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DIMENSIONS OF SOUNDSCAPE PERCEPTION UNDER CONDITIONS OF WAR

Abstract

The acoustic environment is a continuous component of human experience, but under conditions of war its psychological significance is transformed by persistent uncertainty, threat, and heightened demands on environmental monitoring. The aim of this article is to provide a theoretical conceptualization of the dimensions through which the wartime soundscape is perceived and psychologically experienced, and to establish a framework for further empirical investigation of individual differences in auditory experience under conditions of war. The analysis is based on a theoretical synthesis and systematization of psychological, psychoacoustic, and interdisciplinary approaches to environmental sound perception, with particular attention to the processes through which acoustic characteristics acquire subjective psychological meaning.

The analysis demonstrates that wartime soundscape perception cannot be adequately explained by objective acoustic exposure alone. Rather, it represents a multidimensional psychological system in which acoustic information is processed through interconnected acoustic, psychoacoustic, cognitive, affective, phenomenological, and behavioural dimensions. The acoustic dimension concerns objectively measurable characteristics of sound; the psychoacoustic dimension reflects their subjective perceptual salience; the cognitive dimension encompasses source identification, interpretation, contextual appraisal, memory, predictability, and perceived threat; the affective dimension concerns emotional and

physiological activation; the phenomenological dimension captures the lived experience of safety, bodily readiness, temporality, spatiality, and environmental predictability; and the behavioural dimension involves attentional orientation, avoidance, monitoring, and other regulatory responses. These dimensions are analytically distinguishable but functionally interdependent.

Particular theoretical importance is attributed to the distinction between psychoacoustic and psychological salience, demonstrating that perceptual prominence does not necessarily correspond to perceived threat or psychological impact. Under prolonged threat, auditory processing may become oriented toward detecting potentially significant acoustic cues; therefore, auditory vigilance is conceptualized here as a possible functional mode of attention rather than an established independent psychological construct. The framework further distinguishes perceived acoustic properties, affective appraisal, and consciously experienced states, acknowledging that activation and bodily readiness may precede explicit emotional interpretation.

The proposed multidimensional framework conceptualizes wartime soundscape perception as a dynamic interaction between acoustic signals, individual experience, contextual conditions, and their psychological meaning. It provides a theoretical basis for empirical research on individual differences in auditory experience and on the relationships among sound perception, threat appraisal, auditory vigilance, phenomenological experience, behavioural regulation, sleep, and psychological well-being under conditions of war.

Keywords: wartime soundscape; sound perception; psychoacoustic salience; threat appraisal; auditory vigilance; phenomenological experience; behavioural regulation; psychological well-being.

Problem statement

The acoustic environment constitutes a continuous component of human

experience, yet its psychological significance becomes qualitatively different under conditions of prolonged threat [4; 5; 15]. In ordinary circumstances, environmental sounds are predominantly processed as elements of everyday activity and may remain outside the focus of conscious attention. Under conditions of war-related stress, however, sounds can acquire direct threat-related meaning [5; 15]. Sirens, explosions, drones, aircraft, gunfire, impacts, distant detonations, and even ambiguous low-frequency sounds may become signals requiring immediate evaluation. Consequently, the psychological perception of a soundscape during war cannot be reduced to the physical intensity or frequency characteristics of acoustic stimuli [12].

Contemporary soundscape research conceptualizes the soundscape as the human perception of the acoustic environment within a particular context, accompanied by psychological and physiological responses [1; 2; 9]. This approach differs fundamentally from conventional environmental-noise research, which primarily examines exposure levels and their adverse effects. Standard ISO 12913-1 explicitly places human perception and contextual experience at the centre of soundscape analysis [9].

This distinction is particularly important in conditions of war. The same acoustic stimulus may have substantially different psychological meanings depending on the listener's previous experience, perceived controllability, situational uncertainty, proximity to the threat, time of day, and expectations concerning possible consequences [5; 16]. A sudden loud sound can therefore function simultaneously as a physical acoustic event, a perceptual object, an emotional stimulus, and a threat signal.

Research on environmental noise has established associations between acoustic exposure, stress responses, annoyance, sleep disturbance, cognitive functioning, and broader health outcomes [3; 10; 13; 14; 17]. However, the dominant models of environmental noise are insufficient for describing a war-

related acoustic environment. They tend to treat sound primarily as an exposure variable, whereas war transforms sound into an information-bearing and potentially threat-signalling component of the environment [5; 12].

