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Sounds that satisfy: Describing the relationship between sound and need fulfilment

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Abstract: Psychological needs of users as a basis for design are at the core of design practice, yet the importance of fundamental human needs when designing soundscapes has not been studied specifically. This paper investigates the relationship between nine fundamental human needs and the affective qualities and categories of soundscapes. In a free-labeling survey study, we collected descriptions of imagined sound environments for the fulfilment of the needs, as well as ratings of the perceived affective quality of these environments. We found that needs were associated with pleasant soundscapes, while their eventfulness varied. 'Human' sounds were a common category for each of the nine needs considered in this study, but systematic variations of the categories were found dependent on the need. Results suggest that designing categorically different soundscapes dependent on the users' needs will have beneficial effects.

Keywords: needs; soundscape; design; well-being

1. Introduction

Sound connects our physical and psychological world, bridging the outer physical world with our inner emotional one through vibrations (Bennett, 2019). It is a powerful, universal variable that accompanies us our entire lives. Even though our experience of the world is dominated by the preference of vision over other modes of sensory perception (Posner, 1976), our senses of touch and hearing are stimulated before that of vision, as a mother's tissue will block most all light. Aside from being one of the first senses to allow us to comprehend the world, it is possibly the last one to go in a person's final moments. Research has shown that some unresponsive patients receiving palliative care before an expected natural death can still respond to auditory stimuli, up until the last hours of their lives (Blundon et al., 2020). Although sound forms this perpetual, instinctive, and fundamental property of human life, our daily *acoustic environment* (ISO, 2014), leaves much to be desired. In Europe, daily environmental noise places a major burden on human health and well-being, like sleep disturbance, cognitive impairment in children, tinnitus and annoyance (WHO, 2018). This negative

experience with our environment implies that certain psychological needs are being harmed by it, or at the least remain unfulfilled. Deci and Ryan (2000) proposed that psychological needs form the basic nutriments for an individual's growth, integrity, and well-being, and that the fulfilment of these needs is an ongoing source of meaning and pleasure (Deci & Ryan, 2000). The implementation of needs as a basis for design can support a systematic approach to design for positive experiences and subjective well-being (Desmet et al., 2001; Desmet & Hekkert, 2007). Being characteristically interested in understanding the complexities of users' individual needs to characterize an intended user experience, designers can offer a unique perspective in positively changing acoustic environments, by being able to consider the intended experience from the starting position of a user's psychological needs, and the surrounding circumstances (Wiklund-Engblom et al., 2009; Langeveld et al., 2013; Özcan, 2014).

The focus of this paper is to determine what categories of sounds are associated with different psychological needs. First, the paper introduces a typology of psychological needs, a taxonomy for the categorization of sounds, and a framework for the perceived affective quality of soundscapes from existing literature. Following this, the results of an online free-labeling survey study are presented, reporting participants' responses in terms of affective ratings, and describing the frequency of occurrence of sound categories.

1.1 Need fulfilment

Cross-cultural studies into needs and subjective well-being have shown that certain needs are universal and exist regardless of cultural differences, and that the fulfilment of fundamental human needs contributes to subjective wellbeing, provided that each need is fulfilled to some extent (Tay & Diener, 2011). Several need typologies have been developed over time towards classifying the basic psychological nutriments driving human motivation and pursuit of well-being: the deficit and growth needs of Maslow's need hierarchy (1943), Deci and Ryan's needs as part of self-determination theory (2000), and the model of candidate needs proposed by Sheldon et al. (2001) being chief examples (Maslow, 1943; Deci & Ryan, 2000; Sheldon et al., 2001). In a revision of these typologies, Desmet and Fokkinga (2020) developed a complete, design-focused typology of human needs, consisting of thirteen fundamental human needs: the need for *Autonomy*, *Beauty*, *Comfort*, *Community*, *Competence*, *Fitness*, *Impact*, *Morality*, *Purpose*, *Recognition*, *Relatedness*, *Security*, and *Stimulation* (Desmet & Fokkinga, 2020). This typology is intended to be utilized as a source for positive, user-centered design practice, with a focus on user experience and well-being. Hassenzahl et al. (2010) showed that a positive relationship between need fulfilment and experiences with technology exists, that sets of needs combined into 'need-profiles' can characterize a user's experience (Hassenzahl et al., 2010), and Hassenzahl and Diefenbach (2012) showed that individual, positive experiences can often be characterized by a single, dominant need (Hassenzahl & Diefenbach, 2012). Additionally, previous studies into need fulfilment and user experience (Partala & Kallinen, 2012; Sheldon et al., 2001; Hassenzahl et al., 2010) have shown a methodology with adapted surveys to measure the extent to which psychological needs in

peoples' experiences are fulfilled/thwarted, making this approach both measurable and operationalizable.

1.2 Environmental sounds and soundscapes

As the perception of isolated environmental sounds disregards the role of the daily contexts in which psychological need fulfilment takes place, sounds should be considered as a part of a soundscape. Originally rooted in acoustic ecology, the term soundscape was first mentioned in the work of Southworth (Southworth, 1969), and popularized by Canadian composer and environmentalist R. Murray Schafer, in his book The Tuning of the World (Murray Schafer, 1977). The term soundscape was standardized in 2014 by the International Standard and defined as 'the acoustic environment as perceived or experienced and/or understood by a person or people, in context' (ISO, 2014); in this definition, a soundscape can be seen as the perceptual representation of the entire collection of sounds (i.e. acoustic environment). In soundscape studies, the emphasis lies on the holistic experience of the acoustic environment.

