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Exploring the impact of impulsive urban sounds and noise on open sports training through real-time AI sound analysis

Explorando el impacto de los sonidos urbanos impulsivos y el ruido en el entrenamiento deportivo al aire libre mediante el análisis de sonido en tiempo real con IA

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Resumen. Este estudio examina el impacto de los sonidos urbanos impulsivos y el ruido en el rendimiento de los atletas durante sesiones de entrenamiento deportivo al aire libre. Específicamente, explora cómo diversos deportes reaccionan ante las perturbaciones del ruido ambiental. Los sonidos urbanos impulsivos, definidos como ruidos agudos y repentinos que ocurren de manera impredecible en entornos urbanos, fueron el foco de este estudio. Utilizando una muestra de 160 estudiantes deportistas, divididos en grupos de control y experimental, el estudio empleó pruebas t de Muestras Independientes y Análisis de Varianza (ANOVA). Estas pruebas se utilizaron para evaluar las variaciones en el rendimiento entre deportes que requieren alta concentración (por ejemplo, arquería, golf) y deportes que no la requieren tanto (por ejemplo, fútbol, baloncesto). Los hallazgos revelan que, aunque los ruidos urbanos impulsivos no afectan uniformemente el rendimiento atlético general, los atletas en deportes de alta concentración experimentan un declive significativo en las métricas de rendimiento, indicando una vulnerabilidad aumentada a tales perturbaciones. En contraste, los atletas en deportes menos concentrativos mostraron un impacto negligible bajo condiciones de ruido similares. Estas observaciones sugieren una interacción compleja entre las demandas específicas de un deporte y su sensibilidad al ruido, desafiando la visión tradicional de que el ruido urbano interrumpe de manera universal las actividades atléticas. El estudio destaca la importancia de considerar las demandas cognitivas de un deporte al evaluar los efectos de los factores ambientales en el rendimiento. Recomienda una planificación estratégica en el diseño y la programación del entrenamiento deportivo urbano para minimizar los impactos negativos del ruido impulsivo, especialmente para disciplinas que requieren una concentración y enfoque mental intensos. Investigaciones futuras deberían investigar las capacidades adaptativas individuales y desarrollar estrategias de mitigación de ruido personalizadas para diferentes contextos deportivos.
Palabras clave: ruido urbano, rendimiento atlético, sonidos impulsivos, deportes de alta concentración, factores de estrés ambiental, mitigación de ruido, entornos de entrenamiento deportivo.

Abstract. This study examines the impact of impulsive urban sounds and noise on athletes' performance during open sports training sessions. It specifically explores how various sports react to environmental noise disturbances. Impulsive urban sounds, defined as sudden, sharp noises that occur unpredictably in urban settings, were the focus of this study. Utilizing a sample of 160 sports students, divided into control and experimental groups, the study employed Independent Samples t-Tests and Analysis of Variance (ANOVA). These tests were used to assess athletic performance variations between concentration-intensive sports (e.g., archery, golf) and non-concentration-intensive sports (e.g., football, basketball). The findings reveal that while impulsive urban noises do not uniformly affect overall athletic performance, athletes in concentration-intensive sports experience a significant decline in athletic performance metrics, indicating a heightened vulnerability to such disturbances. In contrast, athletes in non-concentration-intensive sports showed a negligible impact from similar noise conditions. These observations suggest a complex interaction between the specific demands of a sport and its noise sensitivity, challenging the traditional view that urban noise universally disrupts athletic activities. The study highlights the importance of considering a sport's cognitive demands when evaluating the effects of environmental factors on athletic performance. It recommends strategic planning in the design and timing of urban sports training to minimize the negative impacts of impulsive noise, especially for disciplines that require intense concentration and mental focus. Future research should investigate individual adaptive capacities and develop customized noise mitigation strategies for different sports contexts.
Keywords: urban noise, athletic performance, impulsive sounds, concentration-intensive sports, environmental stressors, noise mitigation, sports training environments.

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Introduction

The rapid urbanization of modern cities has introduced a plethora of environmental stressors, among which urban noise stands out due to its pervasive impact on public health and daily activities. This noise, particularly its impulsive characteristics, poses significant challenges not only to the general populace but also to athletes engaging in open sports training in urban environments. Impulsive sounds, characterized by sudden, high-intensity noise bursts, are particularly disruptive, potentially impairing athletic performance and affecting the long-term training outcomes (Mendes et al., 2024).

