The Influence of Acoustic Stressors in Educational Environments for Autistic Individuals: Preliminary Investigations

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Abstract

Today, the increasing need for inclusive school environments is driven by the growing population of neurodivergent individuals, particularly those sensitive to sudden and loud noises. Addressing their specific needs enhances their educational and social performance and improves conditions for all students. Inclusive design can lead to more effective learning environments, fostering a sense of belonging and reducing stress for all occupants. This study investigates the influence of acoustic stressors in school environments that accommodate neurodivergent individuals who are sensitive to sudden and loud noises. The research focuses on identifying noise sources such as objects falling, doors shutting, school bells and chairs scraping. A range of classroom settings will be simulated to determine whether the produced noise could be configured as a potential stressor for autistic individuals.

1. Introduction

In recent years, the need for inclusive spaces for living and learning has become increasingly urgent. Research by numerous scholars (Alison et al., 2020; Sherilyn, 2018; Kanakri et al., 2017) on indoor comfort has revealed that parameters such as acoustics, and more specifically noise levels within living environments, can significantly impact the well-being of individuals in these spaces. This importance is amplified in environments where individual performance needs appropriate conditions, such as schools. For instance, (Huang et al., 2012) demonstrated that performance on specific tasks decreased when background noise exceeded 50 dB(A).

When considering neurodivergent individuals, particularly those with autism, these thresholds have yet to be determined. Testing on vulnerable populations presents challenges, making it difficult to obtain consistent responses from such tests.

The significance of acoustics within educational buildings has been well-documented (Bistafa & Bradley, 2000; Minelli et al., 2022). Research indicates that parameters like reverberation time, clarity, and speech intelligibility play crucial roles in creating environments where students and teachers can listen and speak effortlessly. However, despite their scientific importance, these studies do not provide guidelines regarding sound pressure levels caused by common internal noise sources, such as falling books or pens, scraping chairs, slamming doors, and school bells. Many of these auditory events are neither standardized nor intentional but contribute to the overall acoustic climate of a classroom, potentially causing stress for students.

It is well-known (Chang et al, 2014; Belek, 2019) that neurodivergent individuals are often more sensitive to auditory events than neurotypical individuals. Therefore, this study aims to begin examining certain auditory events within classrooms as potential stressors for neurodivergent individuals. Typical sources considered include a falling book, a slamming door, a school bell, falling pens, and a chair scraping the floor. These sources are virtually placed within various real environments to understand their impact on the typical acoustic climate of a classroom (Megan et al., 2012; Noble et al., 2018; Caren, 2016).

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2. Materials and Method

2.1 Environment

Three distinct environments were considered:
- Elementary school classroom
- Elementary school cafeteria
- University classroom

These environments were paired with their respective atriums or corridors, where school bells were located. The classroom configurations were as follows:
- Reverberant classroom as found during site inspections (Scenario 1)
- The same environment as the previous point, but with the addition of sound-absorbing materials to meet the UNI 11532-2 standard (UNI 11532-2:2020, 2020) (Scenario 2).

2.2 Sound Sources

The following sound sources were considered as acoustic stressors:
- Mechanical school bell (A)
- Dragging chair (B)
- Falling book (C)
- Falling markers (D)
- Slamming door (E)

3. Sound Level Measurement Methods

The noise sources were measured using a sound level meter positioned one meter away in a semi-reverberant field. The reverberation time of the rooms was measured using the impulse response technique with a logarithmic sine sweep source, following the guidelines of UNI EN ISO 3382 (ISO Standard, 2009).