Categorizations of sounds allow for the identification of individual sound sources, while still perceiving soundscapes as a whole. Several taxonomies for the classification for sounds have been proposed (Gaver, 1993; Özcan et al., 2014). A taxonomy is a system by which categories are related to each other, in different levels of categorical representation (Rosch et al., 1976). Super-ordinate categories are widely inclusive, like Schafer's (1977) referential aspects, categorizing different sounds as 'Natural sounds' (e.g., sounds of water, sounds of seasons, sounds of fire), 'Human sounds' (e.g., sounds of the body), 'Sounds and society' (e.g., sounds of entertainment), 'Mechanical sounds' (e.g., trains and trolleys), 'Quiet and silence', and 'Sounds as indicators' (e.g., bells and gongs), and Krause's taxonomy of sound sources (Krause, 1987; Krause, 2008): the geophony (natural sounds emanating from nonbiological sources in a given habitat), biophony (all of the biological sources of sound from microscopic to megafauna that transpire over time within a particular territory) and anthrophony (all of the human-generated sounds that occur in a given environment).

At a lower level of specification, basic categories carry the most information, and are best distinguishable from one another (e.g., weather, wind, water). Finally, below the basic level, specific, sub-ordinate categories are positioned, like waterfalls, rain, and thunder. Axelsson et al. (2010) used super-ordinate categories of 'Natural', 'Human', and 'Technological' sound categories to assign dominant sound categories to soundscapes, and Lenzi et al. (2021) presented a three-tier structured taxonomy of all previously mentioned taxonomies of sounds (Axelsson et al., 2010; Lenzi et al., 2021). These classifications make it possible to compare and generalize perceived soundscapes in terms of their composition of distinctive elements, as well as the perception of the soundscape as a whole.

1.3 Soundscape descriptor: Perceived affective quality

The perceptual constructs associated with soundscape perception are called *soundscape descriptors*, and are defined as measures of how people perceive the acoustic environment (ISO, 2018). Following a principal component analysis, Axelsson and colleagues (2010) found three dimensions for the soundscape descriptor 'perceived affective quality' of soundscapes: *pleasantness*, *eventfulness* and *appropriateness* (Axelsson et al., 2010).

Affective attributes found on the first dimension described an *unpleasant-pleasant* relationship, on the second dimension an *uneventful-eventful* relationship, and the third dimension of *inappropriate-appropriateness*. This orthogonal, three-dimensional framework was developed into the Swedish Soundscape Quality Protocol (SSQP) and has shown to accurately distinguish between soundscapes and assess their perceived affective quality in urban environments (Axelsson, 2015). The pleasantness and eventfulness axes of perceived affective quality create quadrants (clockwise) of exciting/vibrant, chaotic, monotonous/boring, and calm. Being able to measure and position the perceived affective quality of current as well as intended soundscapes, it is possible to quantify and compare the influence of sound interventions in specific contexts.

1.4 Relevance for sound-driven design

Research has shown that removing unwanted sounds is not always appropriate, as it can create anxiety, due to the absence of events (Stockfelt, 1991). Interestingly, in studies on a similar framework as the framework of Axelsson et al. (2010), Cain et al. (2013) showed that dB(A) levels of urban soundscapes corresponded to roughly similar levels, yet were perceived very differently on calmness and vibrancy axes (Axelsson et al., 2010; Cain et al., 2013). This incidentally shows that objective measures (e.g., loudness) alone are not sufficient to evaluate a listener's perceptions. Studies in parks and cities have shown that perceptual properties of soundscapes are better at predicting perceived soundscape quality than psychoacoustic measures. These studies seem to suggest that positively perceived elements of urban soundscapes are associated with natural sounds (e.g., water, birds), and negatively perceived elements with technological ones (e.g., traffic, cars) (Nilsson, 2007; Guastavino, 2006).

Cain et al. (2013) showed that if an existing soundscape is positioned within the perceptual space indicating the perceived quality of said soundscape, a target for an intervention can be identified, by indicating its position in the perceptual space too. In order to move the perception of the soundscape from the first position to the second, however, it is necessary to know what that intervention then should consist of, taking into account both the context and the listener. By making use of fundamental human needs as a basis for design, categorizations of sounds related to those needs, and perceived affective quality, designers can introduce sounds that can result in a positive perceptual outcome, which in turn is associated with increased well-being and quality of life.

1.5 Present study

In the pursuit of a systematical approach to compose soundscapes to satisfy human needs, we tested which sounds are associated with a selection of psychological human needs, and how these needs compare in terms of their perceived quality. To this aim, we performed an online survey study with open-ended questions, into imagined, need-specific sound environments, for a set of nine pre-selected needs.

2. Methods

2.1 Participants

Participants were adults of no specific nationality, proficient in English and without a history of hearing impairment. Participants were between 23 to 52 (M = 27.9 years, SD = 5.5) years of age. All participants (17 male, 17 female) voluntarily completed the survey after filling in a consent form. No monetary compensation for their participation in the study was offered. A survey generally took under 60 minutes to complete (M = 53.2, SD = 24.3). Our study protocol with human subjects was approved by the Human Research Ethics Committee (HREC) of Delft University of Technology on the 21st of October 2021.

