PHYSIOLOGICAL REGULATION AND MULTISENSORY ENVIRONMENTS: AN ANALYSIS OF CARDIAC COHERENCE AND HEART RATE VARIABILITY IN UPPER SECONDARY SCHOOL STUDENTS

REGOLAZIONE FISIOLOGICA E AMBIENTI MULTISENSORIALI: ANALISI DELLA COERENZA CARDIACA E DELLA VARIABILITÀ DELLA FREQUENZA CARDIACA IN STUDENTI DELLA SCUOLA SECONDARIA DI SECONDO GRADO

Stefania Morsanuto
Università Telematica Pegaso
stefania.morsanuto@unipegaso.it

Luna Lembo
Università Niccolò Cusano
luna.lembo@unicusano.it

Davide Perrotta
Università Telematica Pegaso
davide.perrotta@unicusano.it

Elisabetta Tombolini
Università Niccolò Cusano
elisabetta.tombolini@unicusano.it

Giorgia Peluso Cassese
Università Telematica San Raffaele
giorgia.pelusocassese@uniroma5.it

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ABSTRACT
This study examines the impact of a multisensory environment on the physiological regulation of upper secondary students. Using biometric sensors, heart rate, coherence, and coherence peaks were recorded in both classroom and sensory room. Results showed greater physiological stability and a significant reduction in coherence peaks in the multisensory setting.

Lo studio analizza l'impatto di un ambiente multisensoriale sulla regolazione fisiologica di studenti delle scuole superiori. Attraverso sensori biometrici, sono stati rilevati frequenza cardiaca, coerenza e picchi di coerenza in aula e in una stanza sensoriale. I risultati evidenziano una maggiore stabilità fisiologica e una significativa riduzione dei picchi in ambiente multisensoriale.

KEYWORDS
HRV, AVG, Stanza multisensoriale, Ambienti educativi innovativi
HRV, AVG, Multisensory Room, Innovative Educational Environments

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1. Introduction

In the contemporary educational context, promoting students' psychophysical well-being has become an educational and institutional priority. The growing recognition of the role of emotions in cognitive processes and relational dynamics has led to the integration of pedagogical approaches aimed at supporting emotional development, affective regulation, and bodily awareness (Goleman, 1995; Immordino-Yang & Damasio, 2007). In particular, interest in the neurophysiological effects of the learning environment has opened new avenues of interdisciplinary research across neuroscience, educational psychology, and experimental pedagogy.

Among the emerging concepts in this field, cardiac coherence (heart rate coherence) stands out as a significant physiological indicator for assessing the quality of an individual's self-regulatory state. It refers to a synchronised and harmonious pattern of heart rate variability (HRV), associated with calm alertness, sustained attention, and subjective well-being (McCraty et al., 2009). Recent studies highlight how multisensory environmental conditions—characterised by balanced visual, auditory, and tactile stimulation—can enhance coherence by acting on the neurovegetative circuits involved in stress regulation and homeostasis (Ben-Soussan et al., 2021).

At the same time, the school environment is increasingly seen as an integrated educational space, where spatial design and sensory experience contribute to shaping students' engagement and participation (Trninic et al., 2022). In this light, multisensory rooms—originally developed in clinical and rehabilitative settings—are progressively being adopted in educational contexts as resources for emotional regulation and inclusive learning (Pagliano, 2012).

This paper aims to explore the effect of exposure to a multisensory environment on the physiological dynamics of secondary school students, with a specific focus on heart rate and cardiac coherence. The objective is to assess whether and to what extent such exposure can enhance indicators of self-regulation and psychophysical well-being, offering useful insights for the design of neurocompatible educational environments.

2. Multisensory environments: theory, development, and context

The use of multisensory environments originated in the Netherlands in the early 1970s, where they were introduced as a non-pharmacological therapeutic approach to treat dementia. These environments are designed to provide immersive and engaging experiences through the controlled stimulation of sensory channels, using elements such as lights, colours, sounds, scents, and vibrations, all within a precisely regulated artificial space (Paschoarelli et al., 2022), with the aim of enhancing individuals' subjective experience and promoting overall well-being.