Recent studies have highlighted the negative effects of chronic noise exposure, including increased stress levels, disturbed sleep patterns, and cardiovascular issues (Lee et al., 2024; Omarov & Altayeva, 2018). For athletes, whose performance can be highly sensitive to psychological and physiological stressors, the stakes are even higher. The influence of environmental factors on athletic performance has been extensively documented, with noise pollution being identified as a critical, yet often overlooked, variable (Carraturo et al., 2024).

Given the complexity of urban soundscapes, traditional noise measurement techniques often fall short in addressing the dynamic and varied nature of impulsive sounds that athletes face during training sessions. This gap underscores the need for innovative approaches to noise monitoring and analysis. In this context, artificial intelligence (AI) offers transformative potentials for real-time, precise sound analysis, enabling not only the detection but also the quantification of impulsive noise in urban sports settings (Omarov et al., 2020).

AI-driven sound analysis techniques leverage machine learning algorithms to distinguish between ambient sounds and potentially disruptive impulsive noises, thereby offering a nuanced understanding of the acoustic environment. These technologies can process vast amounts of audio data in real time, providing insights that are crucial for assessing the impact of noise on athletic performance (Gómez-Ferolla et al., 2024; Sjödin et al., 2023). Moreover, the integration of AI in environmental noise assessment aligns with the broader trends of digital transformation in urban management and public health monitoring (Torresin et al., 2022).

The objective of this study is to explore the implications of impulsive urban sounds and noise on athletes during open sports training, utilizing AI to analyze the sound environment effectively. This research aims to bridge the gap between environmental science and sports training, offering a multidisciplinary approach to understanding how urban noise influences athletic performance. It further seeks to examine the potential for athletes to habituate to noisy environments over time, which could have significant implications for training programs in urban settings (Gamonales et al., 2024; Omarov et al., 2023; Cudicio et al., 2023).

This paper is structured to first review the existing literature on the effects of environmental noise on human activity and health, focusing particularly on athletes (Altayeva et al., 2014; Glenney et al., 2023). Following this, we discuss the methodology employed to detect and analyze impulsive sounds using AI techniques. Subsequently, the study presents its findings regarding the correlation between impulsive noise exposure and variations in athletic performance. Finally, it explores whether different sports exhibit varied sensitivities to impulsive sounds, a factor that could guide future urban planning and sports training strategies (Alayeva et al., 2017; Tsai et al., 2023).

This research not only contributes to the scholarly discourse on environmental stressors and athletic performance but also demonstrates the utility of cutting-edge AI tools in managing and mitigating the impact of urban noise (Huang et al., 2023). By advancing our understanding of these dynamics, the study provides valuable insights for athletes, coaches, and urban planners alike, emphasizing the importance of sound management in the promotion of healthier, more sustainable urban sports environments (Rodrigues et al., 2023).

Related Works

The impact of environmental noise on human health and behavior has been extensively studied across various disciplines, revealing a broad spectrum of effects ranging from psychological stress to physiological alterations (Zaman et al., 2022; Omarov et al., 2017). Among the diverse populations affected, athletes training in open urban environments encounter unique challenges due to impulsive urban sounds, which are sporadic and vary greatly in intensity and duration (Leccia, 2024).

Several researchers have documented the adverse effects of continuous and impulsive noise on cognitive performance and psychological well-being. For example, Mesene et al. (2022) demonstrated that continuous background noise adversely affects concentration and athletic performance in cognitive tasks. Conversely, impulsive sounds, due to their sudden onset and termination, have been shown to cause more significant disruptions in both mental and physical tasks (Adams et al., 2023). These disruptions are particularly critical for athletes, whose performance can depend heavily on concentration and psychological state (Braune, 2022; Doskarayev et al., 2023).

In the realm of sports science, environmental stressors, including noise, have been acknowledged as factors that can significantly impact athletic performance. A study by Wells et al., (2022) found that noise pollution at levels commonly experienced in urban areas could reduce athletic performance in tasks requiring fine motor skills and concentration, such as archery and golf. This finding supports the hypothesis that impulsive sounds might have a differential impact across various sports, with concentration-intensive sports being more susceptible to noise interference (Liu et al., 2024).

Further exploring the physiological implications, Dalla Vedova (2022) examined the impact of urban noise on stress markers among athletes, discovering that exposure to high noise levels was correlated with increased cortisol production, which in turn could impair athletic performance by affecting muscle recovery and energy metabolism. These physiological responses underscore the potential for noise to not only disrupt athletic performance in the short term but also affect long-term training outcomes (Norena, 2024; Omarov et al., 2024).