2.2 Sensitizing with audio samples

Four audio samples were designed as sensitizers for soundscapes, to be presented before the survey in which the relationships between needs and soundscapes were investigated. Each audio sample was twenty seconds in duration. Audio sample 1, representing a pleasant and eventful soundscape, was designed to be perceived as 'exciting/vibrant' and featured a blackbird, European robins and a dunnock with additional sounds of footsteps along a gravel path, with cars passing and soft sounds of wind through trees forming a keynote. Audio sample 2, representing an unpleasant and eventful soundscape, was designed to be chaotic and featured cars passing and wind, but included a superimposed recording of busy traffic. Audio sample 3, representing a pleasant and uneventful soundscape, was designed to be calm and featured background cars and wind, but with only a lone blackbird's song. Audio sample 4, representing an unpleasant and uneventful soundscape was designed to be boring/monotonous and featured the atmospheric tone of an empty computer room with a continuous humming sound. The samples are available on Soundcloud (https://tinyurl.com/4nrexhw3).

To validate our sensitizers, the audio samples were reviewed independently by five researchers in a rank-order task, without labels indicating their corresponding pleasantness or eventfulness attributes of the soundscapes. The reviewers were first asked to rank the randomly presented audio samples in terms of relative pleasantness and then relative eventfulness. All reviewers ranked the soundscapes correctly as intended in its respective design. The audio samples were consequently deemed appropriate to serve as sensitizers for pleasantness and eventfulness in this survey study.

Table 1. Needs and definitions provided to participants

Need	Need definition
Beauty	Feeling that your environment is a place of elegance, coherence and harmony, rather than feeling that it is disharmonious, unappealing or ugly.
Stimulation	Being mentally and physically stimulated by novel, varied and relevant impulses and stimuli, rather than feeling bored, indifferent or apathetic.
Comfort	Having an easy, simple relaxing life, rather than experiencing strain, difficulty or over-stimulation.
Security	Feeling that your conditions and environment keep you safe from harm and threats, rather than feeling that the world is dangerous, risky or a place of uncertainty.
Competence	Having control over your environment and being able to exercise your skills to master challenges, rather than feeling that you are incompetent or ineffective.
Relatedness	Having warm, mutual, trusting relationships with people who you care about, rather than feeling isolated or unable to make personal connections.
Fitness	Having and using a body that is strong, healthy and full of energy, rather than having a body that feels ill, weak, or listless.
Autonomy	Being the cause of your actions and feelings that you can do things your own way, rather than feeling as though external conditions and other people determine your actions.
Recognition	Getting appreciation for what you do and respect for who you are, instead of being disrespected, under-appreciated or ignored.

2.3 Fundamental needs and need-specific imagined environment

A set of nine fundamental needs were selected from the typology of Desmet and Fokkinga: the need for Autonomy, Beauty, Comfort, Competence, Fitness, Recognition, Relatedness, Security and Stimulation. This selection was made to limit the amount of time spent on the surveys. The nine selected needs were argued to be clinically most relevant for the authors' area of research, being designing for the needs of critically ill patients on intensive care wards. Participants were asked to imagine an environment that would satisfy a specific need within the selected set. They were given the instruction to 'Try to imagine an environment that makes you feel [need-specific feeling]. Please describe it in the text box below'. For each of the nine need-specific feelings, this instruction was accompanied by definitions: e.g., the need for beauty, 'Feeling a sense of beauty: Feeling that the world is a place of elegance, coherence and harmony, rather than feeling that the world is disharmonious, unappealing or ugly.' An overview of the needs and definitions is shown in Table 1. Participants could use a multi-line text field for their response to this open question.

Participants were asked to answer an open-ended question for each of the nine need-specific situations and corresponding descriptions of an imagined environment: 'What things (or events) are happening in this environment?'. Responses were recorded in a multi-line text field.

Regarding the events described within the context of the need-specific environment, participants responded to the question: 'What sounds would these events make?'. Responses were again recorded in a multi-line text field.

Table 2. Examples of participants responses to three survey items with labels.

Need	Environment	Events	Sounds	Labels
Beauty	A natural environment with bright light and colors. A nice beach with waves clashing at the shore and a strong wind. I am looking at it from higher up. Standing at the cliff.	Waves clashing at the shore. Sitting at the cliff. Drinking a beer.	The sound of the waves and the wind whooshing. Maybe some seagulls.	Biophony (1), geophony (2)
Security	At home, comfortable on the couch when it is raining outside	I am sitting on the couch. There are other people around me. It's raining outside. We have lit a fire.	Rain. Fireplace cracking. Soft sound of voices/people talking.	Geophony (1), geophysics (1), voice (1)

2.4 Sound-categories in three-tiered taxonomy

In this survey study, we aimed to collect descriptions of individual sound events, corresponding to specific needs as input for need-specific imagined environments. Since the process of listening involves meaning creation based on action-sound couplings (Tuuri & Eerola, 2012), participants were guided towards describing sounds in several steps, examples of which are shown in Table 2. First, they described an imagined environment based on the presented need in the survey. Then, participants described events taking place in this imagined environment. Finally, they described which sounds took place as a result of these events. We used the results of the final stage (i.e., sounds) for further analysis.

During the analysis of participants' responses, based on the taxonomies of sound categorization mentioned in the introduction and responses of participants, a three-tiered revised taxonomy of sound categories was made, consisting of four superordinate categories: Human, Natural, Musical, and Technological. This taxonomy is shown in Figure 1. The Human category represented all of the human-generated sounds that occur in an environment, like speech and bodily sounds (e.g., rustling clothes); the Natural category represented all biological and non-biological sources of natural sounds that occur in a given environment, and the Technological category consisted of all sounds generated by machines, electronics, cars. As sounds perceived as music can be both labeled as Technological (e.g., music from a speaker) and Human (e.g., music made by interacting with an instrument), a separate Musical category was added, in line with observations made by Lenzi et al. (2021) (Lenzi et al., 2021). The Musical category represents all vocal, electronic or instrumental elements music comprises of in a

given environment.