This approach is grounded in a neurofunctional conception of the brain as a dynamic and plastic system, highly responsive to environmental stimuli and deeply influenced by experience (Siegel, 2001). In this perspective, the interactive relationship between brain, body, and environment is emphasised, with action playing a central role in learning processes. Multisensory stimulation aims to activate multiple sensory receptors and brain areas simultaneously, based on specific tasks, thereby contributing to learning, consolidation, and individual development.

Numerous scientific studies have highlighted the effectiveness of such environments, particularly in supporting individuals with disabilities, by creating holistic settings that address cognitive, physical, and emotional-relational dimensions simultaneously (Rossetti & Tonetti, 2023). Targeted stimuli can help to enhance or restore fundamental cognitive functions such as memory, attention, and concentration, thereby improving learning processes.

At the same time, multisensory environments engage perceptual channels through both bottom-up processes (stimulus-driven) and top-down processes (cortical processing), fostering perceptual integration and strengthening the kinaesthetic channel (Briscoe, 2019).

Finally, these controlled and protective settings also facilitate the development of social skills, providing a safe space in which individuals can explore, interact, and build relationships at their own emotional and relational pace, with positive outcomes in terms of constructing functional and meaningful connections (Acosta et al., 2024).

2.1 Educational applications of multisensory environments

Multisensory environments represent an increasingly widespread pedagogical innovation, especially in inclusive educational contexts. Over time, the concept has evolved, and these environments have been adopted in education not only to promote well-being but also to support learning, intercultural interaction, and the development of cognitive and social skills (Pagliano, 1999). These spaces may be co-designed by students and teachers to encourage intercultural dialogue and the exploration of both personal and collective identity, enhancing emotional and sensory engagement as a didactic resource (Stephenson, 2002).

Despite their growing diffusion, several studies have pointed to a lack of solid empirical evidence supporting the educational effectiveness of these environments (Martin et al., 1998; Cavet & Mount, 1995). Available data are often anecdotal, descriptive, or based on small sample studies, particularly in school contexts (Houghton et al., 1998). Nevertheless, the adoption of unvalidated practices may be driven by emotional and relational motivations, such as teachers' desire to form emotional bonds with students or to respond to ambiguous behavioural cues interpreted positively (Gersten & Brengelman, 1996; Huebner & Emery, 1998).

The literature thus suggests the need for a critical and reflective approach to the use of multisensory environments in education. While the potential of multisensory environments for fostering engagement, inclusion, and relational development is widely recognised, it remains essential to adopt evidence-based practices, supported by appropriate assessment tools and aligned with clearly defined educational objectives (Gersten et al., 1997; Simpson & Myles, 1995).

2.2 Psychophysiological monitoring in multisensory environments

In recent years, multisensory environments have emerged as privileged contexts for promoting educational, therapeutic, and relational experiences focused on holistic personal engagement. However, to ensure their effectiveness and appropriateness, it is increasingly important to accompany interventions with robust psychophysiological monitoring, enabling real-time assessment of the user's emotional and bodily state. In this context, the use of wearable, non-invasive technologies represents a promising frontier for collecting objective data and personalising interventions based on individual responses.

One of the most widely used tools is *emWave*, developed by the HeartMath Institute, which measures heart rate variability (HRV) and provides immediate feedback on cardiac coherence—a physiological state reflecting balance between the sympathetic and parasympathetic nervous systems. Cardiac coherence is now considered an important marker of emotional regulation and self-regulation (Withed et al., 2014). By visualising heart rhythms in real time and employing guided breathing techniques, *emWave* helps users, even in educational and rehabilitative contexts, to manage stress, enhance concentration, and foster states of calm and mental presence (Whited et al., 2014).

Alongside *emWave*, more advanced devices such as *EmbracePlus* by Empatica are gaining ground. This clinically approved wearable wristband monitors various autonomic parameters, including electrodermal activity (EDA), heart rate, skin temperature, motor activity, and sleep quality. EDA, in particular, is a reliable indicator of emotional arousal and sympathetic nervous system activation in response to environmental stimuli. Its integration into multisensory settings allows for the detection of subtle variations related to users' subjective experience. Recent studies confirm the reliability of the device in both educational and experimental settings (Qu, 2024), suggesting its potential use in tracking the long-term impact of multisensory experiences on psychophysical well-being.