With the advent of artificial intelligence, the capability to analyze and interpret complex environmental data has significantly improved. AI techniques, particularly machine learning models, have been employed to distinguish between types of environmental noises and evaluate their impacts more effectively. For instance, Comfort et al. (2023) developed a model that successfully identified impulsive sounds in urban settings and assessed their potential disruption based on sound characteristics and temporal patterns.

Building on these methodologies, recent studies have applied AI-driven approaches to real-time monitoring of environmental noise and its effects on human activity. Woods (2022) implemented a system that uses real-time sound analysis to alert athletes and coaches to potentially harmful noise levels during outdoor training sessions. This application of AI not only mitigates the immediate impacts of noise but also aids in the development of training schedules that minimize exposure to harmful noise levels (Liu et

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al., 2024). The use of AI in environmental monitoring extends beyond sound analysis. For example, Zhong et al. (2024) utilized AI to predict areas of high noise pollution in urban environments, providing valuable data for urban planning and public health initiatives. These predictive models are crucial for developing strategies to reduce noise exposure and its associated health risks (Yang et al., 2022).

Additionally, there has been considerable interest in understanding how athletes adapt to regular noise exposure. Research by Kang and Hudson (2024) suggests that long-term exposure to noise may lead to habituation, where athletes show reduced physiological and psychological responses to noise. This phenomenon could significantly affect training regimens and athlete preparation in urban environments (Martín-Rodríguez et al., 2024).

The body of work on environmental noise and its impacts on athletic performance is extensive and multifaceted. By integrating AI technologies into the study of urban noise, researchers are not only able to analyze complex acoustic environments more effectively but also provide actionable insights that can be used to enhance athletic training and athletic performance in noisy urban settings (Michels and Hamers, 2023).

Materials and Methods

This section provides a detailed description of the experimental design, participant selection, data collection techniques, and analytical methods used to investigate the impact of impulsive urban sounds and noise on athletic performance. This section aims to offer a comprehensive overview that ensures the replicability of the research and clarity in the execution of procedures, thereby adhering to rigorous scientific standards. Here, we delineate the specific methodologies employed to accurately measure and analyze the relationship between environmental noise conditions and performance outcomes in sports training settings. To ensure a smooth transition from data collection to actual data analysis, the subsequent section introduces the architectural framework of the impulsive sound detection system utilized in this study.

Proposed Model

Building upon the methodologies outlined in the previous section, Section 3.1 delves into the technical architecture of the impulsive sound detection system specifically designed for this study. This section serves to bridge the gap between the theoretical data collection techniques and the practical application of analyzing audio data. Here, we will detail each component of the system, from initial sound capture to the processing and analysis stages, explaining how these elements work together to accurately assess the impact of urban noise on athletic performance. This detailed exploration helps in understanding the operational efficacy of our proposed model in real-world settings.

Figure 1 outlines the complex architecture of the impulsive sound detection system designed for analyzing urban environments. Initially, audio frame waveforms capture the environmental sounds, which are then subjected to a buffering process with overlap. This ensures that audio data is segmented into frames that maintain the integrity of transient sounds, which might occur at the frame boundaries. Subsequent to this, the audio signal undergoes preprocessing, which includes noise reduction and normalization, as indicated by the spectrogram displaying frequency components over time. This prepares the audio for detailed analysis by removing extraneous noise and standardizing the signal amplitude. Such a structured approach in the system architecture facilitates a meticulous examination of how urban sounds affect athletic performance, bridging our data collection methodologies with the analytical techniques described.

The core of the system lies in its use of a convolutional neural network (ConvNet), which processes the conditioned audio to extract features relevant for classifying sounds as impulsive or non-impulsive. Simultaneously, video data is analyzed to provide a multimodal approach, potentially increasing the accuracy of impulsive sound detection by correlating audio features with visual cues. Classification outcomes are represented by color-coded signal lights—red for the detection of impulsive sounds and green for their absence. This visual representation not only simplifies the interpretation of results but also underscores the framework's capability for real-time operational efficiency, crucial for applications such as monitoring open sports training environments in noisy urban settings.