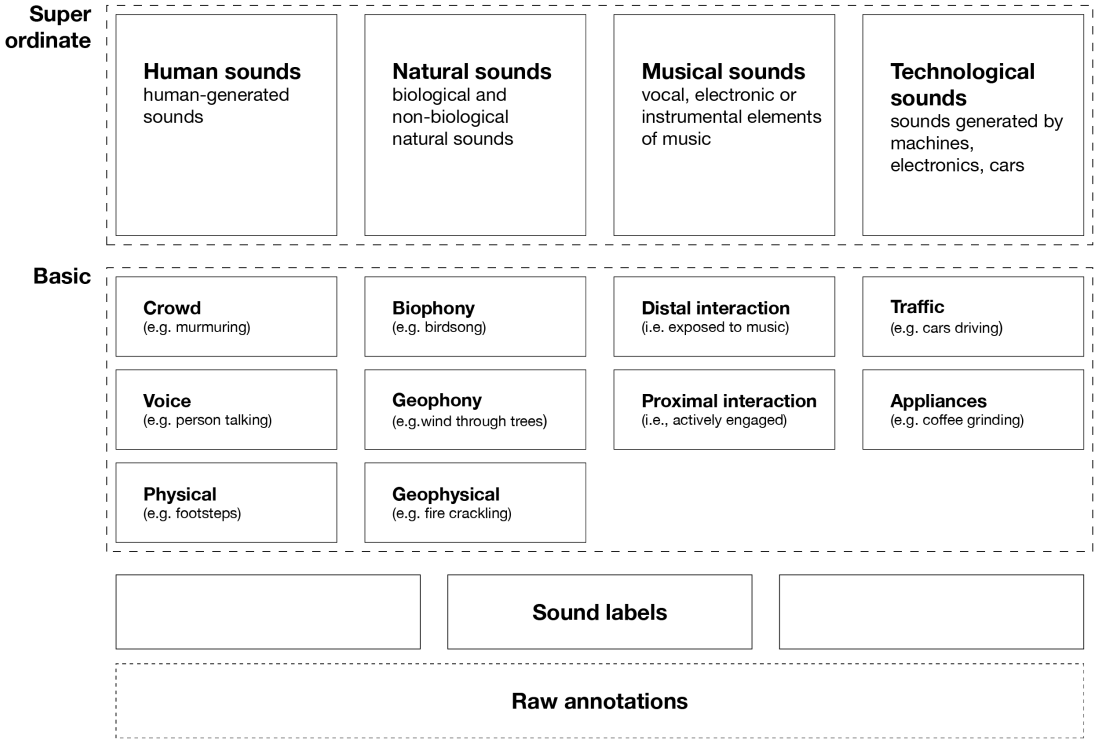

Figure 1. Schematic representation of superordinate and basic categories of sounds.

The super-ordinate level categories represent ten basic level categories: the Human category includes Crowd (e.g., murmuring), Voice (e.g., person talking), Physical (e.g., footsteps). The Nature category includes Biophony (e.g., birdsong), Geophony (e.g., wind through trees), Geophysics (e.g., fire crackling). The Music category includes a Proximal interaction (i.e., actively engaged) and a Distal interaction (i.e., being exposed) with the music. The Technology category includes Traffic (e.g., cars driving), and Appliances (e.g., coffee grinding). Raw annotations of sounds were separated into labels and matched to the basic categories. Examples of these labels are shown in Table 2.

2.5 Perceived affective quality of the imagined environment

The described imagined environment, events and sounds formed a need-specific imagined soundscape. Its perceived affective quality was assessed by the two affective attributes of pleasantness and eventfulness. They were both measured on a 7-point scale, ranging from 'Unpleasant' to 'Pleasant' and 'Uneventful' to 'Eventful' respectively.

2.6 Procedure

This survey study was performed with Qualtrics (www.qualtrics.com), and was accessed by participants through a link in an invite distributed by email. The survey consisted of three parts: (1) introduction and demographics, (2) listening to audio samples, and (3) imagining and rating need-specific soundscapes. All materials were in English. Participants were asked

to use headphones or earphones for the audio stimuli included in this survey, to be in a quiet environment where they felt comfortable throughout the duration of the survey, and to perform the survey on a personal computer or laptop for optimal performance of the visual layout of the survey. Finally, participants were asked to complete the survey in one session.

Participants were first introduced to the study, explaining the aims and the tasks to be performed. Following their consent, they were asked to fill out their date of birth and sex. They were then presented with the audio samples. The audio samples were labeled with 'pleasant/eventful', 'unpleasant/eventful' and 'pleasant/uneventful' or 'unpleasant/uneventful'. Participants were allowed to listen to the soundscapes as many times as they wanted.

Afterwards, descriptions of need-specific imagined soundscapes and corresponding ratings in terms of perceived affective quality were collected. The order in which need-specific situations were presented was randomized, and each featured the same subset of measures: (i) need-specific imagined environment, (ii) descriptions of imagined events, (iii) event-based imagined sounds, (iv) perceived pleasantness, and (v) perceived eventfulness.

