Duration-Dependent Effects of Auditory Music Stimulation on Physiological and Behavioural Parameters in Wistar Rats

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ABSTRACT

Auditory stimulation has been reported to influence physiological arousal and behavioural performance; however, experimental evidence regarding the effects of music exposure duration remains limited. The present study evaluated the effects of different durations of instrumental auditory music exposure on selected physiological and behavioural parameters in Wistar rats.

Adult Wistar rats were allocated to four experimental groups (n = 16 per group) and exposed to instrumental music for 10, 30, or 60 minutes. Body weight and body temperature were recorded before and after exposure. Behavioural assessment included spatial learning and memory using the Morris Water Maze test and social behaviour using a helping behaviour paradigm. Pre- and post-exposure values were compared using appropriate parametric or non-parametric statistical tests.

Music exposure did not alter body weight at any exposure duration. Body temperature increased significantly following exposure in all groups, with greater changes observed after 30- and 60-minute exposure compared with 10 minutes. Spatial learning performance improved significantly following exposure across all durations, as indicated by reduced escape latency in the Morris Water Maze, with no significant differences among exposure durations. Social behaviour showed duration-dependent effects, with significant improvement following 10-minute exposure, while longer exposure durations did not produce consistent changes.

These findings demonstrate that auditory music exposure induces measurable changes in physiological arousal and behaviour in rats, and that exposure duration is an important determinant of behavioural outcomes. The results provide experimental evidence relevant to the study of auditory modulation of physiological and behavioural responses.

KEYWORDS: Auditory Stimulation; Physiological Arousal; Body Temperature; Spatial Learning; Wistar Rats.

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INTRODUCTION

Auditory stimulation represents an important environmental input capable of influencing both physiological regulation and behavioural performance through interactions between sensory, limbic, and autonomic neural systems. Sound processing extends beyond primary auditory cortices and engages subcortical structures involved in emotional processing and homeostatic regulation, including the amygdala, hypothalamus, and brainstem nuclei. Through these pathways, auditory stimuli can modulate autonomic output, thermoregulation, and behavioural state, making them relevant to vascular and non-vascular physiological research (Koelsch, 2014).

One physiological marker frequently used to assess autonomic activation in experimental animals is body temperature. Increases in core or rectal temperature following sensory or emotional stimulation are commonly interpreted as psychological stress- or arousal-induced hyperthermia, a response mediated primarily by sympathetic activation rather than inflammatory mechanisms (Oka et al., 2001). This response reflects alterations in central autonomic regulation and has been used as a non-invasive index of arousal and emotional state under controlled experimental conditions.

Behavioural performance is closely linked to arousal state. Tasks assessing spatial learning and memory, such as the Morris Water Maze, are sensitive not only to hippocampal integrity but also to motivation, attention, and autonomic balance (Morris, 1984; Vorhees & Williams, 2006). Optimal arousal levels facilitate task engagement and learning, whereas excessive or sustained activation may impair performance consistency. Consequently, changes in behavioural output must be interpreted in conjunction with physiological indices of arousal.

A growing body of animal research suggests that structured auditory stimuli, including music, can influence cognitive and behavioural outcomes. Experimental studies have reported improved spatial learning and memory following music exposure, accompanied by changes in neuroplasticity-related markers such as brain-derived neurotrophic factor (BDNF) and its receptor TrkB within the hippocampus (Chikahisa et al., 2006; Xing et al., 2016). Systematic evaluation of this literature indicates that auditory stimulation can affect rodent behaviour and neurobiology; however, outcomes vary substantially depending on stimulus characteristics, exposure duration, and experimental context (Kühlmann et al., 2018).

Social behaviour represents another behavioural domain sensitive to autonomic and emotional modulation. Rodent models of helping or rescue behaviour have demonstrated that rats exhibit pro-social responses toward conspecifics under specific conditions, and that these behaviours are influenced by affective state and environmental factors (Bartal et al., 2011). Alterations in arousal and autonomic tone can therefore be expected to modulate social responsiveness, potentially producing non-linear effects across different exposure intensities or durations.

Despite increasing interest in auditory modulation of physiology and behaviour, exposure duration remains insufficiently characterised as an experimental variable. Short-duration auditory stimulation may enhance alertness and behavioural efficiency, whereas prolonged exposure may sustain autonomic activation and alter behavioural outcomes in a domain-specific manner. From a biomedical perspective, defining duration-dependent effects is essential for understanding how auditory stimuli influence autonomic balance and behaviour without confounding effects related to handling, metabolic change, or chronic stress.