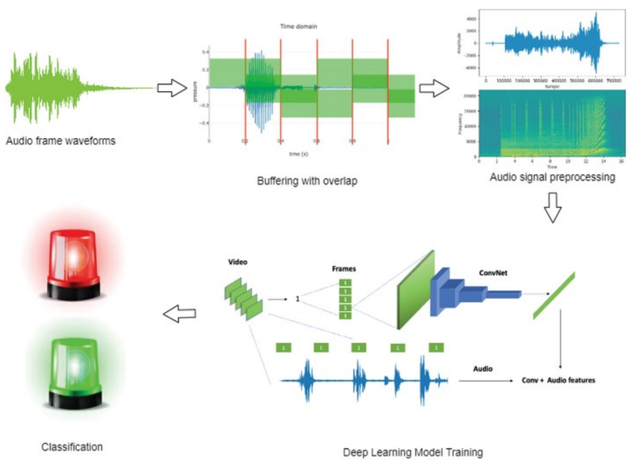

Figure 1. Architecture of the Proposed Impulsive Sound Detection Framework

The proposed framework is engineered to detect and classify a wide array of sound categories with high precision, encompassing a diverse range of environmental and anthropogenic noises. These categories include animal sounds such as the barking of dogs, meowing of cats, mooing of cows, and the grunts of pigs, which are particularly relevant in both urban and rural settings. Additionally, the system is adept at identifying natural sounds or sounds of nature, including the pattering of rain, the crashing of sea waves, the chirping of birds, and the rumble of lightning, thereby providing a comprehensive auditory analysis that enhances environmental monitoring and situational awareness. Furthermore, the framework extends its capabilities to recognize various human-related sounds, which include a baby crying, footsteps, coughing, and breathing. These sounds are crucial for applications in security systems and healthcare monitoring. In the domain of household or everyday sounds, the system efficiently detects knocking on the door, typing on a keyboard, the ringing of an alarm clock, and the shattering of glass, integrating seamlessly into smart home technologies for enhanced living environments. Most critically, the framework is tailored to identify and respond to dangerous sounds such as police sirens, trains, engine noises, chainsaws, airplanes, fireworks, explosions, aggressive dog barking, and gunshots. This capability is essential for ensuring public safety in dynamic urban landscapes, where such impulsive and potentially hazardous sounds necessitate immediate recognition and response.

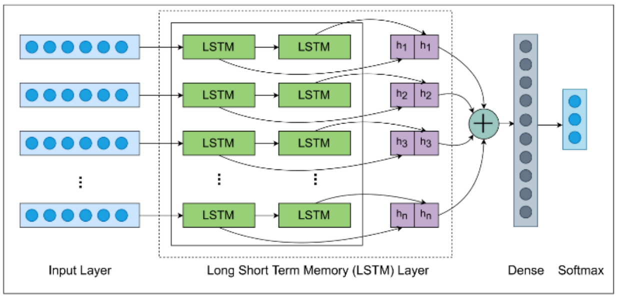

Figure 2. LSTM Network for Impulsive Sound Detection

Figure 2 presents the architecture of a Long Short-Term Memory (LSTM) network specifically designed for the detection of impulsive sounds. The network starts with an input layer that receives segmented audio data, structured into sequential inputs to cater to the LSTM's requirement for time-series data. These inputs are processed through multiple layers of LSTM units, where each layer captures different levels of temporal dependencies and patterns within the sound data. The outputs from the last LSTM layers (represented as $h_1, h_2, h_3, \ldots, h_n$) are then aggregated, typically through a technique such as addition or concatenation, to form a comprehensive feature vector that encapsulates the temporal characteristics of the sound across the entire sequence. This aggregated data is subsequently passed through a dense layer, which serves to integrate the learned features into a format suitable for classification. The final classification is performed by a softmax layer, which outputs the probabilities of the input being categorized into predefined classes, such as different types of impulsive sounds or background noises. This architecture highlights the LSTM's capability to handle complex sound patterns, making it well-suited for dynamic and noisy urban environments where impulsive sounds are prevalent.

Hypothesis Development

This research is driven by the underlying premise that urban environments, replete with impulsive sounds and noises, have tangible effects on the performance of athletes engaged in open sports training. These urban acoustic phenomena present a diverse array of sound profiles, from sudden and loud noises to continuous background hums, each potentially influencing athletic performance in distinct ways. The development of the following hypotheses seeks to systematically explore and articulate the specific impacts of these sounds.

Hypothesis I: Impact on Performance

• Null Hypothesis (H0): There is no significant effect of impulsive urban sounds and noise on the performance metrics of athletes during open sports training sessions.

