Exploring the Impact of Neck Muscle Vibration on Visual Search in an Ecological Environment: Insights from a Museum Study - A Brief Report

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ABSTRACT

Background: Ecological research provides authentic insights into behaviour and sensory integration. Neck muscle vibration (NMV) influences proprioception and gaze control, yet its effects in natural settings remain underexplored. **Objectives:** This study assessed the impact of NMV on visual search and postural activity in a museum setting while addressing methodological challenges of ecological research. **Methods**: Seventeen older adults (66–79 years) participated in visual search tasks on three large paintings at the Montreal Museum of Fine Arts. Eye-tracking technology and lumbar accelerometer recorded gaze and postural activity under three conditions: no vibration, left NMV, and right NMV. Gaze shifts were analysed through heatmaps and confidence intervals of gaze extremities. Postural data were compared using non-parametric tests. **Results**: NMV induced small, non-specific gaze shifts (2.8°–2.9°) beyond control conditions, with behaviours varying between ipsilateral and contralateral shifts. Postural activity showed no significant differences during static tasks but revealed task-dependent changes during visual search in certain paintings. Inter-painting variability and participant-specific visual strategies complicated comparisons. **Discussion**: The ecological setting modulated NMV effects on gaze, highlighting individual differences in sensory integration. Results diverged from laboratory studies, where conditions are more controlled. Methodological challenges included variability in gaze patterns and confounding factors like arm movements. Future research should incorporate virtual simulations and standardized stimuli to refine ecological methodologies and reduce variability.

KEYWORDS: museum, neck muscle vibration, postural balance, visual exploration.

Background

Conducting research in an ecological environment is crucial because it allows observing behaviours and interactions in their natural context, providing more authentic and generalisable insights than in laboratories. In human movement and rehabilitation sciences, it is time to consider the robustness of the knowledge produced in controlled situations to face the complexity of daily life activities. Nevertheless, conducting research in ecological settings brings many experimental challenges. Researchers must become aware of the challenges associated with conducting research in ecological settings to fully embrace it, overcome its obstacles, and enhance the quality of their studies.

The human body integrates vestibular, visual, and proprioceptive cues

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to maintain stability and navigate effectively. Proprioception informs body orientation, while visual inputs provide spatial orientation and enhance visual search [1]. Neck proprioception is crucial for directing gaze, integrating visual and vestibular information [2].

Muscle vibration is commonly used to study sensory integration and proprioception [3]. Due to its position, the vibration of neck muscles can influence postural orientation and visual search [2, 4]. Most research has been conducted in controlled laboratory environments, which may not reflect real-world conditions, limiting the application of these findings to real-world environments. Laboratory conditions frequently lack the complexity of natural settings, where various uncontrollable factors influence sensory processing and behaviour. Thus, testing visual search in natural settings becomes imperative, as it can impact acuity (e.g., light) and attention (e.g., ambient noise or distractions).

Museums are an interesting environment in which to study visual research in ecological settings. Art contemplation and visits to museums have many health benefits, including stress reduction and improvements in well-being, mood, and quality of life [5, 6]. However, visual exploration impairments or posture alterations can limit these benefits. Conditions like visuo-spatial hemineglect, often resulting from brain damage, disrupt attention and cause individuals to neglect one side of a painting or environment [7]. Such impairments can also coincide with postural balance disorders, further complicating daily activities and social participation [8]. In this context, neck muscle vibrations offer a promising approach to correcting attentional biases linked to hemineglect. By facilitating the reorientation of attention toward the neglected side [9, 10], this technique could enhance visuospatial exploration in daily life. Before applying this method to patients, it is crucial to validate its effects in healthy participants in ecological conditions.

In December 2019, we conducted a pilot study in a museum to investigate how neck muscle vibration affects visual search and postural activity. As skilled researchers in analysing human behaviour in controlled settings, we were of the opinion that we possessed the requisite expertise to conduct this research in an ecological setting. However, it turns out we underestimated the inherent complexity of this different setting. Through this brief report, we wish to share some lessons learned.