Animal models provide a controlled framework to address these questions. Wistar rats are extensively used for investigations of thermoregulation, spatial cognition, and social behaviour, allowing integration of physiological and behavioural measurements within a single experimental design. Simultaneous assessment of body temperature and behavioural performance enables evaluation of how auditory-induced arousal is translated into autonomic output and behavioural expression, a relationship of direct relevance to vascular and non-vascular physiology.

The present study was therefore designed to evaluate the effects of different durations of instrumental auditory music exposure on selected physiological and behavioural parameters in Wistar rats. By comparing pre- and post-exposure measures of body weight, body temperature, spatial learning, and social behaviour, the study aimed to determine whether exposure duration differentially influences physiological arousal and behavioural performance under controlled experimental conditions.

Auditory stimulation can modulate behavioural performance through activation of the central autonomic network (CAN). The CAN integrates auditory input with limbic and hypothalamic signalling to regulate sympathetic and parasympathetic outflow. Increased auditory-driven arousal elevates sympathetic tone, leading to changes in peripheral vascular resistance, thermogenic vasoconstriction, and metabolic heat production. These processes contribute to arousal-related increases in core body temperature, a recognised marker of sympathetic activation distinct from inflammatory or pyrogenic responses. Altered autonomic balance influences cardiovascular control, cerebral perfusion, and attentional state. Behavioural tasks requiring spatial navigation or social interaction are sensitive to these autonomic conditions. Moderate sympathetic activation may facilitate task engagement and motor output. Sustained or excessive sympathetic dominance may increase physiological load and behavioural variability. Simultaneous assessment of thermoregulatory responses and behavioural outcomes therefore provides a mechanistic framework for examining how auditory-induced autonomic and cardiovascular modulation translates into behavioural performance, a relationship central to vascular and non-vascular physiology.

MATERIALS AND METHODS

Animals

Adult Wistar rats (*Rattus norvegicus*) (body weight 120–140 g) were used in the study. Animals were obtained from the institutional animal facility of Indian Veterinary Research Institute (IVRI), Bareilly, Uttar Pradesh and housed in standard polypropylene cages with stainless-steel wire tops. Bedding consisted of autoclaved rice husk. Rats were maintained under controlled laboratory conditions (temperature 22 ± 2 °C; relative humidity 50–60%; 12 h light–dark cycle). Standard pellet diet and water were provided *ad libitum*. All experiments were conducted during the light phase.

Ethical Approval

All experimental procedures were approved by the Institutional Animal Ethics Committee (IAEC) of Hygia Institute of Pharmaceutical Education and Research, Lucknow, with IEC No. HIPER/IAEC/105/04/2022 and conducted in accordance with the guidelines of the Committee for the Control and Supervision of Experiments on Animals (CCSEA), Government of India.

Experimental Design

A pre–post experimental design was employed. Animals were randomly allocated into four experimental groups (n = 16 per group) based on the duration of auditory exposure:

Group I: Control (No Auditory Stimulation by Music Exposure))

Group II: 10-minute exposure

Group III: 30-minute exposure

Group IV: 60-minute exposure

Physiological and behavioural parameters were recorded immediately before and after the assigned exposure session.

Auditory Stimulation Protocol

The auditory stimulus consisted of instrumental music presented at a moderate sound intensity (approximately 60–65 dB) on Indian classical instrumental music Raga Darbari Kanada played on Veena. Sound levels were measured using a sound-level meter to ensure uniform exposure. Music was delivered through external speakers positioned at a fixed distance from the cages. Animals were exposed individually in their home cages to minimise novelty-induced stress and handling-related autonomic activation.

PHYSIOLOGICAL MEASUREMENTS

Body Weight

Body weight was measured using a calibrated electronic balance with a sensitivity of 0.01 g. Measurements were recorded immediately before and after auditory exposure.

Body Temperature

Body temperature was measured using a calibrated digital rectal thermometer suitable for small laboratory animals. Measurements were obtained with minimal restraint to limit handling-induced sympathetic activation. Pre- and post-exposure readings were recorded under identical conditions.

Behavioural Assessments

Spatial Learning and Memory

Spatial learning and memory were assessed using the Morris Water Maze apparatus. The maze consisted of a circular pool filled with water rendered opaque using non-toxic colouring. A circular escape platform was submerged below the water surface in a fixed quadrant.