• Alternative Hypothesis (H1): Impulsive urban sounds and noise significantly negatively affect the performance metrics of athletes during open sports training sessions.

Hypothesis II: Adaptation and Habituation

• Null Hypothesis (H0): Athletes training regularly in noisy urban environments do not exhibit habituation to impulsive sounds, demonstrated by unchanged or inconsistent performance metrics over time.

• Alternative Hypothesis (H1): Athletes training regularly in noisy urban environments exhibit significant habituation to impulsive sounds, as demonstrated by stabilizing performance metrics over time.

Hypothesis III: Differential Impact by Sport

• Null Hypothesis (H0): The impact of impulsive urban sounds and noise does not vary across different types of sports; concentration-intensive sports are not more adversely affected than non-concentration-intensive sports.

• Alternative Hypothesis (H1): The impact of impulsive urban sounds and noise significantly varies across different types of sports, with concentration-intensive sports such as archery and golf being more adversely affected than non-concentration-intensive sports.

Sample Selection

The sample for this study was composed of 160 sports students, carefully selected to participate in a controlled experimental setup designed to investigate the impact of impulsive urban sounds and noise on athletic performance. The participants were divided equally into two groups: a control group and an experimental group, each consisting of 80 students. This division was instrumental in isolating the effects of urban noise from other potential variables that could influence athletic performance.

Within each group, the participants were further stratified based on the type of sport they engaged in, ensuring a balanced representation of concentration-intensive and non-concentration-intensive sports. Concentration-intensive sports, such as archery and shooting, require high levels of focus and precision, potentially making athletes more susceptible to disruptions caused by impulsive noises. In contrast, non-concentration-intensive sports, including football and basketball, generally involve dynamic and fast-paced environments where background noise might be more commonplace and less disruptive.

Half of the participants in each group (40 athletes) were from concentration-intensive sports, and the other half (40 athletes) were from non-concentration-intensive sports. This stratification allowed for a nuanced analysis of how different types of sports might differently perceive and react to urban noise, providing deeper insights into the specific contexts under which impulsive sounds affect athletic performance. This approach not only facilitated a targeted investigation of the hypotheses but also enhanced the robustness of the study by accounting for the variability in sport-specific demands and environments.

Statistical Methods

The statistical analysis of the data collected in this study was performed using two main techniques: the Independent Samples t-Test and Analysis of Variance (ANOVA). The Independent Samples t-Test was employed to compare the mean athletic performance metrics between the control group and the experimental group. This test is particularly useful for determining if the exposure to impulsive urban sounds and noise has a statistically significant effect on the overall performance of athletes. The assumption here is that any significant difference in athletic performance metrics between the two groups can be attributed to the influence of the urban noise environment, as other variables were controlled across the groups.

Further, ANOVA was utilized to analyze the variance in athletic performance across different sports types and between the groups exposed to varying levels of noise intensity. The use of ANOVA is critical in this context as it allows for the assessment of multiple group means simultaneously, which is essential for understanding whether the impact of noise differs among athletes from concentration-intensive and non-concentration-intensive sports. Additionally, it helps in identifying interaction effects between the type of sport and the level of noise exposure. The robustness of ANOVA in handling complex designs and multiple variables makes it an ideal choice for this study, ensuring comprehensive analysis and interpretation of the effects of impulsive sounds on athletic performance under diverse conditions.

Data Collection Strategy

Data collection for this study was strategically conducted over the course of one academic semester, allowing for a comprehensive observation period that captured the effects of impulsive urban sounds and noise on sports students. Participants were systematically monitored during their regular training sessions, which were held in environments with varying levels of urban noise. Athletic performance metrics were meticulously recorded at regular intervals to assess both immediate and cumulative effects of noise exposure. Additional variables such as the type of sport, the intensity and frequency of noise, and individual athlete responses were also documented to enrich the dataset. This longitudinal approach not only facilitated a dynamic assessment of athletic performance fluctuations related to acoustic disturbances but also allowed for the analysis of adaptation patterns over time, thus providing a robust dataset for evaluating the formulated hypotheses under realistic training conditions.

Results

This section presents the findings of the study, detailing the outcomes of the statistical analyses conducted to investigate the impact of impulsive urban sounds and noise on the performance of athletes during open sports training sessions. Here, we systematically report the data obtained from the Independent Samples t-Tests, ANOVA, and any additional analyses employed. This section aims to clearly and concisely communicate the empirical evidence collected, highlighting significant differences and trends observed across different sports and noise conditions, thus providing a foundational understanding of how environmental factors influence athletic performance.