3.1 Model Calibration

The three-dimensional model of the environments was created through virtual reconstruction using geometric surveys of the spaces. A *3D* acoustic software utilizing pyramid tracing algorithm was employed for acoustic simulations. The sound-absorbing properties were assigned using the software's database. The sound-absorbing material used for the "absorptive" configuration included polyester fiber covered with an acoustically transparent membrane, placed in square panels of 1.2 m x 1.2 m dimensions. The certified laboratory sound absorption coefficient is as follows (Fig. 1):

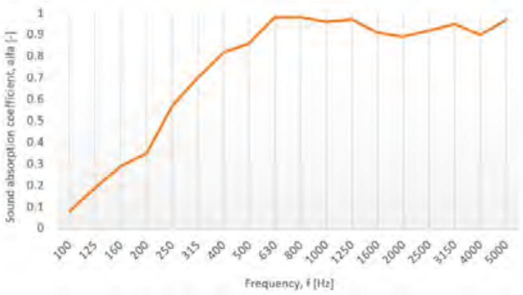

Fig. 1 – Sound absorption coefficient of polyester fiber

4. Results and Discussions

The results of the experimental and numerical investigations are depicted below.

4.1 Sources Sound Pressure Levels

The measured levels of the considered sound sources are reported in Fig. 2.

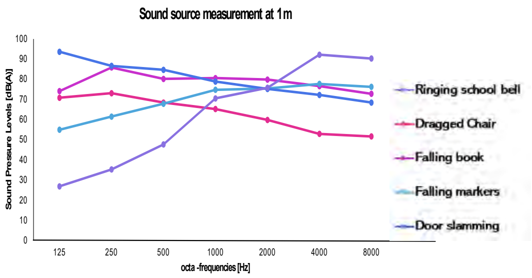

Fig. 2 – Sound pressure levels of different sound sources

It is clear that the ringing bell is the only noise source with a different frequency trend. All the other sources present similar frequency trends, yielding low frequencies.

4.2 2D-Sound Pressure Level Mapping

In the following pictures (Fig. 3–14), the 2D sound pressure levels are reported for the condition “open door” (for brevity) for the two above-depicted scenarios (1= reverberant room, 2= room with sound absorbing materials).

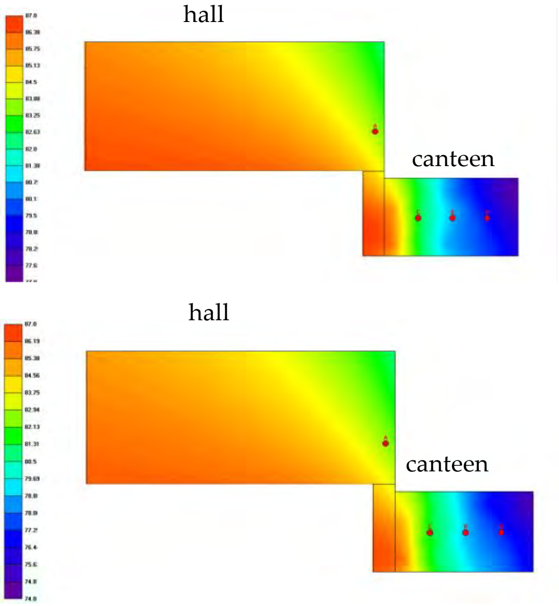

Fig. 3 – Canteen with open door. Sound source: school bell. Scenario 1 (UP), Scenario 2 (DOWN)

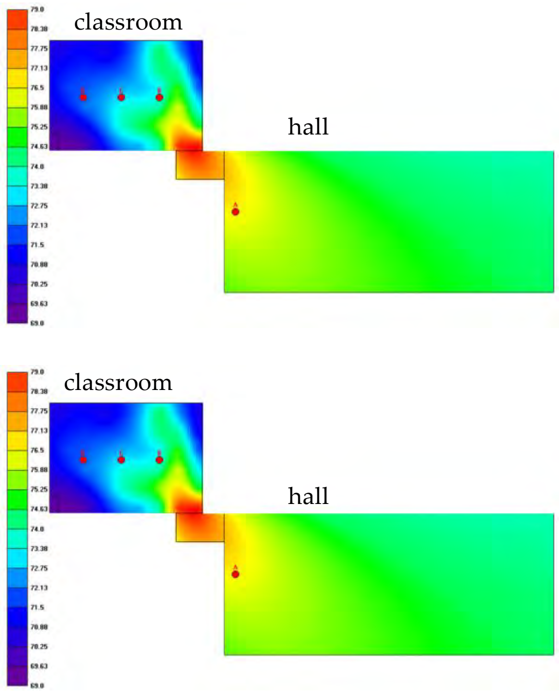

Fig. 4 – Elementary school classroom with open door. Sound source: school bell. Scenario 1 (UP), Scenario 2 (DOWN)