Each rat was placed into the pool and allowed to locate the hidden platform. Escape latency (time to reach the platform) was recorded as the primary outcome measure. Identical testing conditions were maintained for pre- and post-exposure assessments.

Social Behaviour

Social behaviour was evaluated using a helping behaviour paradigm. The test animal was placed in an arena containing a conspecific restrained within a transparent enclosure. The latency to initiate helping behaviour, including attempts to open or interact with the restrainer, was recorded. Measurements were obtained before and after auditory exposure.

Data Processing

For each parameter, pre- and post-exposure values were recorded. Change scores (Δ) were calculated using the formula:
Δ=Post-exposure value−Pre-exposure value\Delta = \text{Post-exposure value} - \text{Pre-exposure value}Δ=Post-exposure value−Pre-exposure value
Data were compiled for statistical analysis.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed using the Shapiro–Wilk test.
Within-group comparisons (pre vs post) were analysed using paired Student's t-test for normally distributed data and Wilcoxon signed-rank test for non-normal data. Between-group comparisons across exposure durations were performed on change scores using the Kruskal–Wallis test with Bonferroni-adjusted post-hoc comparisons where applicable.
Effect sizes were calculated as Cohen's d for parametric tests and rank-biserial correlation (rrb) for non-parametric tests, with 95% confidence intervals. Data are presented as mean ± standard deviation. A p-value < 0.05 was considered statistically significant.

RESULTS

Body Weight

Body weight remained unchanged following auditory exposure across all exposure durations. No variability was observed between pre- and post-exposure values in any group. Consequently, no inferential statistical analysis was performed for this parameter (Table 1).

Body Temperature

Auditory exposure produced a significant increase in body temperature in all three exposure groups (Table 1).
In the 10-minute exposure group, body temperature increased significantly following exposure (Wilcoxon signed-rank test, p = 0.0205; rank-biserial correlation r = 0.59, 95% CI: 0.18–0.82).

In the 30-minute exposure group, a significant increase in body temperature was observed (paired t-test, p < 0.0001; Cohen's d = 2.67, 95% CI: 1.66–3.62).

In the 60-minute exposure group, body temperature also increased significantly following exposure (paired t-test, p < 0.0001; Cohen's d = 2.64, 95% CI: 1.64–3.58).

Comparison of temperature change scores across exposure durations demonstrated a significant between-group difference (Kruskal–Wallis test, p = 0.0041). Post hoc analysis showed greater temperature increases in the 30- and 60-minute groups compared with the 10-minute group (Bonferroni-adjusted p < 0.05), while no difference was observed between the 30- and 60-minute groups.

Table 1. Physiological parameters before and after auditory exposure

Exposure duration	Parameter	Pre-exposure (Mean ± SD)	Post-exposure (Mean ± SD)	Statistical test	p value
10 min	Body weight (g)	No change	No change	—	—
30 min	Body weight (g)	No change	No change	—	—

60 min	Body weight (g)	No change	No change	—	—
10 min	Body temperature (°C)	34.92 ± 0.54	35.14 ± 0.44	Wilcoxon	0.0205
30 min	Body temperature (°C)	34.76 ± 0.39	35.20 ± 0.37	Paired t	<0.0001
60 min	Body temperature (°C)	34.90 ± 0.44	35.35 ± 0.39	Paired t	<0.0001

Spatial Learning and Memory

Escape latency in the Morris Water Maze was significantly reduced following auditory exposure in all exposure groups (Table 2).

In the 10-minute group, post-exposure escape latency was significantly lower than baseline values (paired t-test, $p < 0.0001$; Cohen's d = 6.27, 95% CI: 4.35–8.12).

In the 30-minute group, a significant reduction in escape latency was also observed (paired t-test, $p < 0.0001$; Cohen's d = 5.01, 95% CI: 3.45–6.48).

Similarly, the 60-minute group demonstrated a significant decrease in escape latency following exposure (paired t-test, $p < 0.0001$; Cohen's d = 3.98, 95% CI: 2.69–5.21).

Between-group comparison of change scores did not reveal a significant difference among exposure durations (Kruskal–Wallis test, p = 0.6979).

