier. While the distraction seemed to be enough to influence the talk distance, it apparently did not manage to overcome the discomfort created by a breach of inner distance, so the participants did not significantly change the point when they stopped the assistant for the second time. This possible explanation is supported by the standard deviations: while the talk distances in the bone-conduction condition varied between 47 to 59 cm, the inner distances were more consistent and only varied between 26 and 30 cm. A second explanation for the barely or non-significant findings with bone-conduction headphones might be that these kinds of headphones were mostly unknown to the participants, so this might have led to more cautious behaviour compared to with air-conduction headphones. However, further research is needed on the differences between air-conduction and bone-conduction headphones while listening to music, which might provide explanations that are not yet available.

None of the other factors considered in this study were found to influence personal space—which disagrees with previous studies pertaining to personal space where a whole range of different factors were discovered to affect the size of personal space (e.g., Adams & Zuckerman, 1991; D'Angelo et al., 2019; Leventhal et al., 1978; Welsch et al., 2020). On the one hand, this might be due to the pandemic and the fact that everyone apart from the participants wore a face mask. This might have made the assistant more anonymous and therefore the size of personal space was less affected by the assistant's attributes. However, this does not explain why other factors, such as personality, gender or height, were not found to impact the size of personal space in this study. On the other hand, these findings might be due to the music that was part of the experiment, which would be rather encouraging, because this indicates that everyone, regardless of height, age, gender or personality, can feel less crowded when listening to music. This, again, agrees with previous results of qualitative studies, where a variety of people all reported that they feel less affected by surrounding people in mobile music listening situations.

At the beginning of this paper, the effect of music listening on personal space was equated with the auditory bubble. And while Bull (2005) claimed that the auditory bubble comes into existence through mobile music listening, it is not quite clear how exactly the bubble is created nor how it operates. It could have several sources, for instance, the music itself, or the fact that it masks surrounding sounds and distracts from them. Thus, while the present research can conclude that listening to music seems to influence the required personal space, more research and a clearer definition of the auditory bubble is needed to be able to say that the underlying concept of what was measured here was indeed the auditory bubble.

Limitations

One of the main limitations of this study is that it was carried out during the pandemic, thus the results cannot be directly transferred to circumstances before or after the pandemic. The assistants wore masks, which could have influenced the distance because the participants felt safe from being infected (Iachini et al., 2021). Interestingly, however, the distances kept in this experiment were shorter than those in the study by Tajadura-Jiménez et al. (2011). In both studies, there was one measure of distance where the participants stopped the approaching person at the point they started to feel uncomfortable (i.e., the inner distance). This distance was between 60–75 cm in the study from 2011 and 51–61 cm in the current experiment. Thus, although people were required to keep apart throughout the pandemic, these measures actually show that the distances measured during the pandemic were smaller than before Covid-19. Again, the assistant wearing a mask could have had an impact here, but further research would be necessary to probe the causes of this difference in personal space. Since there are at least 11 years between the two studies, other factors or societal changes might have led to a reduced size of personal space in general.

A second limitation is the convenience sample and the number of participants. Future studies should and could approach the sampling more systematically: they might compare different age groups, people with and without regular headphone experiences, and maybe even people with and without claustrophobia, since the feeling of more space created through the music might be helpful for them. A more balanced and larger sample of participants could lead to more conclusive results.

Two kinds of headphones were compared in the current study, and the participants listened to music. As listeners may use other kinds of headphones in their daily lives, widening the study to include these could lead to more differentiated data that correspond more closely with everyday behaviour. One possibility, for example, could be to include noise-cancelling or in-ear headphones, or to use AirPods with their range of different modes, including a transparent mode to hear surrounding sounds. Additionally, mobile music listeners in previous studies reported that they not only listened to music but also to other digital formats such as podcasts (e.g., in Schurig, 2019, p. 248). Subsequent studies could therefore include other kinds of auditory stimuli (e.g., music, talking, noise, or silence) and explore whether these also lead to the creation of the auditory bubble and the consequent reduction of personal space. Including other kinds of auditory stimuli along with music might also indicate whether the auditory bubble is created when the listener is distracted or whether it is purely music-related.

Conclusion

The present study revealed that listening to music through headphones—and therefore the auditory bubble—affects how close another person is allowed to approach. With music, the required personal space shrinks, particularly while using over-ear air-conduction headphones. Thus, the impression of mobile music listeners who report that they feel enveloped within their own personal bubble and are less concerned by the closeness of others is reflected in the size of personal space measured here. Additionally, the findings that there are differences between bone- and air-conduction headphones encourage the inclusion of different kinds of headphones in studies on music listening.

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Competing Interests

The author has declared that no competing interests exist.

Ethics Statement

The study was carried out in accordance with relevant institutional and national guidelines and regulations (Deutsche Gesellschaft für Psychologie, 2022; Hanover University of Music, Drama and Media, 2017) and with the principles outlined in the Declaration of Helsinki. Formal approval of the study by the ethics committee of the Hanover University of Music, Drama and Media was not mandatory, as the study adhered to all required regulations.

Data Availability

For this article, the dataset is freely available (see Schurig, 2023a).

Supplementary Materials

For this article, the dataset and codebook (see Schurig, 2023a) and the questionnaire (see Schurig, 2023b) are available as Supplementary Materials.

Index of Supplementary Materials

Schurig, E. (2023a). *Dataset for: Measuring the auditory bubble* [Data, codebook]. PsychArchives. https://doi.org/10.23668/psycharchives.13466

Schurig, E. (2023b). *Questionnaire for: Measuring the auditory bubble* [Questionnaire]. PsychArchives. https://doi.org/10.23668/psycharchives.13467

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