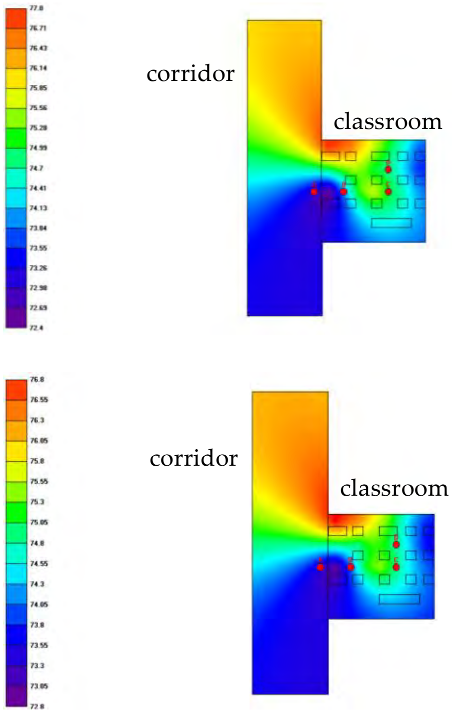

Fig. 5 – University classroom with open door. Sound source: school bell. Scenario 1 (UP), Scenario 2 (DOWN)

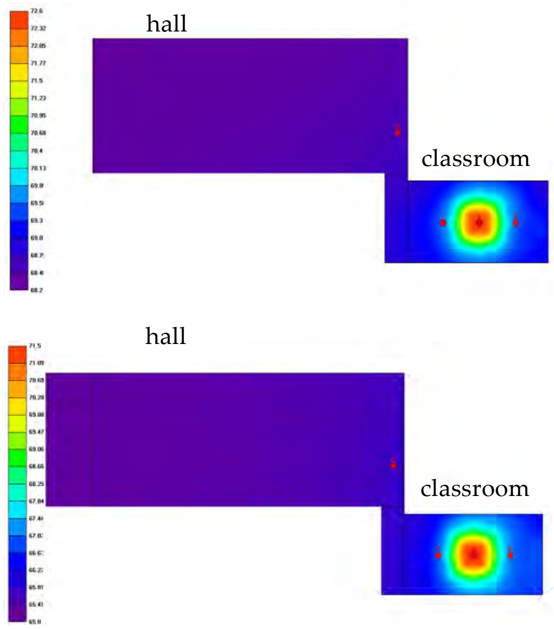

Fig. 6 – Canteen. Sound source: dragging chair. Scenario 1 (UP), Scenario 2 (DOWN)

