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Research Notes

# Effects of anxiety, visual target predictability and pain on gaze behavior during a visuomotor task

MAYSA P. G. LEOPOLDO[1] | CASSIO M. MEIRA JUNIOR[1] | RENATA M. SILVA[1] | CARLOS E. B. RODEGUER[1] | MARCIO F. GOETHEL[2] | FERNANDO H. MAGALHÃES[1] | ULYSSES F. ERVILHA[1]

[1] University of Sao Paulo, School of Arts, Sciences, and Humanities, São Paulo, SP, Brazil
[2] University of Porto, Faculty of Sport, Porto, Portugal

Correspondence to: Cassio M. Meira Jr.
Av. Arlindo Bettio 1000, São Paulo, SP 03828-000 Brazil.
email: cmj@usp.br
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## HIGHLIGHTS

- High-anxious individuals exhibit greater cognitive effort compared to low-anxious individuals during a postural control task with visual pursuit.
- Minimal visual attention is directed toward a deterministic, predictable target during a postural control task with visual pursuit.
- Acute muscle pain and placebo muscle pain produce similar effects on gaze behavior during a postural control task with visual pursuit.

## ABBREVIATIONS

| | |
|---|---|
| CTGT | Continuous time of gaze on target |
| M | Means |
| PVD | Pupil diameter variability |
| SD | Standard deviations |
| STAI/IDATE | State and Trait Anxiety Inventory |

## PUBLICATION DATA

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**BACKGROUND:** Attention and cognitive effort during postural control can be influenced by under threatening situations, such as pain, particularly in anxious individuals when visually tracking a target.
**AIM:** This study aimed to investigate the effects of anxiety, visual target type, and acute lumbar muscle pain on gaze behavior during a visual pursuit/postural control task.
**METHOD:** Nine young adult participants underwent testing over three time periods: (1) pre-infusion, (2) intramuscular (multifidus muscles) infusion of hypertonic (acute pain)/isotonic (placebo) solution, and (3) post-infusion (after 40 minutes after pain is vanished). The two sessions were separated by one week, in a counterbalanced order. During each session, participants performed a postural control task with visual pursuit, focusing on three targets (fixed, stochastic, and deterministic - 3 trials per target) while wearing an eye-tracker. STAI/IDATE was used to assess the participants' level of state anxiety: n=4 high-anxious and n=5 low-anxious. Continuous time of gaze on target (CTGT) and pupil diameter variability (PDV) were grouped into blocks of 3 trials.
**RESULTS:** High-anxious participants exhibited greater variability in PDV during the infusion period. The deterministic target required less visual attention (shorter CTGT) compared to the fixed and stochastic targets. Both injected solutions (hypertonic and isotonic) had similar effects on CTGT and PDV.
**CONCLUSION:** During the postural control task with visual pursuit: (1) high-anxious participants exerted greater cognitive effort, (2) participants deflected visual attention on the deterministic target, (3) acute and placebo muscle pain did not affect visual attention and cognitive effort.

**KEYWORDS**: Posture | Lumbar Pain | Visual Search | Motor Control | Anxious

## INTRODUCTION

Postural control is a complex motor function influenced by the integration of sensory information and cognitive processes. The perception of environmental cues plays a pivotal role in shaping postural responses. For instance, research has shown that body sway amplitude is influenced by the coordination of visual information, as observed during saccadic eye movements (rapid, simultaneous shifts of gaze between fixation points) [1-3]. Additionally, postural oscillations can be modulated by the visual tracking of moving targets within the surroundings [4]. Beyond visual cues, factors such as acute pain, psychological states like anxiety, and threat perception are considered significant contributors to the intricate interplay between perception and postural control [5-8]. Notably, anxiety, characterized by heightened vigilance and responsiveness to potential threats, has been associated with physiological changes such as increased heart rate, perspiration, and enhanced attention to threat-related stimuli [9-11]. These effects extend to postural adjustments and gaze behaviors, reflecting the comprehensive influence of emotional states on motor coordination [12,13].

Given the intricate relationship between emotional states, sensory processing, and postural adjustments, it becomes essential to investigate how individuals with varying levels of anxiety interpret and respond to environmental cues during postural tasks.

Furthermore, in the context of pain perception, the interplay between anxiety and pain can modulate attentional focus and cognitive effort, thereby impacting postural responses. To gain insights into these multifaceted interactions, this study focuses on examining the effects of anxiety, visual target characteristics, and acute lumbar muscle pain on gaze behavior during a visuomotor task. For this purpose, we evaluated gaze time on target and variability of pupil diameter, as these variables have been used to infer visual attention and cognitive effort, respectively [14-16]. More specifically, two critical variables were employed: (A) continuous time of gaze on target (CTGT) and (B) pupil diameter variability (PDV). The former, CTGT, represents the time duration an individual fixates on the visual target, reflecting the allocation of visual attention to task-relevant information, while the latter, PDV, captures the variability in pupillary diameter, serving as a proxy for cognitive effort and engagement during the task [17-19].