This problem is especially relevant for civilian populations living under prolonged exposure to air-raid alarms, explosions and other war-related sounds [4; 12]. Subjective perceived threat can be strongly associated with post-traumatic stress symptoms and sleep disturbance, providing information that cannot be captured by objective indicators of geographical or physical war exposure alone. The finding suggests that psychological appraisal of threatening events may be a critical mediator between environmental exposure and psychological outcomes [12].

Therefore, an adequate psychological account of wartime sound perception requires integration of two complementary perspectives. The first concerns the psychoacoustic dimension: intensity, frequency composition, temporal structure, roughness, sharpness, loudness, fluctuation, impulsivity and other perceptually relevant properties of sound [6]. The second concerns the phenomenological dimension: how the sound is experienced, interpreted, emotionally appraised, remembered, anticipated and incorporated into the individual's lived environment [5].

The theoretical problem is to explain how acoustic characteristics become psychologically meaningful threat experiences and how prolonged war-related stress modifies the perception and interpretation of the acoustic environment itself [5; 12; 16].

Analysis of recent research and publications

Soundscape research emerged partly as a response to the limitations of traditional noise-oriented approaches [1; 2; 9]. Whereas noise assessment usually focuses on measurable exposure, soundscape research asks how an acoustic

environment is perceived and experienced by people within a particular context [1; 9]. The ISO 12913 framework defines soundscape through human perception of the acoustic environment in context [9]. This conceptualization allows researchers to distinguish between the physical acoustic environment and its psychological representation [2]. A substantial body of soundscape research indicates that perceived acoustic environments can be described using affective dimensions such as pleasantness and eventfulness or related constructs such as calmness and vibrancy [1; 2; 7]. Perceived sound sources and contextual characteristics may provide more informative predictors of subjective soundscape quality than conventional acoustic metrics alone [1]. This is theoretically important for war-related soundscapes because the psychological meaning of a sound is not necessarily proportional to its physical intensity. A relatively quiet but ambiguous sound may generate substantial vigilance when it is interpreted as potentially threatening, whereas a loud sound that has become familiar and predictable may elicit a different psychological response [16].

Psychoacoustics examines the relationship between physical characteristics of acoustic stimuli and their perceptual correlates. Within soundscape research, psychoacoustic indicators have increasingly been used to characterize acoustic environments. A review of psychoacoustic indicators in soundscape research demonstrates considerable diversity in the parameters used to describe acoustic environments and highlights the importance of connecting physical acoustic properties with human perceptual responses. For the study of wartime soundscapes, several psychoacoustic dimensions appear particularly relevant: loudness — perceived magnitude of a sound; sharpness — perceptual correlate of the distribution of high-frequency energy; roughness — perception associated with rapid amplitude modulation; fluctuation strength — perception of slower amplitude changes; impulsivity — perceptual salience of abrupt acoustic events; spectral composition — the distribution of acoustic energy across frequencies;

temporal predictability — regularity or irregularity of sound occurrence; duration and intermittency — temporal properties that influence anticipation and monitoring. These characteristics should not be regarded as direct psychological determinants. Rather, they represent properties of the acoustic signal that enter into a larger perceptual and interpretative process [6; 16].

Research on emotional responses to soundscapes frequently identifies two broad dimensions — valence and arousal — as particularly useful for describing affective reactions to acoustic environments. Importantly, perceived emotional qualities of an acoustic environment cannot always be equated with emotions actually experienced by the listener. This distinction is crucial in wartime conditions. A person may perceive a sound as threatening without experiencing a fully articulated emotion such as fear. Conversely, the individual may experience physiological arousal or anxiety before consciously identifying the sound or its meaning. Thus, three analytically distinct levels should be considered: perceived acoustic properties — what the sound perceptually is; affective appraisal — how the sound is evaluated; felt experience — what the individual subjectively experiences in response [7; 16]. The relationship between these levels is dynamic rather than linear.

Recent work on stress and auditory perception indicates that acute and chronic stress may influence auditory salience, attention and sensory gain through partly different mechanisms. Chronic stress may be associated with more persistent changes in auditory processing and perception. This provides an important theoretical basis for understanding war-related sound perception. Prolonged exposure to threat may alter not only emotional responses to sounds but also the allocation of attention to auditory information. The concept of hypervigilance is particularly relevant. PTSD research has consistently described enhanced processing of threat-related stimuli, hyperarousal, exaggerated startle and attentional biases toward threat cues. Recent research has additionally

reported auditory illusions in individuals with PTSD and linked them to hypervigilance, reliving and dissociative processes. Nevertheless, it would be premature to treat auditory hypervigilance as an established, independent psychological construct applicable to all civilians exposed to war. A theoretically safer approach is to conceptualize auditory vigilance as a potential functional mode of attention characterized by increased monitoring of acoustic information for possible threat significance [8].