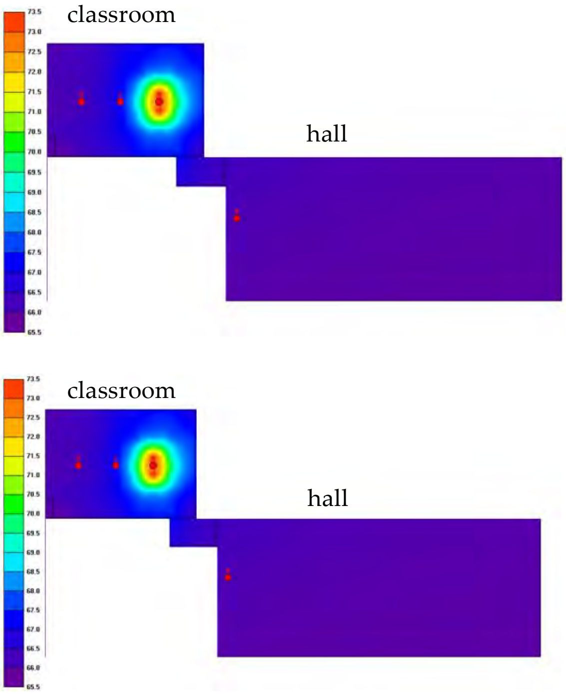

Fig. 7 – Elementary school classroom. Sound source: dragging chair. Scenario 1 (UP), Scenario 2 (DOWN)

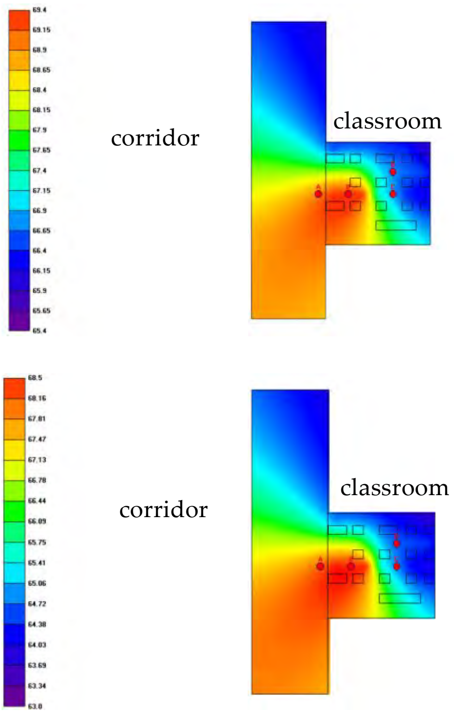

Fig. 8 – University classroom. Sound source: dragging chair. Scenario 1 (UP), Scenario 2 (DOWN)

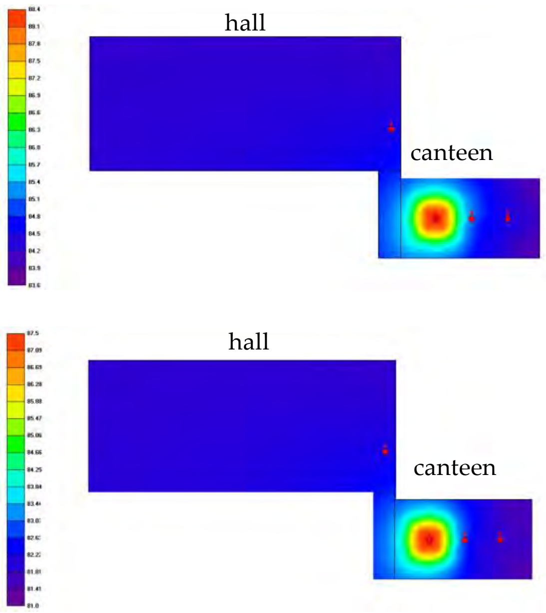

Fig. 9 – Canteen. Sound source: falling book. Scenario 1 (UP), Scenario 2 (DOWN)