These tools offer new opportunities for both research and educational practice. In schools, for example, it is possible to monitor the impact of immersive activities on students with special educational needs, assessing benefits in terms of emotional regulation, sustained attention, and social interaction. In clinical or rehabilitative contexts, such devices can be used to calibrate sensory stimuli based on physiological responses, supporting increasingly individualised and adaptive interventions.

Beyond their evaluative value, real-time monitoring can also serve an educational purpose, helping individuals become more aware of their internal states and fostering the development of metacognitive and self-regulation skills. In this light, the integration of multisensory environments with biofeedback technologies offers a concrete opportunity to develop innovative educational approaches that unite embodiment, emotion, and cognition within a scientifically grounded experiential framework.

3. Biometric indicators in the educational context: a potential strategy for research and intervention?

The introduction of biometric parameter acquisition has been a topic of discussion for several years in educational neuroscience, as already mentioned in previous sections. While such tools have a long-standing history in psychological research and are generally accepted in international educational studies, considerable scepticism remains within the Italian educational context. The adoption of neuroscientific techniques is often subject to criticism, particularly accusations of reductionism or behaviourism, as the complexity of educational phenomena may appear to be reduced to mere biophysical or numerical parameters.

Regardless of the ethical, methodological, epistemological, and economic considerations—particularly in relation to the cost of these tools—the integration of neuroscientific techniques offers a significant opportunity: to refine the observation of emotional and psychophysiological processes, thereby improving the timeliness and accuracy of assessing students' states. In particular, biometric parameters are promising both for studying the dynamics that lead to the onset of anxiety states and for designing relaxation and self-regulation interventions. In both cases, we are dealing with complex nervous system responses triggered by numerous, often inseparable, factors that are not easily observable from an external perspective.

A precise understanding of the psychophysiological processes underpinning these tools is undoubtedly complex; however, the use of biometric indicators may support the evaluation of environmental modulation as a means to introduce relaxation interventions. Among the most widely used indicators are heart rate variability (HRV) and cardiac coherence. HRV is a sensitive indicator of the flexibility of the autonomic nervous system, while cardiac coherence refers to a state in which cardiovascular, respiratory, and neurovegetative functions are synchronised, promoting parasympathetic balance and a state of calm alertness (McCraty et al., 2009). This physiological state is associated with enhanced cognitive clarity, emotional self-regulation, and stress resilience (McCraty & Zayas, 2014).

The growing attention to biopedagogy has promoted the integration of qualitative and quantitative methodologies, making it possible to observe students' subjective experiences through objective means. The use of biometric tools to detect HRV and cardiac coherence allows for the scientifically grounded documentation of students' subjective states in response to environmental stimuli (Shaffer & Ginsberg, 2017). This approach moves beyond the traditional mind–body dichotomy, supporting an educational design centred on sensory integration, self-regulation, and embodied experience as a foundational dimension of the learning process.

4. Multisensory environments and educational transferability: challenges and research perspectives

The aims of this article require a critical reflection on the complexity of multisensory contexts, particularly with regard to their potential to induce either stress or relaxation, and their capacity to simulate realistic educational conditions. A thorough discussion of these aspects is essential for the development of experimental models that can be replicated in real school settings and for exploring intervention or prevention strategies that can be integrated into traditional teaching practices.

Existing literature confirms the effectiveness of multisensory environments in inducing states of relaxation; however, it has not yet clarified which sensory factors are most influential or which combinations are most effective in producing such outcomes. Multisensory rooms—such as those inspired by the Snoezelen model—are increasingly recognised as valuable tools in educational and pedagogical settings, yet most existing protocols have been developed for individuals with severe disabilities, without detailed analysis of the specific contributions of each sensory component.

Recent literature reviews highlight that the mechanisms underpinning Multisensory Structured Environments (MSSE) are not yet fully understood, despite documented behavioural and psychophysiological benefits in individuals with special needs. These reviews have shown that multisensory protocols can exert a significant and lasting influence on behaviour and mood in individuals with dementia, making MSSE a proven therapeutic tool in clinical contexts.

To illustrate this, two experimental studies are cited as among the most comprehensive contributions concerning the impact of MSSE on the nervous system and emotional responses.
The first study, conducted by Maseda et al. (2014), involved individuals with dementia and followed a 24-week protocol with intermediate assessments at 8, 16, and 24 weeks. This study represents a paradigmatic approach to research in the field, as dementia studies are typically based on observational methods in which experienced professionals evaluate participants' behavioural changes.