The psychological importance of sound is also mediated by its effects on sleep. A systematic review and meta-analysis found significant associations between nighttime environmental noise and self-reported sleep disturbance [14]. The WHO likewise identifies sleep disturbance, annoyance, cognitive effects, psychophysiological responses and mental-health-related outcomes among the consequences associated with excessive environmental noise [3; 10; 17]. War-related sounds differ from ordinary environmental noise in one particularly important respect: their potential meaning may remain uncertain but consequential. An explosion during the night is not merely a loud acoustic event; it may signal immediate danger, require behavioural action, interrupt sleep, activate memory of previous attacks and generate anticipatory monitoring for subsequent sounds [12; 17]. Thus, the psychological effect of a wartime soundscape cannot be adequately explained by acoustic exposure alone.

Purpose of the article

The purpose of this theoretical article is to conceptualize the dimensions of soundscape perception under conditions of war-related stress and to develop an integrative psychological framework explaining how acoustic properties, perceptual processing, contextual appraisal, emotional activation, memory and threat monitoring interact in the formation of wartime auditory experience.

Presentation of the main material of the study

The central theoretical proposition is that a wartime soundscape should be conceptualized not as a collection of acoustic stimuli but as a multilayered psychological system [1; 9]. Its first level is the physical-acoustic environment. It includes measurable properties of sounds and their temporal distribution. The second level is psychoacoustic perception, through which physical acoustic parameters become perceptually meaningful qualities such as loudness, sharpness, roughness, impulsivity or prominence [6]. The third level is source identification. The listener attempts to determine what produced the sound: an aircraft, explosion, drone, siren, vehicle, building, household object or an unidentified source [16]. The fourth level is contextual appraisal. The sound is evaluated according to questions such as: «Is it dangerous? Is it approaching? Is it directed toward me? Does it require action?» [12; 16]. The fifth level is phenomenological experience, encompassing the subjective character of the experience: tension, fear, alertness, uncertainty, helplessness, familiarity, bodily activation, temporal distortion, intrusive memories or a feeling that the environment has become unsafe [5; 7]. The sixth level is behavioural regulation, which includes monitoring, seeking information, moving to shelter, checking communication channels, waking others, avoiding particular locations or attempting to habituate to the sound. These levels should not be interpreted as strictly sequential. They interact continuously and recursively.

Under ordinary conditions, auditory perception is primarily concerned with identifying relevant information in a complex acoustic environment. Under war-related stress, the functional significance of auditory perception may shift from general environmental monitoring toward threat detection [8; 12]. This transformation can be represented conceptually as such a sequence: acoustic event, perceptual salience, source attribution, threat appraisal, affective/physiological activation, behavioural readiness. However, the process is influenced by prior

experience and expectations. Consequently, the same acoustic event may produce different responses in different individuals or in the same individual at different moments. For example, an unfamiliar low-frequency sound may initially be processed as ambiguous. If the individual has previously experienced drone attacks associated with similar sounds, the stimulus may rapidly acquire threat significance. The resulting response may occur before conscious identification is completed. This suggests that the psychological significance of wartime sound is partly learned and memory-dependent [8; 16].

A phenomenological analysis requires attention not only to what a person hears but to how the sound is experienced as part of the person's lived world. Several dimensions can theoretically be distinguished: threat-related meaning (the sound may be experienced as a warning, indication of danger, confirmation of an ongoing attack or anticipation of a possible future event); temporal experience (threat-related sounds may alter subjective temporal experience. A short acoustic event may become phenomenologically extended because attention remains focused on whether another sound will follow); spatial experience (the perceived distance and direction of a sound may acquire particular importance. The question is not simply what is the sound? But where is it, and how close is it?) [5; 15]; bodily experience (auditory threat may be accompanied by increased muscle tension, heart-rate changes, startle responses and a subjective sense of bodily readiness. Existing soundscape research demonstrates that physiological responses can accompany acoustic perception, although their relationship with subjective descriptors is not yet consistently established); predictability and uncertainty (a predictable sound can be psychologically different from an unpredictable one even when their acoustic characteristics are similar. Uncertainty concerning when the next sound will occur may itself become a source of stress); familiarity and learning (repeated exposure can produce familiarity, but familiarity does not necessarily imply complete habituation. In a threat environment, repeated

exposure may instead strengthen associations between particular acoustic patterns and danger). Consequently, habituation and sensitization should be considered competing or context-dependent processes rather than assuming that repeated exposure automatically reduces responsiveness.