By manipulating three key independent variables—(A) pain induction (hypertonic vs. isotonic solution) in lumbar erector muscles, (B) visual target types (fixed vs. deterministic vs. stochastic), and (C) levels of state anxiety (high vs. low anxious participants) — we aimed to address three specific hypotheses during the visuomotor task: (a) Injection of hypertonic solution into the lumbar region was expected to lead to shorter CTGT and greater PDV as compared to isotonic solution injection, (b) CTGT was expected to be prolonged and PDV to be reduced when fixating on deterministic and stochastic targets as opposed to a fixed target, (c) High-anxious participants were expected to exhibit shorter CTGT and higher PDV as compared to their low-anxious counterparts. Through this investigation, we strove to shed light on the complex interactions between emotional states, sensory processing, and motor responses in postural control tasks. By elucidating the role of anxiety and pain perception in shaping attentional allocation and cognitive engagement, we aimed to provide a comprehensive understanding of the interwoven nature of motor behavior and cognitive processing.

## METHODS

### Participants

We intentionally selected thirteen healthy volunteers, but three did not finish the experiment and the data of one participant were not registered. The nine participants included in the analysis, one female and eight males, aged between 18 and 35 years (mean age 24.22 ± 5.63 years), with normal vision, who reported no fear of needles, no lower limb surgery within the previous six months, no use of antidepressant or anxiolytic medication within the previous three months, no pain on the day of the experiment or pain lasting more than three consecutive days within a six-week period before the experiment, and no high-intensity exercise within two days before the experiment. All participants received prior information about the procedures and risks and signed an informed consent form. The project was approved by the University Ethics Committee (CAAE: 91074218.2.0000.5390).

### Procedure

The State and Trait Anxiety Inventory (STAI; IDATE - Brazilian version) [17] was used to evaluate the participants' state anxiety levels, which were determined based on the sample median (n=9). The cutoff point was set at 45 (the scale ranges from 20 to 80 points), classifying four participants as high-anxious and five participants as low-anxious. Data collection with each individual consisted of two sessions (days), with a one-week interval between them. On day 1, after signing the consent form and completing the STAI/IDATE questionnaire, each participant performed the visuomotor task, which included three blocks of nine trials, each lasting 60 seconds. The first block of trials (series 1 - pre-infusion) started without any solution injection. Series 2 (infusion 1) involved intramuscular injection of 2 ml of solution (6% hypertonic saline or 0.9% isotonic) into the multifidus muscles at L4, 2 cm laterally from the spinous process. Immediately after the infusion, block 2 (series 2a - immediately after the first infusion) began and was divided into two parts: the first part consisted of five trials, and the second part consisted of four trials. After the fifth trial, the second infusion (infusion 2 and series 2b) of an intramuscular injection of 1 ml of solution (hypertonic or isotonic) into the same muscles was administered. Immediately after, the remaining four trials were performed. The order of the conditions was counterbalanced among the participants, with five in the hypertonic-isotonic condition and four in the isotonic-hypertonic condition.

Forty minutes after pain was vanished, the third block of nine trials (series 3) took place without any injection. The infusions were administered by an experienced researcher. In the pain condition, as one infusion did not provide enough pain for the entire session, saline solution (hypertonic) was administered twice: the first infusion containing 2 ml and the second 1 ml. Pain was quantified before and immediately after infusion of solution and was stopped as soon as the participant no longer reported pain. The average pain value declared on a visual analogue (posteriori digitally converted on a scale of 0-10) was 5.5, which is considered adequate [6]. Participants reported feeling moderate pain for approximately 12 minutes.

The visual pursuit task was developed in Matlab© software. Participants were instructed to keep their eyes fixed on the targets for 60 seconds. For analysis, the first and last five minutes of each trial were excluded, resulting in a trial duration of 50 seconds. The nine trials of each block were presented randomly, with three trials in each pattern: stochastic - red target (2 cm diameter) moving randomly from left to right and up and down at a frequency of 0.5 Hz; deterministic - red target (2 cm diameter) moving constantly from left to right and up and down at a frequency of 0.5 Hz; fixed (static) - black target (2 cm diameter) in the center of the screen that remained motionless for 60 seconds.