Participants were divided into three groups: an experimental group undergoing guided multisensory stimulation; an active group involved in individual activities; and a control group that received no stimulation. The results revealed significant behavioural differences between the MSSE group and the active group ($p < 0.023$), but no relevant differences in comparison to the control group ($p > 0.05$). However, it remains unclear whether the improvements observed were due to the interaction with caregivers or to the specific characteristics of the multisensory environment, indicating the need for further investigation.
While participation in multisensory stimulation appeared more effective than individual activity in reducing behavioural issues, the effects on mood did not

clearly demonstrate whether these improvements were attributable to caregiver interaction or to the environment itself. Further studies are therefore necessary to better understand the underlying mechanisms.

Another condition extensively investigated in the literature is autism spectrum disorder (ASD), a neurodevelopmental disorder primarily studied in relation to theory of mind—that is, the ability to attribute mental and emotional states to others. Less commonly explored, though still highly relevant, is the hypothesis of atypical sensory processing as a key factor in autism traits, in both children and adults.
In this case, the reference study employed an experimental design similar to the dementia model, adapted to the specific characteristics of the target population.

Two experimental groups were compared: one active, in which children could directly manipulate sensory stimuli in the room, and one passive, limited to observation. Observational analyses identified significant differences, particularly in the frequency of vocalisations and the reduction of stereotyped behaviours, suggesting a beneficial impact of active interaction with the environment. The increased sense of agency in active participants appeared to reduce cognitive load, a factor hypothesised to mediate the observed positive effects. These dynamics align with the theoretical framework of top-down and bottom-up sensory processing models, frequently used to interpret autism symptomatology. A key basis for these studies is the evidence that perceptual anticipation reaction times are significantly reduced in individuals with ASD.

Although the study employed a solid methodological structure, the potential to expand and refine the research is limited by the complexity of the subject and the difficulty of isolating individual sensory variables. MSSEs offer an almost limitless range of configurations, combining tactile stimuli (such as ball pools or vibroacoustic cushions), auditory stimuli (such as calming music), and visual stimuli (such as chromatic variations or audiovisual projections). Assessing the effectiveness of each combination would require extremely complex protocols and extended experimental timelines, making it difficult to produce statistically significant results. This represents a crucial challenge for the future of research in this field, calling for the development of more agile and flexible methodologies that integrate observational, psychometric, and biometric tools into a multidimensional and personalised approach.

5. Research Project

5.1. Research Hypothesis

In light of the theoretical framework and preliminary findings from the scientific literature, this study aims to explore the effect of exposure to a multisensory environment on students' physiological regulation, with particular focus on heart coherence as a key indicator of autonomic balance and emotional stability. Numerous studies indicate that heart coherence, measurable through heart rate variability (HRV), is a reliable marker of an individual's psychophysiological state, capable of reflecting self-regulation capacity and overall well-being (McCraty et al., 2006; Whited et al., 2014). Protected, structured environments with controlled sensory stimulation—such as multisensory rooms—have proven effective in promoting relaxation and modulating autonomic nervous system activation (Pagliano, 1999; Hirstwood & Smith, 1996).

Based on these assumptions, the research hypothesis is as follows: exposure to a multisensory room leads to a significant improvement in students' heart coherence levels compared to baseline values recorded under standard classroom conditions, indicating a positive effect of the environment on physiological regulation. Specifically, it is hypothesised that the multisensory environment will promote an increase in average coherence, a reduction in heart rate, and greater stability in coherence peaks, more so than in an ordinary learning context.

5.2. Sample

The sample consisted of 72 students (44 female and 28 male), as shown in Figure 1, aged between 17 and 18. The students attended an upper secondary art school located in the Tuscany region. Participation was voluntary, with prior authorisation from parents and the school headteacher, in compliance with EU Regulation 2016/679 (GDPR) on personal data protection.