3. Results

All rating data were exported from Qualtrics, and saved as a data sheet in a local computer for analysis. Out of the completed surveys (N=34), five participants in total completed the survey with missing entries; of these five participants, the first had missing text responses for *Security*, *Competence,* and *Autonomy*, another had two missing text responses for *Competence and Comfort*, a third participant had one missing response for *Autonomy*, a fourth for *Recognition*, and a fifth for *Comfort*. All participants rated pleasantness and eventfulness even for the missing text responses for event description. Ratings for these participants with missing text were replaced by the mean of the respective rating per item. To accommodate for personal differences between judgements of participants with regards to perceived affective quality, participants' raw pleasantness and eventfulness ratings were normalized to a 0-1 ratio, with reference to their baseline measures and the normalized data were used for further analysis: *Normalized rating = ((raw value – minimum rating given)/maximum new rating given)*

Table 3. Means and standard deviations of perceived affective quality.

Need	**Mean pleasantness (M_{PL})**	**SD pleasantness (SD_{PL})**	**Mean eventfulness (M_{EV})**	**SD eventfulness (SD_{EV})**
Beauty	0.91	0.16	0.50	0.32
Stimulation	0.69	0.30	0.82	0.29
Comfort	0.85	0.29	0.36	0.38
Security	0.82	0.25	0.33	0.38

Competence	0.61	0.33	0.54	0.38
Relatedness	0.79	0.27	0.63	0.34
Fitness	0.66	0.33	0.71	0.34
Autonomy	0.80	0.28	0.46	0.39
Recognition	0.64	0.30	0.70	0.31
Total	0.75	0.28	0.56	0.35

3.1 Means of perceived affective quality

For each of the need-specific imagined environments, means and standard errors were calculated for normalized ratings of perceived affective quality. Normalized means and standard deviations are presented in Table 3, and plotted in Figure 2. All imagined sound environments were rated as relatively pleasant (M_{PL}= 0.75, SD_{PL} = 0.28). Means of eventfulness ratings for each sound environment and needs ranged between 0.33 and 0.82, with medium eventfulness score for all ratings (M_{EV} = 0.56, SD_{EV}= 0.35). Agreement between participants for pleasantness ratings was higher than those of eventfulness (SD_{PL}(0.28) < SD_{EV}(0.35)).

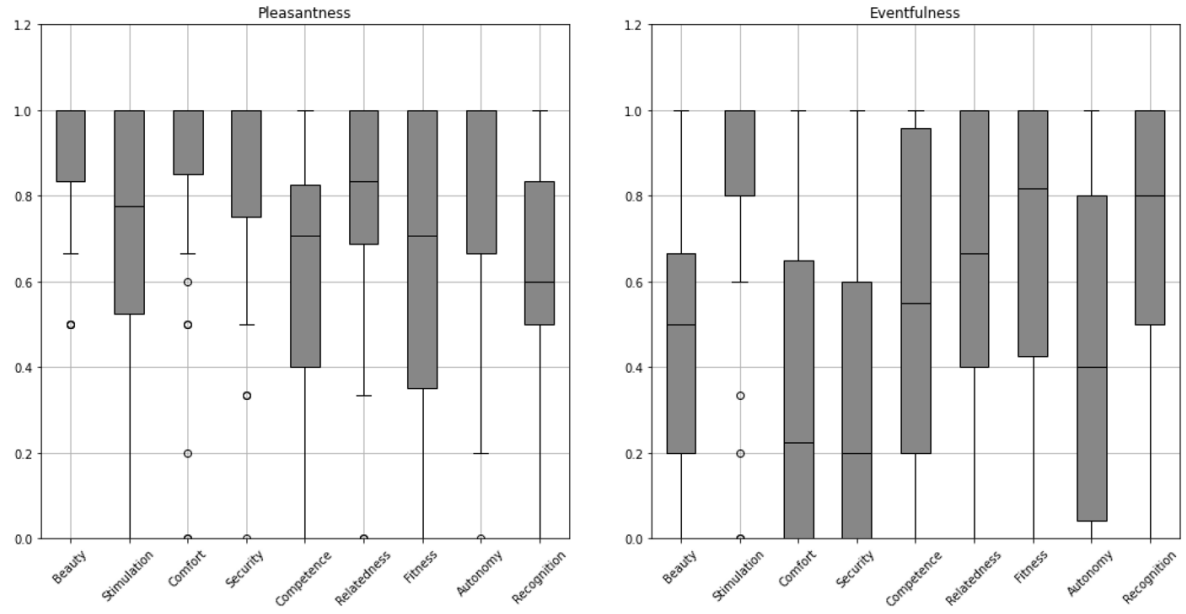

Figure 2. Means and standard deviations on normalized data between needs. Left: pleasantness, right: eventfulness.

3.2 Frequencies of sounds

In Figure 3, the distributions of the frequencies of the four super-ordinate sound categories have been plotted. Out of all labels mentioned for the nine needs (see Total), 50.8% (N =

454) of the responses included sounds belonging to the superordinate category of Human. This was followed by the category of Natural sounds, covering 25.2% (N = 225) of the responses, and Technological, for 14.6% (N = 130); finally, Music related sounds were mentioned the least overall, representing 9.4% (N = 84) of the labels.