Methods

Seventeen healthy volunteers, aged 66 to 79, were recruited from the museum's subscriber list. All participants provided informed consent, and the study received approval from the Research Ethics Committee of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal. The experiment took place in the Pavilion for Peace at the Montreal Museum of Fine Arts. Eight paintings were initially chosen for their size (minimum width of one meter), detailed composition, and painter's death date (over 70 years ago for copyright reasons). Three paintings were selected by consensus among the authors. All paintings were on the same floor to avoid moving participants and equipment. Inspired by the Bells test, each painting was divided into seven columns, and predefined details located within these columns were chosen to be searched for by participants.

The study consisted of two tasks: one involving visual exploration of the paintings and another focusing on postural control without visual search. Participants stood 1.5 meters from the paintings or a black wall (postural control task), and their visual search and postural stability were assessed under three vibration conditions. Two vibrators were placed on the neck muscles of the participants and were turned on depending on the condition: no vibration, left neck muscle vibration, or right neck muscle vibration. Visual search was measured using eye-tracking technology, and postural activity was measured by an accelerometer placed at the lumbar level. Raw data of gaze position coordinates (X, Y) were processed, and heatmaps were generated to visualise gaze distribution. The horizontal coordinates of gaze positions were analysed to assess the effect of vibration. Regarding postural activity, pelvis acceleration data along three axes (x, y, z) were also analysed. Root mean square (RMS) acceleration values were calculated for the mediolateral and anteroposterior axes. Non-parametric tests were used due to non-normal data distribution to compare acceleration under different vibration conditions during the postural control task, postural activity with and without visual search for each painting, and the impact of vibration on postural activity during the visual search task.

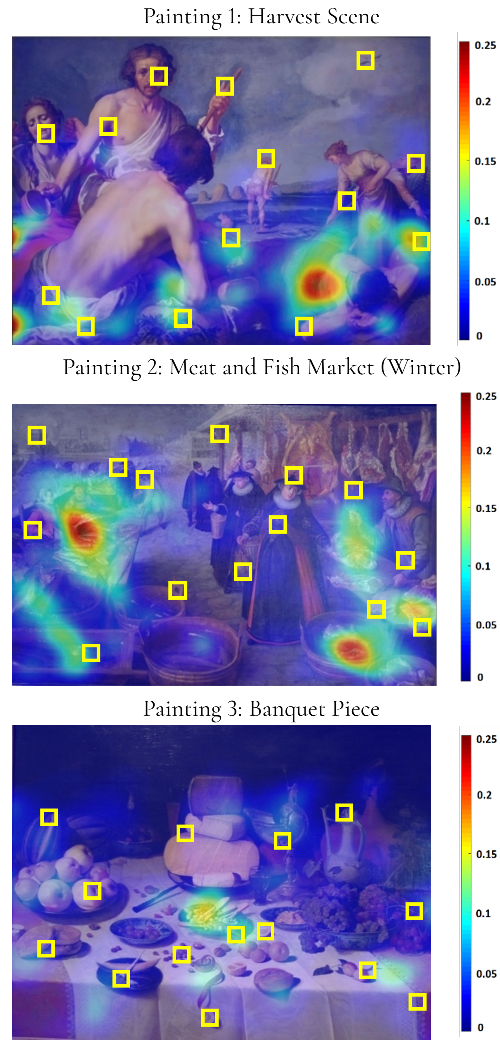

Figure 1 Heatmaps of the three paintings of the participants without neck muscle vibration (n=5 to 6). Areas of the painting with a longest duration of fixation are shown in red, with a descending scale in blue for areas with a shorter duration of fixation in terms of total search time. Yellow squares represent the details extracted as visual search targets.