During the visual pursuit task, participants also performed the postural control task by standing upright in a bipedal orthostatic posture, facing the projection screen, and looking at the center of the screen at eye height. Participants stood barefoot with their feet separated by hip width. The gaze behavior of participants was tracked using the Mobile Eye XG (Applied Science Laboratories) eye tracking system. This system operates within a safe range of infrared illumination. Before starting the acquisition of gaze behavior data, the equipment was calibrated to adjust to the participant's eye.

### Data analysis

The eye data were analyzed using ASL Results software. Continuous tracking gaze time (CTGT) on target was obtained by tracking the targets frame by frame on each trial. For analysis, the sum of the three trials was calculated, resulting in a total of 150 seconds (50 seconds per trial). Pupil diameter variability (PDV) was the standard deviation in pixels for each trial. Data were organized in blocks of three trials. Anxiety levels were determined based on the median of the sample, with a cutoff point of 45 (20-80). Participants scoring above this cutoff were classified as high anxious (four participants), while those scoring below were classified as low anxious (five participants).

Data were tabulated and organized in Microsoft Excel spreadsheets and analyzed using IBM SPSS software, version 24. Descriptive analysis and the Shapiro-Wilk statistical test were conducted to examine the data distribution. Due to the non-normality of the distributions, inferential analyses were performed using nonparametric techniques (Mann-Whitney tests for pain and anxiety comparisons; Kruskal-Wallis tests for target comparisons). The significance level was set at 5% for all analyzes. We reported effect sizes for the significant effects.

## RESULTS

The variables continuous time of gaze on target (CTGT) and pupil diameter variability (PDV) were collected in two different conditions (painful and placebo) and in three time windows, namely, pre-infusion (before the intramuscular infusion of hypertonic saline solution/painful condition or isotonic saline solution/placebo condition), during-infusion (immediately after the infusion), and post-infusion (thirty minutes after the pain has ceased completely). No significant differences were found for CTGT (Pre: U=179.5, p=0.1; During: U=211, p=0.11; Post: U=284.5, p=0.942) and PDV (Pre: U=246, p=0.386; During: U=259, p=0.912; Post: U=253, p=0.49) (Table 1).

The deterministic pattern resulted in shorter CTGT compared to the fixed and stochastic targets during all three time periods (Pre: $X^2$=20.84, p=0.0001, $\eta^2$H=0.42; During: $X^2$=15.53, p=0.0004, $\eta^2$H=0.3; Post: $X^2$=21.36, p=0.0001, $\eta^2$H=0.44). No differences among targets were found for PDV (Pre: $X^2$=2.26, p=0.323; During: $X^2$=3.23, p=0.199; Post: $X^2$=0.7, p=0.704) (Table 2).

Data from high and low anxious participants are presented in Table 3. Although no differences were observed for CTGT (Pre: U=189, p=0.146; During: U=277, p=0.82; Post: U=248, p=0.409), high-anxious participants exhibited greater variability in pupil diameter during the infusion period compared to low-anxious participants (U=155, p=0.02, $\eta^2$=0.13). No significant effects were found for PDV in the pre-infusion (U=270, p=0.71) or post-infusion (U=218, p=0.217) periods.

**Table 1.** Continuous time of gaze on target (CTGT) and pupil diameter variability (PDV) means (M) and standard deviations (SD) obtained during the painful (hypertonic saline infusion) and placebo (isotonic saline infusion) conditions performed in three time windows: pre-infusion, during-infusion, and post-infusion.

| | Isotonic | | Hypertonic | |
|---|---|---|---|---|
| | M | SD | M | SD |
| **CTGT (seconds)** | | | | |
| Pre-infusion | 83.24 | 14.24 | 88.77 | 13.56 |
| During-infusion | 80.79 | 15.05 | 81.47 | 17.70 |
| Post-infusion | 77.33 | 16.73 | 81.14 | 15.15 |
| **PDV (pixels)** | | | | |
| Pre-infusion | 22.88 | 06.93 | 20.13 | 8.62 |
| During-infusion | 22.88 | 17.88 | 25.94 | 10.89 |
| Post-infusion | 24.91 | 11.24 | 22.84 | 9.45 |

* pre-infusion (before the intramuscular infusion of hypertonic saline solution/painful condition or isotonic saline solution/placebo condition), during-infusion (immediately after the infusion), and post-infusion (thirty minutes after the pain has ceased completely).