Out of the nine needs, Human sounds were mentioned most often for *Recognition* (80%), followed by *Relatedness* (72.3%), and *Stimulation* (56.5%), and least often for *Beauty* (29.2%), *Security* (37.6%), and *Autonomy* (39.8%). Natural sounds were most commonly encountered for *Beauty* (55.7%), *Security* (32.9%), and Fitness (30.8%), and least common for *Recognition* (6.7%), *Stimulation* (7.4%), and *Relatedness* (8.9%). The category of Technological sounds was most occurring for *Autonomy* (26.9%), *Competence* (21.7%), and *Stimulation* (20.4%), and least occurring for *Beauty* (8.5%), *Recognition* (8.9%), and *Comfort* (9%). Finally, Music related sound labels were regularly found for *Stimulation* (15.7%), *Security* (12.9%), and *Competence* (9.8%), and uncommon for *Recognition* (4.4%), *Beauty* (6.6%), and *Autonomy* (7.5%).

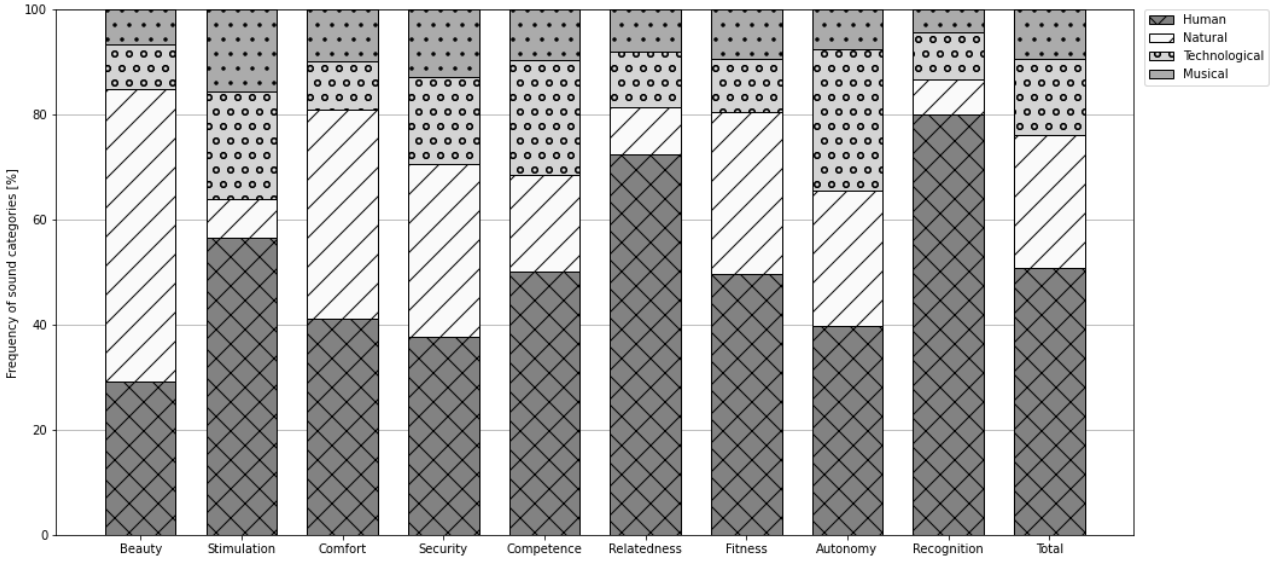

Figure 3. Distributions of four superordinate categories per need.

Illustrated in Figure 4, the distributions of the ten basic categories of sounds per need, and in Table 4 the relative frequencies have been shown. Out of all labels mentioned for the nine needs (see Total), sound labels belonging to the category of Voice were mentioned most often (27.2%), while the least commonly mentioned, over all nine needs, was Geophysics (2.4%). Crowd was found to be common for *Recognition* (18.9%), yet not present for *Security*, and seldom mentioned for *Beauty* (1.9%).

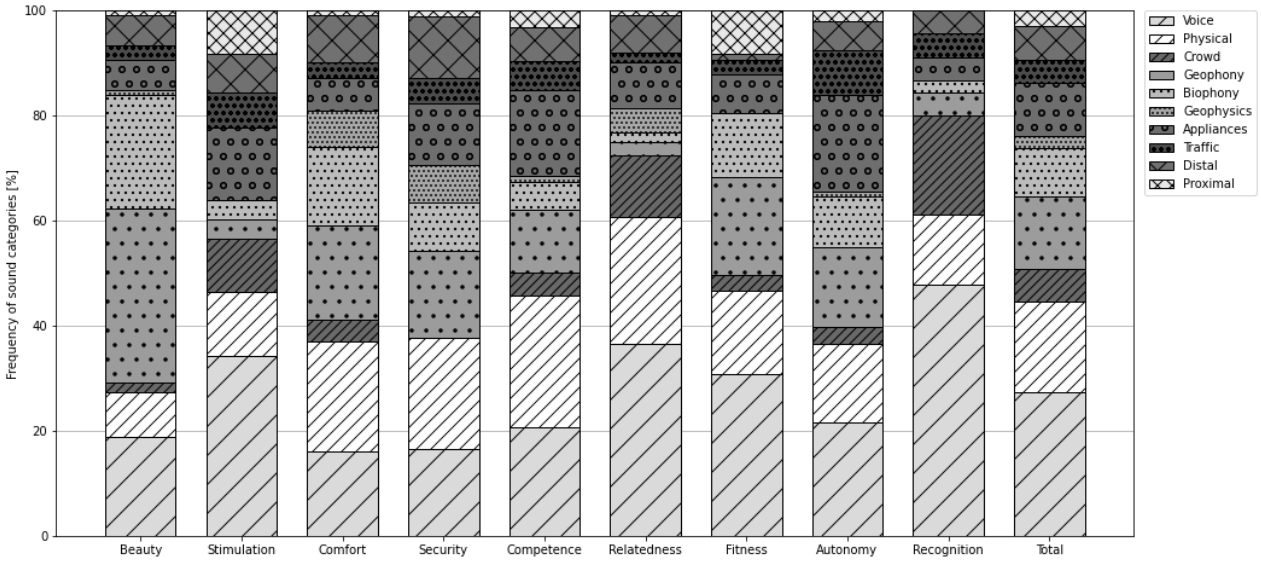

Figure 4. Distributions of ten basic categories per need.