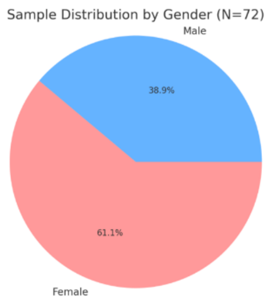


Figure 1. Gender distribution of the sample

5.3. Tools and Methodology

Biometric sensors validated for continuous measurement of heart rate and heart coherence (AVG) were used, in accordance with the parameters established by the HeartMath Institute (McCraty et al., 2009).
Three key physiological indicators were considered in this study, each providing complementary information about students' psychophysiological states across the two observed environments.

Heart rate (HR), expressed in beats per minute (bpm), is a direct index of physiological arousal. Higher HR values are generally associated with sympathetic activation—such as stress, anxiety or increased alertness—while lower rates are typically indicative of relaxation and parasympathetic regulation. Average coherence (AVG or AVH), measured on a scale from 0 to 3, reflects the harmony between heart rate variability and respiratory rhythms. High coherence suggests autonomic balance and emotional centring, indicating greater self-regulatory capacity, mental clarity, and internal stability.
Finally, coherence peaks (POINT) identify brief intervals of maximum psychophysiological synchronisation—states of deep alignment between body and mind. These peaks represent highly adaptive responses and may be interpreted as physiological manifestations of optimal emotional and cognitive well-being.

Data were collected through 5-minute sessions. A baseline measurement was first recorded for each student. Then, students took part in two separate sessions. In the first, they were monitored in a classroom during standard educational activity, while seated and silent. In the second, they were observed in a multisensory room equipped with soft lighting, harmonious visual stimuli, natural sounds and tactile materials—designed to reduce overstimulation and promote relaxation (Pagliano, 2012). In both conditions, the timing and content of the activities were kept consistent.

The data were analysed using various statistical tools to investigate the impact of the multisensory environment on the physiological parameters. Initially, descriptive statistics were calculated, including means and standard deviations for each variable. Subsequently, a paired-samples t-test was conducted to compare values recorded in the classroom versus the multisensory room and assess statistically significant differences.

To examine the effects of environment and gender on heart coherence in greater depth, a 2×2 repeated-measures ANOVA was conducted, testing both main effects (pre/post exposure and gender) and their interaction. Additionally, Pearson's correlation analysis was performed to explore the relationship between average coherence values and coherence peaks across both contexts.

Finally, a simple linear regression was carried out to determine whether baseline coherence values in the classroom (AVG1) could significantly predict those recorded in the multisensory room (AVG2). The level of statistical significance was set at $p < 0.05$.

All analyses were conducted using SPSS software (version 27) and cross-checked with R to ensure reliability and reproducibility of results.

To maintain consistency and data reliability, contextual factors were controlled across all measurement sessions: timing of data collection was standardised to the morning, immediately after the first lesson; ambient temperature and lighting were kept constant; students' posture remained neutral and relaxed; and no verbal interaction or distracting stimuli were allowed during the recordings.

5.4 Data Analysis and Results

The descriptive analysis of the main physiological indicators provided a preliminary overview of participants' responses across the two observed settings—traditional classroom and multisensory room. The data presented in Figure 1 show a general tendency towards reduced values in the variables measured. Mean heart rate (HR) decreased from 78.35 bpm in the classroom (HR1) to 75.46 bpm in the multisensory room (HR2). Similarly, average heart coherence (AVG) dropped from 1.41 (AVG1) to 1.25 (AVG2), while coherence peaks (POINT) decreased from 75.38 to 61.07. A comparison of standard deviations also revealed a notable reduction in variability within the multisensory condition, indicating greater stability in physiological responses.

	HR1	**AVG1**	**POINT1**	**HR2**	**AVG2**	**POINT2**
count	52.0	52.0	52.0	52.0	52.0	52.0
mean	78.35	1.41	75.38	75.46	1.25	61.08
std	12.34	0.63	38.07	10.25	0.37	26.08
min	60.0	0.2	3.0	56.0	0.7	10.0
25%	69.0	0.9	52.0	69.0	1.0	49.0
50%	78.5	1.3	76.5	75.5	1.1	55.0
75%	84.0	1.9	103.0	83.0	1.4	77.0
max	109.0	2.6	147.0	96.0	2.3	133.0

Table 1. Descriptive Statistics

These findings are consistent with the distribution of minimum, maximum, and quartile values: notably, coherence peaks were considerably more variable in the traditional classroom (range: 3.0–147.0) than in the multisensory room (range: 10.0–133.0), confirming the modulating effect of the environment on autonomic nervous system activity.