Results

The first difficulty we encountered was for the statistical analysis. Indeed, the qualitative heatmap analysis revealed differences in gaze positions among the 17 participants for each painting without vibration (Figure 1). Thus inter-painting comparisons of vibration effects was impossible. Instead, vibration effects were only analysed within each painting, using the non-vibration condition as the control. As each painting was explored once by each participant (regardless of the vibration condition) and we

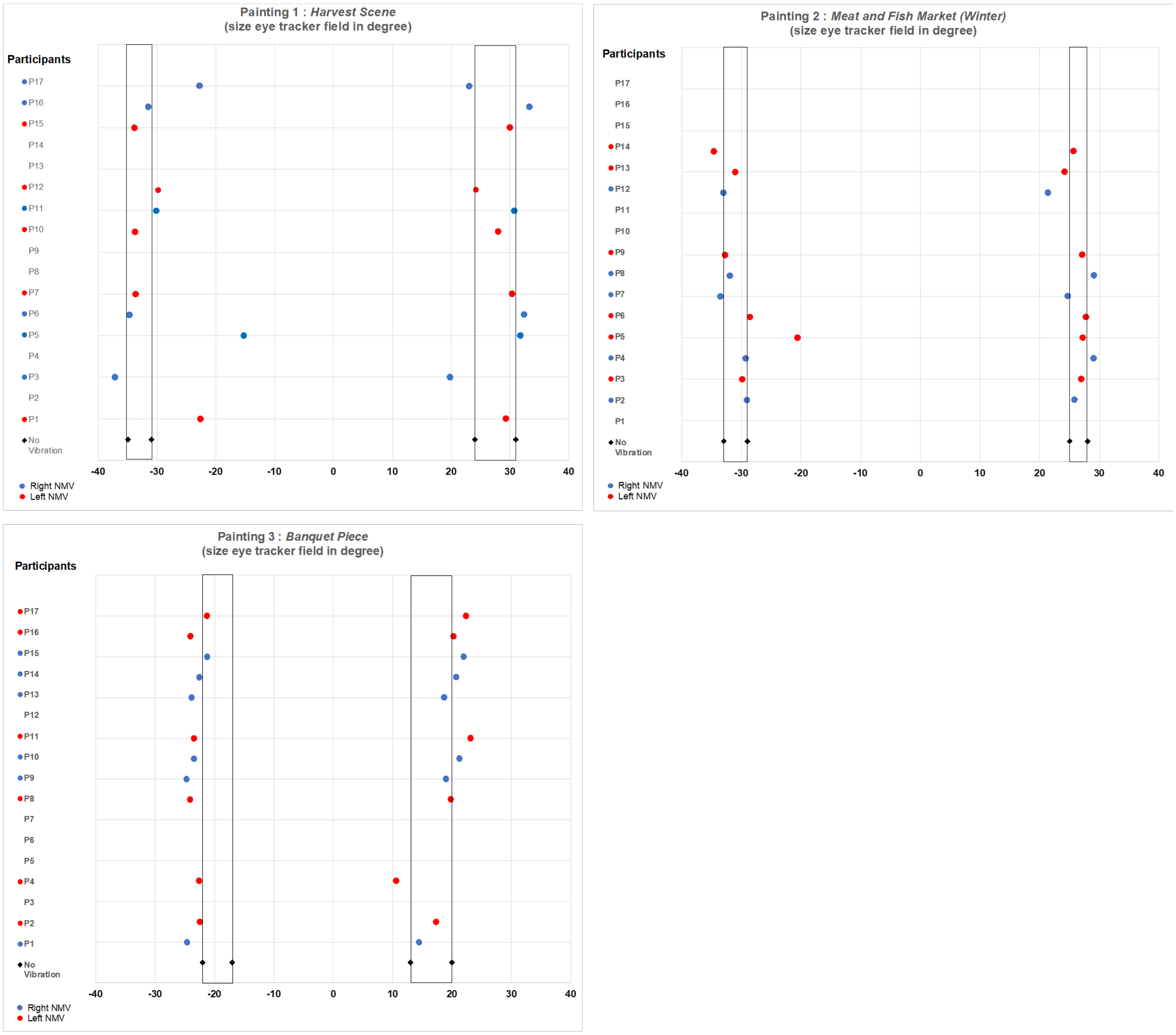

Figure 2 Comparison of the effect of neck muscle vibration based on the confidence interval (CI) of the 17 participants (P). Each dot corresponds to the rightmost and leftmost 10% of the extremities visual search. Blue dots correspond to a right neck muscle vibration (NMV) and red dots to left NMV. The vertical black lines correspond to the CI of the visual search of participants without NMV (n=5 to 6 – without dot). The x-axis represents the size of the eye tracker field of view in degree, with 0 being in the middle of the painting.

had chosen to randomise the order of the paintings between participants, it drastically diminished the number of data considered for each vibration condition. It also led us to determine an outcome as independent as possible from the visual pattern adopted to explore the painting. The 10% of the rightmost and leftmost gaze positions without vibration were used to calculate the 95% confidence interval (CI) for each painting. The vibration effects were then assessed by comparing the rightmost and leftmost gaze positions under each vibration condition (left or right) to the control CI. Gaze positions outside the control CI were considered shifted, and the extent of these shifts was averaged for each vibration condition. During right NMV, the gaze position of participants shifted by a mean of 2.9° ± 3.8 beyond the CI of the control search (Figure 2). Eight participants shifted gaze ipsilaterally, with two also shifting contralaterally. Seven shifted gaze contralaterally, including two who shortened their search ipsilaterally. Gaze was shortened on the left for three participants and on the right for four. During left NMV, the gaze position shifted