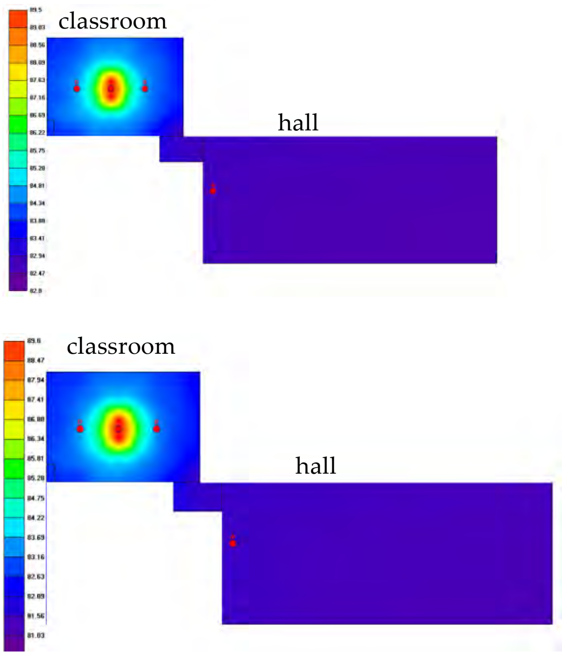

Fig. 10 – Elementary school classroom. Sound source: falling book. Scenario 1 (UP), Scenario 2 (DOWN)

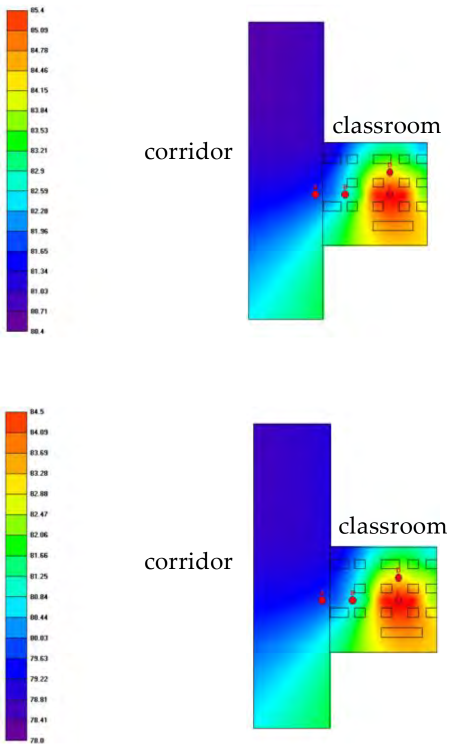

Fig. 11 – University classroom. Sound source: falling book. Scenario 1 (UP), Scenario 2 (DOWN)

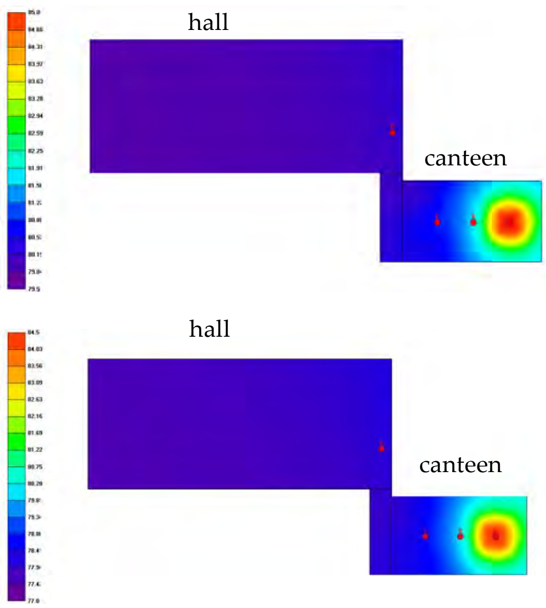

Fig. 12 – Canteen. Sound source: falling markers. Scenario 1 (UP), Scenario 2 (DOWN)