Interesting gender differences also emerged (Figure 2). Female students exhibited higher average coherence than their male peers in both settings, with a more compact distribution within the multisensory room.

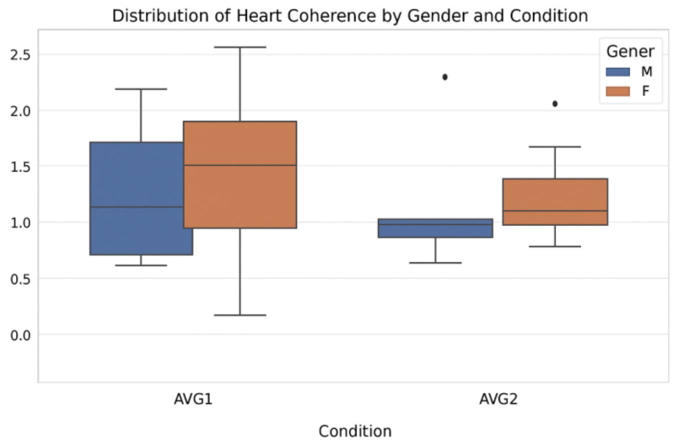


Figure 2. Distribution of heart coherence by gender and condition

Figure 3, concerning coherence peaks, reinforces this trend, showing a clear reduction in variability and fewer outliers in the multisensory condition.

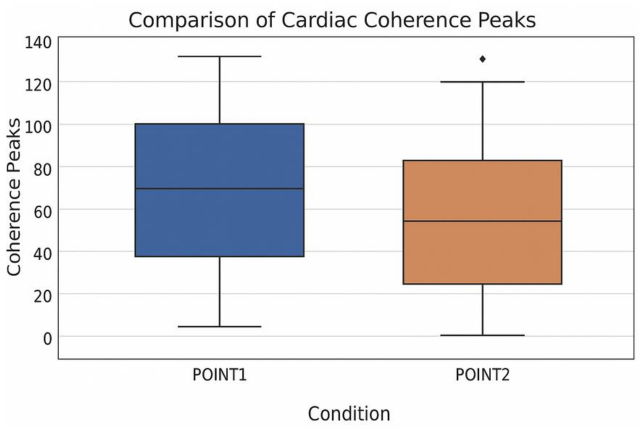


Figure 3. Comparison of cardiac coherence peaks

At the individual level, females showed a decrease in mean heart rate from 77.7 to 75.8 bpm, in average coherence from 1.46 to 1.29, and in coherence peaks from 78.5 to 61.6. Male participants also exhibited a decrease in heart rate from 80.0 to 74.6 bpm, along with a modest reduction in average coherence (from 1.26 to 1.14) and peaks (from 67.0 to 59.6). These data suggest a general trend towards greater physiological stability in the multisensory room. However, individual variability points to heterogeneous subjective responses, warranting further investigation.

To assess statistical significance, a paired-samples t-test was conducted. The results, summarised in Table 2, reveal a downward trend in heart rate ($t = 1.89$, $p = 0.065$) and average coherence ($t = 1.94$, $p = 0.058$), although not reaching conventional significance thresholds ($p < 0.05$). By contrast, the difference in coherence peaks (POINT) was statistically significant ($t = 2.71$, $p = 0.009$), indicating a tangible physiological shift between the two conditions.

Variable	t-statistic	p-value	Outcome
HR	1.89	0.065	Near-significant downward trend
AVG	1.94	0.058	Non-significant trend towards improvement
POINT	2.71	0.009	Statistically significant difference

Table 2. T-test Results for HR, AVG, and POINT

An ANOVA was conducted to assess the main effects of gender, time (classroom vs room), and their interaction on average coherence. As reported in Table 3, none of the factors reached statistical significance: neither gender ($p = 0.13$), nor time ($p = 0.13$), nor the interaction between them ($p = 0.80$). This suggests that observed variations are not attributable to generalised gender or contextual effects, but rather to more complex, individualised responses.