by a mean of 2.8° ± 3.1 beyond the CI of the control search. Six participants shifted gaze ipsilaterally, two contralaterally, and one shifted further bilaterally. Four participants reduced gaze on the left, and two on the right. The RMS acceleration values of pelvic accelerations are shown in Table 1. No significant differences were found between the three conditions (no vibration, right NMV, and left NMV) in the anteroposterior ($p = 0.9$) or mediolateral planes ($p = 0.2$) when participants were not exploring a painting. During painting exploration, a significant effect was observed in both planes for painting 3 compared to no task, and in the anteroposterior plane for painting 1 ($p = 0.03$). However, no significant effect was found for painting 2 ($p = 0.06$). No differences were found between conditions when exploring each painting individually, except in the mediolateral plane for paintings 2 and 3 ($p = 0.03$).

Table 1 Medio-lateral and antero-posterior acceleration (Root Mean Square (RMS), in mm/s^2 (mean and standard deviation SD). Significant effect are marked with a star.

Antero-posterior acceleration (Root Mean Square)												
	No painting			*Painting 1*			*Painting 2*			*Painting 3*		
Mean	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV
Standard Deviation	0.009	0.009	0.012	0.022	0.019	0.013	0.018	0.019	0.016	0.016	0.018	0.03
P value between No paiting and painting for the same condition	0.005	0.003	0.01	0.009	0.009	0.006	0.008	0.005	0.004	0.004	0.002	0.018
P value between condition for the same painting		-		**p=0.03***	**p=0.03***	p=0.06	p=0.15	p=0.06	p=0.06	p=0.06	**p=0.03***	p=0.43
		p=0.90			p=0.09			p=0.76			p=0.08	
Medio-lateral acceleration (Root Mean Square)												
	No painting			*Painting 1*			*Painting 2*			*Painting 3*		
Mean	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV	Left NMV	No NMV	Right NMV
Standard Deviation	0.004	0.005	0.006	0.009	0.009	0.009	0.01	0.009	0.01	0.007	0.014	0.014
P value between No paiting and painting for the same condition	0.001	0.002	0.004	0.002	0.005	0.001	0.003	0.001	0.004	0.001	0.005	0.004
P value between condition for the same painting		-		p=0.09	p=0.31	p=0.06	**p=0.03***	p=0.06	p=0.09	p=0.06	**p=0.03***	p=0.21
		p=0.29			p=0.60			p=0.03			p=0.01	