**Table 2.** Continuous time of gaze on target (CTGT) and pupil diameter variability (PDV) means (M) and standard deviations (SD) according to the type of visual target used in the experiment, whether fixed, deterministic or stochastic in three time windows: pre-infusion, during-infusion, and post-infusion.

| | Fixed | | Deterministic | | Stocastic | |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | M | SD |
| **CTGT (seconds)** | | | | | | |
| Pre-infusion | 93.85 | 10.43 | 73.25 * | 12.85 | 90.92 | 8.86 |
| During-infusion | 89.36 | 12.81 | 69.08 * | 13.33 | 84.95 | 15.61 |
| Post-infusion | 90.78 | 11.90 | 64.64 * | 9.73 | 82.29 | 13.31 |
| **PDV (pixels)** | | | | | | |
| Pre-infusion | 19.75 | 8.66 | 22.35 | 7.73 | 22.15 | 7.59 |
| During-infusion | 22.92 | 9.15 | 34.27 | 20.54 | 24.49 | 7.65 |
| Post-infusion | 22.75 | 10.76 | 22.05 | 5.36 | 26.65 | 13.05 |

* significant differences. p <0.001.
* pre-infusion (before the intramuscular infusion of hypertonic saline solution/painful condition or isotonic saline solution/placebo condition), during-infusion (immediately after the infusion), and post-infusion (thirty minutes after the pain has ceased completely).

**Table 3.** Continuous time of gaze on target (CTGT) and pupil diameter variability (PDV) means (M) and standard deviations (SD) of high and low anxiety individuals in three time windows: pre-infusion, during-infusion, and post-infusion.

| | Low Anxiety | | High Anxiety | |
|---|---|---|---|---|
| | M | SD | M | SD |
| **CTGT (seconds)** | | | | |
| Pre-infusion | 85.44 | 14.71 | 86.58 | 13.63 |
| During-infusion | 82.82 | 16.49 | 79.44 | 16.19 |
| Post-infusion | 79.75 | 17.23 | 78.72 | 14.82 |
| **PDV (pixels)** | | | | |
| Pre-infusion | 20.11 | 7.78 | 22.78 | 7.99 |
| During-infusion | 24.90 | 16.35 | 29.80 | 12.41 |
| Post-infusion | 21.40 | 7.30 | 26.21 | 12.24 |

* significant differences. p <0.03.
* pre-infusion (before the intramuscular infusion of hypertonic saline solution/painful condition or isotonic saline solution/placebo condition), during-infusion (immediately after the infusion), and post-infusion (thirty minutes after the pain has ceased completely).

## DISCUSSION

The analyses of CTGT and PDV revealed no significant differences between painful and placebo conditions, which contradicts the hypothesis that the injection of a hypertonic solution affects visual attention [5] and cognitive effort compared to an isotonic solution injection. It is worth noting that both solutions appeared to have led to increased PDV, indicating greater cognitive effort required to perform the visuomotor task. One possible explanation for this finding is that the injection itself may have created a sense of threat for the participants.

The hypothesis that the fixed target would increase visual attention during pain was refuted, as the findings indicated that CTGT was shorter when participants gazed at the deterministic target compared to when they focused on the fixed and stochastic targets in all three time periods. It can be inferred that in all three time periods, the deterministic condition attracted less visual attention, likely because participants perceived an up-and-down pattern of the target and employed an energy-saving strategy by anchoring their gaze near the center of the screen based on visual prediction [4]. The shorter CTGT for the deterministic target may also be associated with easier pattern recognition, which could reduce focal vision [16]. Our findings also do not support the notion that the unpredictability of the stochastic target would result in shorter CTGT [18]. The PDV analysis revealed no significant differences among targets, suggesting that the cognitive effort employed to perform the task was similar in all three time periods, regardless of target type. This finding contradicts studies on neutral and exciting scene recognition situations and complex cognitive task execution [19,20].

The hypothesis that high-anxious participants during the visuomotor task would exhibit shorter CTGT compared to low-anxious participants was refuted, as both low-anxious and high-anxious participants showed similar values across the three time periods. Individuals with high levels of state anxiety who perform tasks under threat tend to compensate for this stress process by increasing heart rate, perspiration, and altering gaze behavior [10,11]. These psychophysiological variables should be investigated in future studies. Our findings support the hypothesis that high-anxious participants would show higher PDV compared to low-anxious participants after receiving the injection. This provides evidence that high-anxious individuals are more likely to exhibit weaker gaze behavior parameters when confronted with threatening stimuli [14,15].

The main limitation of this study was the small sample size due to (1) refusal to initiate the experiment (owing to needle fear) and (2) withdrawal from data collection (as a result of the prolonged data collection sessions and the invasive technique of substance injections). Also, we highlight as a limitation the loss of gaze behavior data during some trials owing to blinks or abrupt head movements.

## CONCLUSION

In conclusion, the findings of the present study indicate that during a visuomotor task: (1) high-anxious individuals exerted greater cognitive effort compared to low-anxious individuals, (2) the deterministic, predictable target attracted less visual attention, and (3) acute and placebo muscle pain did not affect visual attention and cognitive effort.

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