Factor	p-value	Interpretation
Gender	0.13	No significant effect
Time (class vs room)	0.13	No overall significant variation
Gender*Time	0.80	No interaction effect

Table 3. ANOVA Results – Effects of Gender and Time on AVG

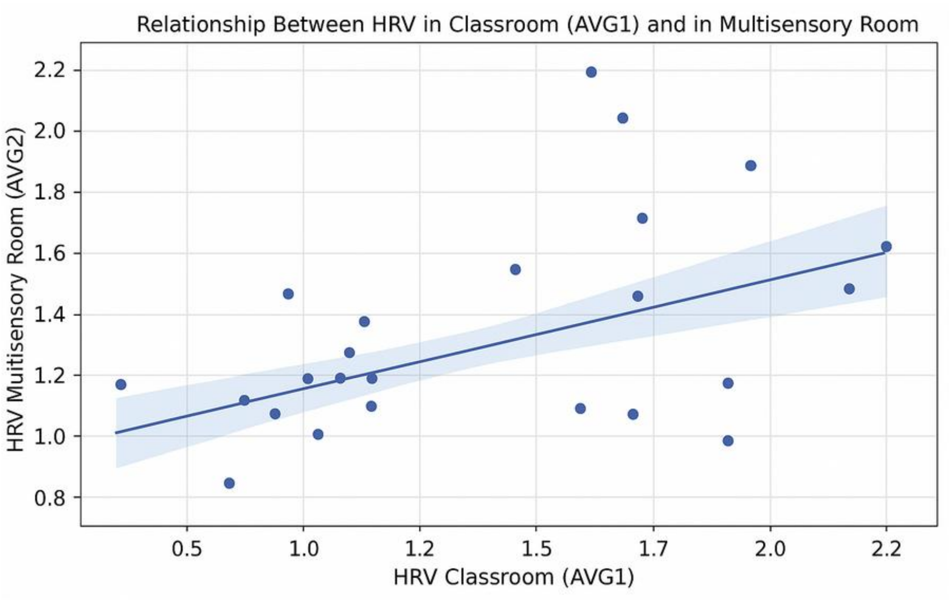
Correlation analysis revealed a strong association between average coherence and coherence peaks in both contexts: $r = 0.94$ in the classroom and $r = 0.80$ in the multisensory room, suggesting internal consistency in individual regulation patterns. Additionally, moderate correlations were observed between heart rate values across conditions (r = 0.54) and between average coherence levels (r = 0.43), indicating a degree of continuity in individual profiles.

To further explore this continuity, a simple linear regression model was constructed using AVG1 as the predictor and AVG2 as the outcome. As shown in Table 4, the regression coefficient was positive and statistically significant (β = +0.25; p = 0.002), with a determination coefficient R^2 of 0.18. This suggests that approximately 18% of the variability in multisensory room coherence can be explained by classroom values.

Model	Coeff. AVG1	p-value	R^2	Interpretation
AVG2 ~ AVG1	+0.25	0.002	0.18	Each additional point of classroom coherence predicts +0.25 in the room

Table 4. Linear Regression – Predicting AVG2 from AVG1

The relationship between these variables is graphically represented in Figure 4, showing a positive linear trend with some dispersion.



These results support the effectiveness of the multisensory environment in promoting greater physiological regulation and suggest that such an environment may act as a facilitating context capable of enhancing pre-existing self-regulatory capacities. The fact that already regulated individuals in the traditional classroom condition either maintained or improved coherence in the multisensory setting strengthens the hypothesis of adaptive continuity. These findings are particularly relevant within an inclusive educational perspective, where the personalisation of learning environments is a strategic lever for promoting well-being, engagement, and socio-emotional development.

6. Discussion

The data suggest strong internal coherence in the experiences within each environment—both the classroom and the multisensory room—as indicated by the high correlations observed between average coherence and coherence peaks. In particular, the moderate correlation between the two environments ($r = 0.43$) is noteworthy, as it points to a potential transfer effect of self-regulation skills acquired in a structured and protected setting (such as the multisensory room) to more complex and dynamic contexts such as the classroom. This supports the hypothesis that guided multisensory experiences can have generalisable and lasting impacts across educational contexts.

The comparative analysis of physiological data collected in the classroom and in the multisensory room highlights a number of significant variations, suggesting the potential impact of multisensory educational environments on students' emotional and physiological regulation. The three main variables analysed—heart rate (HR), average coherence (AVG), and coherence peaks (POINT)—respectively represent autonomic nervous system activation, the balance between sympathetic and parasympathetic systems, and access to states of deep psychophysiological integration (McCraty et al., 2009; Shaffer & Ginsberg, 2017).