One of the central theoretical distinctions proposed here is between psychoacoustic salience and psychological salience. Psychoacoustic salience concerns the degree to which a sound stands out perceptually because of its acoustic characteristics [6]. Psychological salience concerns the degree to which the sound is considered relevant to the individual's safety, goals or current situation [16]. The two dimensions may diverge. A loud but familiar household sound may have high psychoacoustic salience but low psychological salience. Conversely, a relatively weak or distant sound may have low physical intensity but high psychological salience because it resembles a previously experienced threat [12]. This distinction provides a possible explanation for why conventional noise metrics cannot fully capture wartime auditory stress [12; 13].

The proposed framework can be summarized through the following relationship: psychoacoustic properties, prior experience, situational context, perceived threat and attentional state form phenomenological sound experience [5; 6; 8; 12; 16]. This formulation implies that the psychological response to sound is neither exclusively stimulus-driven nor exclusively subjective. The acoustic signal provides constraints on perception, but psychological meaning determines how the signal is integrated into the person's current model of the environment [16]. This approach is compatible with contemporary soundscape research, which emphasizes contextual perception rather than acoustic measurement alone [1; 9].

Based on the reviewed literature, the wartime soundscape can be represented through six interacting domains: acoustic domain (core variables: intensity, spectrum, temporal structure, impulsivity; psychological function: physical signal characteristics); psychoacoustic domain (core variables: loudness, sharpness,

roughness, fluctuation, salience; psychological function: perceptual organization) [6]; cognitive domain (core variables: identification, ambiguity, predictability, source attribution; psychological function: interpretation of the sound) [16]; affective domain (core variables: valence, arousal, fear, tension, annoyance; psychological function: emotional appraisal) [7]; phenomenological domain (core variables: felt threat, bodily readiness, temporal/spatial experience, sense of safety; psychological function: lived experience) [5]; behavioural regulation (can be treated as the outcome and feedback component of the system) [11; 12]. This model allows the same sound to be analysed simultaneously at different levels without reducing one level to another.

Conclusions

The theoretical analysis demonstrates that the psychological perception of the acoustic environment under conditions of war-related stress cannot be adequately explained by physical acoustic exposure alone. A wartime soundscape should instead be conceptualized as a multilayered psychological system in which acoustic characteristics acquire meaning through perceptual processing, source identification, contextual threat appraisal, affective activation, phenomenological experience, and behavioural regulation. The analysis identifies six interrelated domains of wartime soundscape perception: acoustic, psychoacoustic, cognitive, affective, phenomenological, and behavioural. These domains should be treated as analytically distinguishable but functionally interconnected components of a dynamic system. In particular, the distinction between psychoacoustic salience and psychological salience demonstrates that the perceptual prominence of a sound and its relevance to perceived safety may diverge substantially. Consequently, acoustic intensity or other objective parameters cannot be assumed to directly determine psychological impact.

The psychological significance of war-related sounds is shaped by the

interaction of acoustic properties with prior experience, memory, situational context, predictability, perceived threat, and attentional state. Prolonged exposure to threat may shift auditory processing toward increased monitoring of acoustic information for potential threat significance. In this context, auditory vigilance is more appropriately understood as a potential functional mode of attention than as an established independent psychological construct applicable to all civilians exposed to war.

The proposed framework also establishes the importance of distinguishing perceived acoustic properties, affective appraisal, and felt experience. A sound may be perceived as threatening without being accompanied by a consciously articulated emotion, while physiological or affective activation may precede conscious identification and interpretation. The phenomenological experience of wartime sound therefore includes not only emotional responses but also changes in perceived safety, bodily readiness, temporal and spatial experience, predictability, and the interpretation of the surrounding environment.

Thus, the perception of a wartime soundscape is best understood as a dynamic interaction between its dimensions (or levels), acoustic signal characteristics and their context-dependent psychological meaning. The proposed multidimensional framework provides a theoretical basis for further empirical investigation of individual differences in wartime auditory experience, including the relationships among psychoacoustic characteristics, threat appraisal, auditory vigilance, phenomenological experience, behavioural regulation, sleep, and psychological well-being.

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