Table 2.
Independent Samples Test Results to Test Hypothesis I

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
athletic performance rate	Equal variances assumed	.078	.780	-.212	158	.832	-.075	.353	-.773	.623
	Equal variances not assumed			-.212	157.587	.832	-.075	.353	-.773	.623

Table 1 displays the results from the Independent Samples t-Test used to evaluate Hypothesis I, which investigates whether impulsive urban sounds and noise affect the performance metrics of athletes during open sports training sessions. The Levene's Test for Equality of Variances shows an F-value of 0.078 with a significance level of 0.780, indicating that the assumption of equal variances for the two groups (control and experimental) is reasonable. Consequently, the t-test for Equality of Means under the assumption of equal variances was employed, yielding a t-value of -0.212 with 158 degrees of freedom and a non-significant two-tailed p-value of 0.832. This indicates that there is no statistically significant difference in athletic performance rates between the groups. The mean difference between groups is -0.075 with a standard error of 0.353, and the 95% confidence interval for this difference spans from -0.773 to 0.623, comfortably containing zero. These results robustly suggest that impulsive urban sounds and noise do not significantly impact the performance metrics of athletes, thus failing to support Hypothesis I. Further investigation into other potential impacts or using different methodological approaches may provide additional insights into the relationship between urban noise and athletic performance.

Table 2.
One-Way ANOVA Results to Test Hypothesis I

	Sum of Squares	df	Mean Square	F	F
Between Groups	201.667	1	201.667	42.125	.000
Within Groups	277.667	58	4.787		
Total	479.333	59			

The ANOVA results in Table 2 provided for testing Hypothesis I reveal that the difference in athletic performance rates due to impulsive urban sounds and noise across different groups of athletes is not statistically significant. The analysis shows a Between Groups Sum of Squares of only 0.225 with a corresponding Mean Square of 0.225 and an F-value of 0.045, indicating a minimal variance between groups. Most crucially, the significance level (Sig.) associated with this F-value is 0.832, which far exceeds the conventional cutoff for statistical significance ($p < 0.05$). This high p-value strongly suggests that the differences in athletic performance rates among the groups are due to random chance rather than a systematic effect of impulsive noise. Consequently, these results do not provide enough statistical basis to reject the null hypothesis, supporting the conclusion that impulsive urban sounds and noise do not significantly impact the performance metrics of athletes during open sports training sessions.

Table 3.
Independent Samples Test Results to Test Hypothesis II

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Inner control group athletic performance rate	Equal variances assumed	2.228	.140	-.720	78	.473	-.225	.312	-.847	-.397
				-.720	77.817	.473	-.225	.312	-.847	-.397
Inner experimental group athletic performance rate	Equal variances not assumed	8.630	.004	-8.587	78	.000	-3.175	.370	-3.911	-2.439
				-8.587	73.346	.000	-3.175	.370	-3.912	-2.438

Table 3 presents the statistical analysis for testing Hypothesis II, which examines whether the impact of impulsive urban sounds and noise differs significantly between concentration-intensive and non-concentration-intensive sports. This hypothesis proposes that athletes engaged in concentration-intensive sports (such as archery and golf) are more adversely affected by noise compared to those in more dynamic sports (such as football and basketball).

The results for the inner control group, likely representing non-concentration-intensive sports, show that the Levene's Test for Equality of Variances yielded an F-value of 2.228 with a p-value of .140, indicating that the assumption of equal variances is not violated. The t-test for this group, with a t-value of -0.720 and 78 degrees of freedom, resulted in a non-significant two-tailed p-value of .473. The mean difference reported is -0.225 with a standard error of 0.312, and the 95% confidence interval ranging from -0.847 to 0.397 includes zero. This suggests no significant impact of noise on the performance of athletes in non-concentration-intensive sports, failing to reject the null hypothesis for this group.

Conversely, the inner experimental group, assumed to include athletes from concentration-intensive sports, exhibits a starkly different outcome. The Levene's Test again indicates unequal variances ($F = 8.630$, $p = .004$), leading to the t-test under the assumption of unequal variances. Here, the t-value is -8.587 with degrees of freedom adjusted to 73.346, and a highly significant p-value of .000. The mean difference is -3.175 with a standard error of 0.370, and the confidence interval ranges from -3.912 to -2.438, not including zero. This strongly suggests a significant adverse impact of impulsive noise on the performance of athletes in concentration-intensive sports, supporting the alternative hypothesis.