Both genders showed a reduction in heart rate within the multisensory room, a key indicator of physiological relaxation. Notably, males exhibited a mean decrease of 5.4 bpm, greater than that observed among females (−1.9 bpm), suggesting greater reactivity to environmental deactivation. Although average cardiac coherence decreased in both settings, this should not necessarily be interpreted negatively: some individuals showed a significant increase in coherence within the multisensory room, indicating strong adaptability to a regulated, low-stimulation environment—a phenomenon that can be interpreted as an expression of emotional resilience (Zimmerman, 2002).

A particularly relevant finding is the significant reduction in coherence peaks (POINT), with a statistically significant difference between the two environments ($p = 0.009$). This may be linked to the lower sensory activation in the multisensory room, which, while reducing peaks, appears to promote psychophysiological stability, as also confirmed by the lower dispersion observed in the boxplots (McCraty et al., 2009). The very high correlation between average coherence and peaks in both the classroom ($r = 0.94$) and the room ($r = 0.80$) suggests that moments of maximum physiological harmony align with each individual's autonomic profile in both contexts.

Regression analyses showed that high coherence in the classroom significantly predicted good coherence levels in the multisensory room ($\beta = 0.25$, $p = 0.002$), demonstrating continuity in the physiological responses of well-regulated individuals. While the t-test and ANOVA did not reveal statistically significant effects for time or gender, individual data patterns suggest that the environment's impact is highly modulated by intra-individual differences—consistent with models of self-regulated and adaptive learning (Salomon & Perkins, 1989).

In conclusion, the multisensory room proves to be a promising context for promoting psychophysiological well-being. The overall reduction in heart rate, the positive coherence response in certain individuals, and the reduced variability in coherence peaks all indicate that carefully designed sensory environments can support emotional regulation. From an applied perspective, these results suggest that elements of the multisensory model may be transferred to mainstream teaching through the integration of sensory design, environmental flexibility, and experiential methodologies. Such approaches could enhance students' capacity for self-regulation and more effective learning, encouraging more balanced and sustainable adaptation to cognitive and relational demands (Bradley et al., 2010; McCraty & Zayas, 2014).

Methodological limitations

Among the limitations of the study are the relatively small sample size, the absence of randomisation in the order of conditions, and the lack of follow-up measurements. Moreover, data were collected across only two short sessions, limiting the ability to draw definitive conclusions regarding the long-term effects of the multisensory intervention.

7. Conclusions

The present findings provide evidence for the potential effectiveness of multisensory environments in promoting physiological regulation and supporting students' psychophysical well-being. In particular, the significant reduction in heart rate observed in the multisensory room provides a clear indicator of relaxation, suggesting that environments designed to reduce sensory overstimulation may contribute to autonomic balance.

Although average cardiac coherence and coherence peaks showed slight overall reductions, individual data revealed strong variability in responses: some students displayed significant improvements, indicating enhanced adaptability and self-regulation. This suggests that the effectiveness of the multisensory environment may depend on individual factors such as emotional resilience and personal regulation style.

Statistical analysis also revealed a moderate correlation between data collected in the classroom and those in the multisensory room, indicating the possibility that guided relaxation experiences in structured environments can foster transferable self-regulation skills in other educational contexts. Despite the absence of statistically significant group effects according to ANOVA, the qualitative evidence and observed individual patterns highlight the educational and preventive value of such interventions.

From an applied perspective, the data support the integration of multisensory spaces within schools as complementary tools to traditional teaching activities—beneficial not only for students with special educational needs, but also for promoting a culture of learning that balances mind and body. Further longitudinal studies with larger samples and more controlled experimental designs are, however, necessary to confirm and extend these preliminary findings.

Author contributions

All authors contributed equally to the development of this work. Specifically, Stefania Morsanuto is the author of Sections 3, 5, and 6; Luna Lembo is the author of Sections 2 and 7; Davide Perrotta is the author of Sections 3 and 4; Elisabetta Tombolini is the author of Sections 2 and 7; and Giorgia Peluso Cassese is the author of Section 1.

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