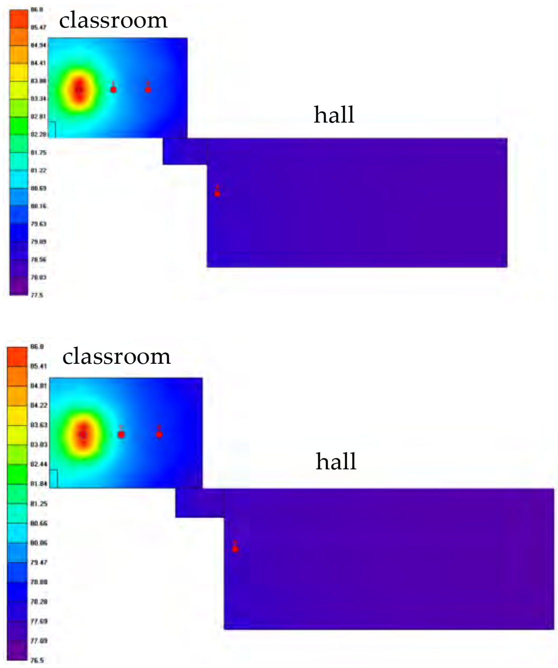

Fig. 13 – Elementary school classroom. Sound source: falling markers. Scenario 1 (UP), Scenario 2 (DOWN)

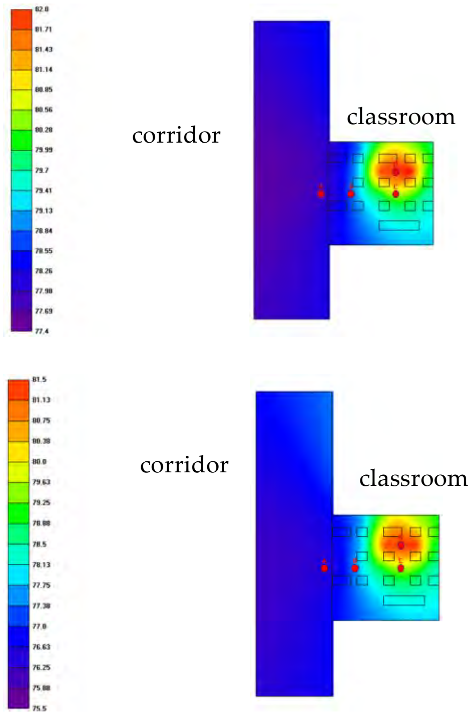

Fig. 14 – University classroom – Sound source: falling markers. Scenario 1 (UP), Scenario 2 (DOWN)

4.3 Frequency Trends Analysis

In Figs. 15–20 the frequency trends are depicted, for each noise source, in all environments and scenarios.