Table 2. Spatial learning performance (Morris Water Maze)

Exposure duration	Pre-exposure latency (s)	Post-exposure latency (s)	Statistical test	p value
10 min	83.94 ± 5.40	29.44 ± 7.55	Paired t	<0.0001
30 min	88.75 ± 5.69	36.81 ± 8.36	Paired t	<0.0001
60 min	79.31 ± 10.23	24.00 ± 13.04	Paired t	<0.0001

Social Behaviour

Auditory exposure produced duration-dependent effects on social behaviour (Table 3).
In the 10-minute exposure group, helping behaviour latency decreased significantly following exposure (Wilcoxon signed-rank test, p = 0.0007; rank-biserial correlation r = 0.86, 95% CI: 0.60–0.95).

In the 30-minute exposure group, no significant change in helping behaviour was observed (Wilcoxon signed-rank test, p = 0.9799; r = 0.01, 95% CI: −0.46–0.48).

In the 60-minute exposure group, post-exposure helping behaviour showed an increase in latency; however, this change did not reach statistical significance (paired t-test, p = 0.0793; Cohen's d = 0.51, 95% CI: −0.04–1.03).
Between-group comparison of change scores revealed no significant difference among exposure durations (Kruskal–Wallis test, p = 0.2839).

Table 3. Social behaviour (Helping behaviour test)

Exposure duration	Pre-exposure latency (s)	Post-exposure latency (s)	Statistical test	p value
10 min	255.19 ± 10.67	215.38 ± 35.64	Wilcoxon	0.0007
30 min	250.62 ± 28.33	248.88 ± 169.19	Wilcoxon	0.9799
60 min	257.75 ± 10.29	398.19 ± 295.52	Paired t	0.0793

Summary of Key Findings

Auditory exposure did not alter body weight. Body temperature increased significantly following exposure, with greater changes observed at longer durations. Spatial learning improved significantly across all exposure durations without duration-dependent differences. Social behaviour showed a significant improvement following short-duration exposure, with no consistent effects at longer exposure durations.

Discussion

The present study examined the effects of different durations of auditory music exposure on physiological and behavioural parameters in Wistar rats, with particular emphasis on indices of autonomic arousal and behavioural performance. The principal findings are that auditory exposure produced (i) a duration-dependent increase in body temperature, (ii) robust improvement in spatial learning across all exposure durations, and (iii) duration-specific modulation of social behaviour, with the clearest effect observed following short-duration exposure.

Auditory exposure and autonomic arousal

A consistent increase in body temperature was observed following auditory exposure in all experimental groups, with larger changes occurring after 30- and 60-minute exposure. In experimental animals, elevations in core or rectal temperature following sensory or emotional stimulation are widely recognised as arousal-induced hyperthermia, reflecting activation of sympathetic thermogenic mechanisms rather than inflammatory or febrile processes (Oka et al., 2001). This response is mediated by hypothalamic and brainstem components of the central autonomic network, which regulate sympathetic outflow to peripheral vasculature and thermogenic tissues.

The graded temperature response observed with increasing exposure duration suggests that longer auditory stimulation sustains or amplifies sympathetic tone. From a vascular physiology perspective, such sympathetic activation is associated with changes in peripheral vascular resistance, thermogenic vasoconstriction, and metabolic heat production. These findings indicate that auditory music exposure, even at moderate intensity, is sufficient to engage autonomic pathways relevant to cardiovascular and thermoregulatory control.

Spatial learning and arousal–performance interactions

Spatial learning performance in the Morris Water Maze improved significantly following auditory exposure across all exposure durations. The Morris Water Maze is a well-validated assay of hippocampus-dependent spatial learning, but performance is also influenced by motivational state, attention, and autonomic balance (Morris, 1984; Vorhees & Williams, 2006). The uniform improvement across durations suggests that auditory exposure did not impair task engagement and may have facilitated learning-related processes.

Previous experimental studies have reported enhanced spatial learning following music exposure in rodents, with proposed mechanisms involving increased hippocampal plasticity and upregulation of neurotrophic factors such as BDNF (Chikahisa et al., 2006; Xing et al., 2016). Although neurobiological markers were not assessed in the present study, the behavioural findings are consistent with the broader literature indicating that structured auditory stimulation can modulate cognitive performance. Importantly, the absence of duration-dependent differences suggests that within the tested exposure window, learning facilitation may reach a functional ceiling, beyond which additional auditory stimulation does not yield further improvement.