Discussion

The main finding is that the deviation was nonspecific, and the shift was small in amplitude. This contrasts with previous findings by Karnath et al. [10], who reported a significant ipsilateral gaze deviation with left neck muscle vibration. In addition, we found that less than half of the participants exhibited a deviation in gaze positions towards the vibrated side. Almost all of the behaviours were observed with participants enlarging or reducing their visual exploration towards the vibrated side. This non-specific deviation could be explained by the inter-individual variability observed with previous research showing inconsistent effects of neck muscle vibration on search strategies and standing position, likely due to individual differences in sensory integration [9]. However, it is not yet clear whether this inter-individual variability was already present in the research done in the laboratory or whether the ecological environment strengthened it.

The limited deviation in gaze could be attributed to the ecological environment itself. Unlike Karnath et al. [4] who conducted their experiment in darkness, our study took place in a well-lit museum, suggesting that environmental conditions significantly influence neck muscle vibration effects. In addition, our study involved a visual search directed toward a specific detail that changed once located. Compared to a spontaneous exploration or looking for a non-existent target (tasks used in the laboratory), it may require a higher level of awareness [11]. It could also explain the differences in results compared to Karnath et al. [4]. In addition, the restricted exploration area within the paintings and fewer features near the edges may have contributed to the small effect of neck muscle vibration of the most lateral positions of the gaze.

Postural activity analysis revealed no significant differences among the vibration conditions without visual search, likely due to the presence of visual information, which may diminish the impact of neck muscle vibration [2]. The connection between neck muscles, visual, and vestibular systems may reduce the proprioceptive input's influence during multisensory integration. A significant effect on postural activity was observed when visual search tasks were performed. However, it was possibly due to the arm movements carried out by participants to point out details in the paintings rather than the visual search itself. Future research should consider alternative methods for identifying pictorial details to mitigate arm movement interference.

A limitation of this study is the selection of the three paintings representing different scenes, which revealed differences in gaze distribution without neck muscle vibration. We had thought that providing three different types of pieces of art would be an advantage for the participants' motivation. We also wished that the effects of neck muscle vibration, combined with asking to look for details repartitioned on the entire frame, would be strong enough to affect the visual behaviour, regardless of the composition of the painting. This presumption was not confirmed, and the inherent variability, influenced by each painting's composition and visual characteristics, restricted our analysis to within-painting comparisons. Future studies should select paintings based on similar visual search strategies to enable valid comparisons. Additionally, participants' level of art expertise, which can significantly influence visual search behaviour, should be reported and considered.

Conclusion

To conclude, conducting such studies in an ecological environment challenges distinguishing task complexity from environmental effects. Future research could benefit from initial studies in controlled environments, potentially using virtual reality to simulate natural-like settings. This would allow controlled manipulation of painting features and points of interest, facilitating clearer interpretations of neck muscle vibration effects. Recommendations include selecting paintings with similar visual search strategies, using alternative methods to identify pictorial details without arm movements, and considering the level of participants' art expertise.

Statement and declaration

Authors' contribution

The authors confirm contribution to the paper as follows: KJ: conceived and designed the analysis, collected the data, performed the analysis, wrote the paper. NCD: conceived and designed the analysis, collected the data, discussed the analysis and reviewed the paper YLK: performed the analysis and reviewed the paper IB: conceived and designed the analysis, discussed the analysis and reviewed the paper CD:conceived and designed the analysis, collected the data, discussed the analysis and reviewed the paper FP: conceived and designed the analysis, collected the data, discussed the analysis and reviewed the paper

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing Interests

On behalf of all the authors, the corresponding author states that there is no conflict of interest.

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