Voice was frequently mentioned for *Recognition* (47.8%), and rarer for *Comfort* (16%). Physical related sounds were typically mentioned for *Competence* (25%), and little mentioned for *Beauty* (8.5%). Biophony was mentioned most often for *Beauty* (21.7%), and least often for *Relatedness* (1.8%).

Table 4. Relative frequencies of super-ordinate and basic categories of sounds (%). Maxima are indicated in bold, minima in italic.

Superordinate	Basic	Beauty	Stimulation	Comfort	Security	Competence	Relatedness	Fitness	Autonomy	Recognition	Total
Human	Crowd	1.9	10.2	4.0	*0.0*	4.3	11.6	2.8	3.2	18.9	6.4
	Voice	18.9	34.3	16.0	16.5	20.7	36.6	30.8	21.5	47.8	27.2
	Physical	8.5	12.0	21.0	21.2	25.0	24.1	15.9	15.1	13.3	17.2
Natural	Biophony	21.7	3.7	15.0	9.4	5.4	1.8	12.1	9.7	2.2	9.1
	Geophony	33.0	3.7	18.0	16.5	12.0	2.7	18.7	15.1	4.4	13.8
	Geophysics	0.9	*0.0*	7.0	7.1	*1.1*	4.5	*0.0*	*1.1*	*0.0*	*2.4*
Music	Distal	5.7	7.4	9.0	11.8	6.5	7.1	0.9	5.4	4.4	6.4

	interaction									
	Proximal interaction	*0.9*	8.3	*1.0*	1.2	3.3	*0.9*	8.4	2.2	*0.0*	3.0
Technological	Traffic	2.8	6.5	3.0	4.7	5.4	1.8	2.8	8.6	4.4	4.4
	Appliances	5.7	13.9	6.0	11.8	16.3	8.9	7.5	18.3	4.4	10.2

Geophony was commonly found for *Beauty* (33.0%), and uncommon for *Relatedness* (2.7%). Geophysics related sounds were found in *Security* (7.1%), but were not present for *Recognition, Stimulation,* or *Fitness.* Distal interaction was most often mentioned in items related to *Security* (11.8%), whereas little mention was made in items related to *Fitness* (0.9%). Proximal interaction was mentioned most often for *Fitness* (8.4%), yet not mentioned for *Recognition*, and least often for *Relatedness* (0.9%). Traffic was commonly found for *Autonomy* (8.6%), and uncommon for *Relatedness* (1.8%). Finally, Appliances popped up most often for *Autonomy* (18.3%), and unusually so for *Recognition* (4.4%).

4. Discussion

4.1 Perceived affective quality

The results of this study on the relationships between human needs and imagined soundscapes show that there are systematic differences between the composition and affective qualities of those soundscapes, dependent on the needs. The perceived affective qualities of the imagined soundscapes showed that ratings of the soundscape descriptors of pleasantness and eventfulness vary between needs. Expectedly, all soundscapes were rated to be relatively pleasant, while eventfulness ratings varied between needs, and within need-specific descriptions of environments. Consequently, when designing soundscapes for psychological need fulfilment, designers should in all cases pursue a pleasantly rated sound environment. One might argue that responses given by participants were impacted while listening to the audio samples; while this concern is justified, our results show that pleasantness and eventfulness are manifested in other sound categories than merely the ones used in the design of the audio samples (i.e. majority of natural sounds for pleasant, majority of technological sounds for unpleasant). This shows that, while we gave an example of what could be a pleasant/unpleasant soundscape, it did not introduce a bias towards specific sound categories in the rest of the survey.

In terms of eventfulness of soundscapes, due to the large differences in means and standard deviations, it can be concluded that designing for this dimension should be considered within the context of the specific need. This shows that designers can play with the eventfulness of a soundscape, while still achieving the fulfilment of the specific need, provided that a selection of sounds categories is used that corresponds to the need in question. In this study, the third dimension found by Axelsson et al. (2010) (i.e. familiarity/appropriateness) was not taken into consideration, because of unfamiliarity seeming to be mutually exclusive towards personal, imagined soundscapes. This dimension in light of appropriateness of sound within context (i.e., lack of a fundamental need in a specific situation) should, however, be included in future research into fundamental need fulfilment and soundscape perception.

It could be argued that due to the fact that participants rated imagined soundscapes, instead of listening to soundscapes in situ, inconsistencies can occur. Aletta et al. (2016) however showed in their conceptual framework for developing predictive soundscape models that a combination of data collection methods like recall, and narrative interviews, and semantic scales can be used to measure the affective quality of specific soundscapes (Aletta et al., 2016); the majority of experiences being based on familiar situations to the participant, it can be assumed that their responses are reliable. Additionally, Özcan and Van Egmond (2007) showed that sounds can be easily reproduced in free recall tasks (Özcan & Van Egmond, 2007). The differences in eventfulness, and relative differences in pleasantness, could however be explained by variations in described themes within the context of a specific need; this should therefore form part of a future thematic content analysis of the qualitative data related to the imagined environments and events collected in the survey.