Social behaviour and duration-dependent effects

In contrast to spatial learning, social behaviour exhibited a clear duration-dependent pattern. Short-duration (10-minute) auditory exposure produced a significant improvement in helping behaviour, whereas longer exposure durations did not yield consistent enhancement. Social and pro-social behaviours in rodents are sensitive to affective state, arousal level, and environmental context (Bartal et al., 2011).

From a mechanistic standpoint, these findings are compatible with an optimal arousal framework, in which moderate autonomic activation facilitates behavioural responsiveness, while excessive or sustained sympathetic dominance may introduce behavioural variability or reduce task efficiency. The parallel observation of greater temperature increases at longer exposure durations supports the interpretation that prolonged auditory stimulation may elevate physiological load, thereby altering the balance between arousal and behavioural performance. Such non-linear relationships between autonomic activation and complex behaviour are well recognised in experimental physiology and behavioural neuroscience.

Integration of physiological and behavioural outcomes

Taken together, the findings demonstrate that auditory music exposure engages autonomic regulatory mechanisms and modulates behaviour in a domain-specific manner. Physiological arousal, indexed by body temperature, increased with exposure duration. Behavioural outcomes differed across domains, with spatial learning showing robust improvement across all durations, while social behaviour was most sensitive to short-duration exposure.

This dissociation highlights the importance of considering both physiological and behavioural endpoints when evaluating the effects of sensory stimulation. Behavioural tasks differ in their sensitivity to autonomic state, attentional demands, and motivational components. Consequently, exposure duration emerges as a critical variable shaping the net behavioural outcome of auditory stimulation.

Limitations and future directions

Several limitations should be acknowledged. First, the study did not include direct cardiovascular measurements such as heart rate or blood pressure, which would provide additional insight into autonomic–vascular coupling. Second, neuroendocrine or molecular correlates of arousal and plasticity were not assessed. Future studies incorporating autonomic, vascular, and neurobiological endpoints would strengthen mechanistic interpretation. Finally, inclusion of a non-auditory control condition would further clarify the specificity of auditory effects.

CONCLUSION

The present findings demonstrate that auditory music exposure induces measurable changes in autonomic arousal and behavioural performance in rats, with exposure duration exerting a critical influence on physiological and social behavioural outcomes. These results provide experimental evidence relevant to vascular and non-vascular physiology by illustrating how sensory stimulation can engage central autonomic networks and modulate behaviour through arousal-dependent mechanisms.

REFERENCES

1. Bartal, I. B.-A., Decety, J., & Mason, P. (2011). Empathy and pro-social behavior in rats. Science, 334(6061), 1427–1430. https://doi.org/10.1126/science.1210789
2. Chikahisa, S., Sei, H., Morishima, M., Sano, A., Kitaoka, K., Nakaya, Y., & Morita, Y. (2006). Exposure to music in the perinatal period enhances learning performance and alters BDNF/TrkB signaling in mice as adults. Behavioural Brain Research, 169(2), 312–319. https://doi.org/10.1016/j.bbr.2006.01.021
3. Koelsch, S. (2014). Brain correlates of music-evoked emotions. Nature Reviews Neuroscience, 15(3), 170–180. https://doi.org/10.1038/nrn3666
4. Kühlmann, A. Y. R., de Rooij, A., Kroese, L. F., van Dijk, M., & Hunink, M. G. M. (2018). Music affects rodents: A systematic review of experimental research. Frontiers in Behavioral Neuroscience, 12, 301. https://doi.org/10.3389/fnbeh.2018.00301
5. Morris, R. (1984). Developments of a water-maze procedure for studying spatial learning in the rat. Journal of Neuroscience Methods, 11(1), 47–60. https://doi.org/10.1016/0165-0270(84)90007-4
6. Oka, T., Oka, K., & Hori, T. (2001). Mechanisms and mediators of psychological stress-induced rise in core temperature. Psychosomatic Medicine, 63(3), 476–486. https://doi.org/10.1097/00006842-200105000-00018
7. Vorhees, C. V., & Williams, M. T. (2006). Morris water maze: Procedures for assessing spatial and related forms of learning and memory in rodents. Nature Protocols, 1(2), 848–858. https://doi.org/10.1038/nprot.2006.116
8. Xing, Y., Chen, W., Wang, Y., Jing, W., Gao, S., Guo, D., & Yao, X. (2016). Music exposure improves spatial cognition by enhancing the BDNF level of dorsal hippocampal subregions in developing rats. Brain Research Bulletin, 121, 131–137. https://doi.org/10.1016/j.brainresbull.2016.01.009