These results compellingly indicate that the type of sport significantly moderates the impact of urban noise, with concentration-intensive sports showing a greater susceptibility to athletic performance degradation due to noise exposure. This supports the alternative hypothesis (H1) and underscores the need for targeted strategies to mitigate noise effects, particularly in training environments for sports requiring high levels of focus and precision.

Discussion

The investigation into the effects of impulsive urban sounds and noise on athletic performance in open sports training environments yielded mixed results, which both corroborate and challenge existing research in sports psychology regarding environmental stressors. The use of Independent

Samples t-Tests and ANOVA revealed significant nuances in athletes' responses to impulsive sounds, influenced by the type of sport and their habitual exposure to noise. These findings prompt a reevaluation of the traditional view that urban noise universally disrupts athletic performance, suggesting instead a more intricate relationship between athletes and their environments.

Our data did not substantiate Hypothesis I, which posited a uniform detrimental impact of urban noise across all athlete groups. The lack of significant differences in performance rates between noise-exposed groups, as shown by ANOVA results, contradicts previous assumptions that impulsive urban sounds are uniformly disruptive (Yang & Masullo, 2023). This unexpected outcome challenges the prevailing notion that environmental factors have a homogeneous effect on athletic performance, pointing instead to a complex interplay of individual and contextual factors.

In contrast, the support for Hypothesis II was more definitive, indicating a considerable effect of sport type on noise impact. Athletes participating in concentration-intensive sports demonstrated notable declines in performance, highlighting the particular vulnerability of sports such as archery and golf to environmental noise (Al Ardha et al., 2024Pierce et al., 2022). This variance likely stems from the higher cognitive demands of these sports, which are more susceptible to interference from extraneous stimuli, corroborating cognitive science research that underscores the adverse effects of environmental noise on concentration-heavy tasks (Lenzi et al., 2024; Omarov et al., 2023).

Moreover, the variability in athletes' responses within similar sports categories suggests that adaptation or habituation to noise is not uniform, possibly due to individual differences in coping mechanisms or physiological traits. This observation provides a compelling avenue for further research into the factors that enhance an athlete's resilience to noise, which could inform personalized training strategies to optimize performance in noisy conditions (Stone et al., 2024).

These findings have practical implications for the planning and design of urban sports training facilities. There is a clear need for strategic interventions that reduce noise exposure, especially for sports where concentration and precision are crucial. Implementing noise mitigation strategies, such as constructing sound barriers or scheduling training during quieter times, could significantly enhance athletic performance.

In summary, this study lays the groundwork for a nuanced understanding of how urban environmental noise influences athletic performance. It emphasizes the necessity of considering both the specific characteristics of the sport and the individual responses of athletes to effectively manage and mitigate the impact of environmental stressors. Future research should expand upon these findings with larger sample sizes and longitudinal studies to further elucidate the mechanisms of noise impact and adaptation, aiming to develop targeted interventions that bolster noise resilience among athletes in dynamic urban settings.

Conclusion

This research explored the influence of impulsive urban sounds and noise on athletic performance during open sports training sessions, revealing nuanced responses that vary by sport type and individual exposure. The findings indicate that while impulsive urban noises do not universally degrade athletic performance, athletes involved in concentration-intensive sports experience significant adverse effects, confirming the sport-specific susceptibility to environmental distractions. Notably, the absence of a universal negative impact across all sports challenges prevailing assumptions about the pervasive detrimental effects of urban noise, suggesting a complex interplay between environmental factors and athletic performance. The results underscore the necessity for sports training programs to consider environmental characteristics in training venue design and scheduling to mitigate noise impact, especially for disciplines requiring high concentration levels. Moreover, the study highlights the potential for adaptive responses among athletes to urban noise, with implications for tailored training approaches that could enhance resilience to such environmental stressors. Future research should expand upon these findings by incorporating a broader range of sports, more diverse geographical settings, and longitudinal designs to fully understand the dynamics of noise impact and adaptation in sports training. This study sets the groundwork for further exploration into effective strategies for improving athletic performance in noisy urban environments, emphasizing the need for a multidisciplinary approach that integrates insights from sports science, urban planning, and environmental psychology.

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