4.2 Occurrence of categories of sounds between needs

The results of this study into the relative frequency of occurrence for categories of sounds within fundamental needs suggest that people associate specific categories of sounds with different fundamental needs, and that certain sounds, present within the context of one need, are absent, or not as important within another. In this way, different sounds can be used by designers to satisfy different needs. *Beauty* is strongly associated with Biophony, like birdsong in woods during long hikes, while Competence stands out with a frequent association to Appliances, like the sound of pedals turning on a bike.

The high frequency of occurrence of sounds belonging to the 'Human' super-ordinate category shows the importance of context in the operationalization of these findings. Sounds made by people, like turning the pages of a book, or the murmur of a crowd in the background, are associated with a degree of fundamental psychological need fulfilment in all of the nine needs included in this study, yet differences exist in expression of this category between needs. In the need for *Beauty*, Human sounds most often occur in the form of indistinguishable conversation and background chatter, while for the need for *Relatedness* these sounds dominate the environment, illustrated by examples of two responses by participants:

for *Beauty*, “a dog or a person walking by (maybe quickly greeting each other), the sound of a little breeze and some traffic very far away”, and for *Relatedness*, “The sound of talking. Beer glasses hitting the table. Rustling of people in the background. People entering and leaving. Music in the background.”.

It was expected that for certain needs like *Beauty* and *Relatedness*, specific categories of sounds would be most frequently mentioned (i.e., high vs. low frequencies of Natural sounds versus Human sounds), yet for other needs, results were more surprising. Participants most often mentioned Technological sounds in *Autonomy*, and least often in *Beauty*, while they most often mentioned Music sounds for *Stimulation*. Noticeably, Music was mentioned by relatively few participants; this could be due to the fact that in the survey items, the phrasing suggested action-sound couplings. Out of the ten basic categories, participants mentioned the presence of sounds related to Voice most often, suggesting that in soundscapes related to fundamental need fulfilment, sounds of people talking and expressing themselves play a vital role.

These outcomes indicate that when designing soundscapes for positive user experiences, the sounds are especially relevant within the context of the specific need. With this assumption in hand, designers can use the outcomes of this study as suggestions for which categories of sounds to consider, when trying to establish the fulfilment of this specific need. When designing with sounds for the fulfilment of a need for *Recognition*, for example, the results of the study could be used to denote which specific kinds of sounds should be used, as sounds related to voices (e.g., a conversation, laughter) or the physical (e.g., moving pots and pans in the kitchen) can serve as inspiration towards composing the elements making up the soundscape, using the relative frequencies of the sound categories within the need-specific imagined environments as a guide.

These rich, personal accounts could be used, within the context of the respective need, to compare imagined soundscapes based on their relative perceived affective quality, and relative differences in frequencies of occurrence of sound categories between these themes; in correspondence analyses, the responses of perceived affective quality could also be used to identify which categories of sounds and which fundamental needs are associated with relatively more/less pleasant or eventful imagined soundscapes. In this way, designers could identify or characterize a target soundscape in terms of a current and desired quadrant (i.e. calm, chaotic, exciting, boring) within the pleasantness and eventfulness framework, as proposed by Cain et al (2013). Positive experiences with acoustic environments in a wide variety of contexts will in this way be achievable by selecting a target quadrant. A currently chaotic (i.e. unpleasant/eventful) soundscape could in this way be directed towards a calm (i.e. pleasant/uneventful) one, by identifying the need to be fulfilled, and, within this context, by matching this with sounds that contribute to the intended experience of the soundscape.

5. Conclusion

The main conclusions of this paper are:

1. When designing for fundamental need fulfilment, designers should compose soundscapes that are rated as pleasant, and there is room for variation in terms of eventfulness.
2. 'Human' sounds are most commonly associated with the fulfilment of each of the nine fundamental needs considered in this study.
3. The nine fundamental human needs are associated with different categories of sounds; designers should consider composing soundscapes consisting of the most prominent sound categories, dependent on the need.

In the process of designing soundscapes that satisfy psychological needs towards facilitating a positive user experience, the results of this study have provided indications that soundscape interventions should be evaluated within the context of the respective experience. In experimental setups investigating the impact of introducing new sounds to an existing context, efforts should be made to simulate the existing and preferred context.

6. Attribution

The audio samples used the following sounds from Freesound: "Soft Wind" by "florianreichelt" (https://tinyurl.com/dfefxfkw), licensed under CC0 1.0; "Passing traffic on country road.wav" by "mike_stranks" (https://tinyurl.com/24nxnyhk), licensed under CC BY-NC 4.0; "Dunnock-nr.mp3" by "acclivity" (https://tinyurl.com/uddrah9m), licensed under CC BY-NC 4.0; "EuropeanRobin.mp3" by "acclivity" (https://tinyurl.com/2ceh88fc), licensed under CC BY-NC 4.0; "Gravel road walk, .wav" by "rempen" (https://tinyurl.com/du2kysvn), licensed under CC0 1.0; "Blackbird in the morning" by "Sesom42" (https://tinyurl.com/h2nahj24), licensed under CC0 1.0; "Ambience 2.wav" by "HumanSolarian" (https://tinyurl.com/2nf8ds6), licensed under CC BY 3.0; "Traffic.wav" by "Flovde" (https://tinyurl.com/3mmfj59a), licensed under CC0 1.0.

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