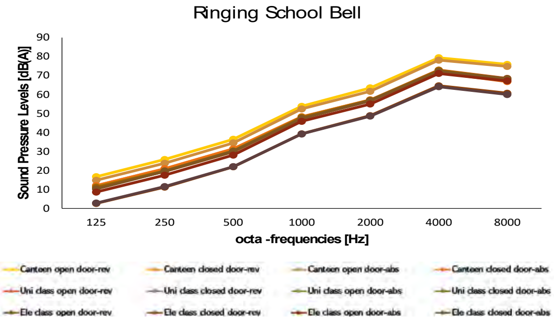

Fig. 15 – Frequency trends - Ringing school bell

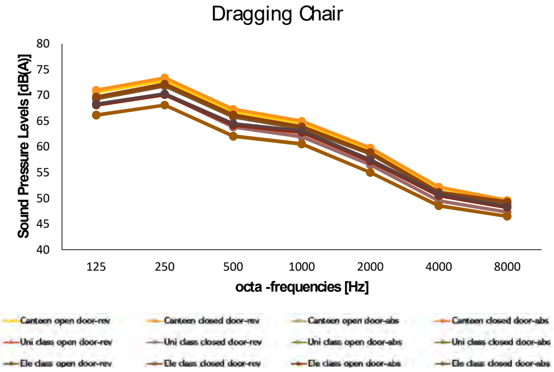

Fig. 16 – Frequency trends – Dragging Chair

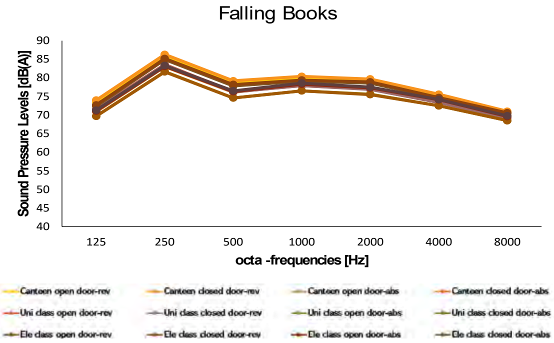

Fig. 17 – Frequency trends – Falling books

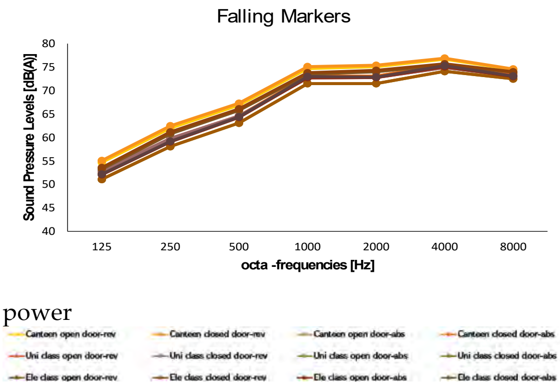

Fig. 18 – Frequency trends – Falling markers

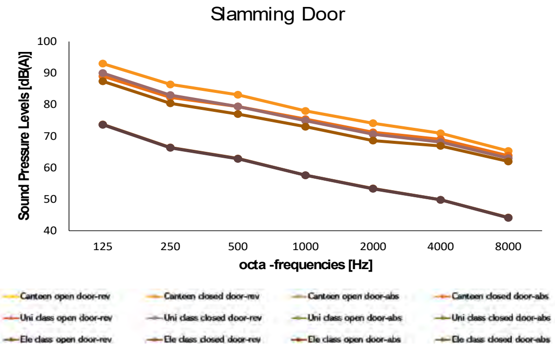

Fig. 19 – Frequency trends – Slamming door

4.4 Discussion

It can be observed that in the different environments, the behavior of impulsive sources and those with low frequencies (see Fig. 2) does not significantly depend on the placement or scenario. However, the maps (Figs. 3–14) show a notable reduction in peak emission when the source is placed in an absorptive environment. This reduction clearly implies less stress for the occupants, particularly for neurodivergent individuals.

Another noteworthy consideration is the levels obtained. None of these sources fall below the 50 dB(A) threshold, where literature (Huang et al., 2012) indicates the onset of stress. Nevertheless, it is important to distinguish between voluntary and involuntary sources. The "falling book" and "falling markers" are almost always involuntary and unavoidable, typically resulting from distractions or unintentional actions.

Conversely, the "slamming door" and "dragging chair," though often unintentional in causing noise, can be easily avoided with simple measures to prevent acoustic stress for the occupants.

A special discussion is warranted for the school bell. This source is intentional and serves the purpose of signaling to students and teachers when it is time to change classes, take breaks, or end the school day. In some cases, it also functions as a fire alarm. Because the bell is a deliberate source, its position can be adjusted, or its volume can be modified based on actual needs. For example, the bell can be relocated if there is a class with neurodivergent individuals nearby (or the students can be moved further away), ensuring that the corridor or atrium is not excessively reverberant, which would negate the distance effect. Another consideration is its volume. As shown in Figs. 3–5, the maximum perceived level is always above 75 dB(A). This level is quite high, considering that a teacher should not exceed 60 dB(A) at one meter (Zannin & Zwirtes, 2009). Reducing the bell's volume could mitigate the stress caused by this repeated, intentional source. Alternative signaling strategies, such as flashing lights or directional sound sources, can also be employed to reduce the induced stress.

5. Conclusion

This paper has presented the preliminary investigation on possible acoustic stressors for neurodivergent hyperacusis individuals in school environments. Diverse noise sources were considered, included in virtual environments featuring several conditions like open or close door, sound absorbing or semireverberant sound field. Preliminary considerations were made about the chance to mitigate the induced stress on neurodivergent individuals. Future works should include more scenarios, noise sources and the compliance of the indoor sound field with the national and European standards.

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