



Research Paper

# Static and dynamic visual vertical perception in subjects with migraine and vestibular migraine



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## KEYWORDS

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**Abstract** *Objective:* To measure the static visual vertical and the effect of visual rotation on the perception of visual vertical in migraine and vestibular migraine subjects. By so doing, we may better understand the vestibular contribution to the pathophysiology of migraine, as well as the capacity for visual compensation.

*Methods:* The perception of visual vertical in the presence of static and dynamic visual cues was prospectively studied in 10 subjects with migraine, 6 subjects with vestibular migraines, and 10 controls. Subjects used a dial to rotate a fluorescent green line to the vertical position. Static visual vertical (SVV) was measured with a black background, as well as with a static random-dot visual pattern. This pattern was then rotated at various velocities to measure dynamic visual vertical (DVV).

*Results:* Migraine subjects had greater deviation from true vertical than controls in SVV ( $P < 0.05$ ). The DVV in migraine subjects was greater than controls when rotated in the counterclockwise at  $-5^\circ/s$  ( $P < 0.01$ ),  $-20^\circ/s$  ( $P < 0.01$ ), and  $-80^\circ/s$  ( $P < 0.01$ ), but not when the line was rotated clockwise. Vestibular migraine subjects did not deviate significantly from controls in SVV ( $P < 0.37$ ,  $P < 0.22$ ), but did show greater deviation in the DVV tasks at  $-80$  and  $-20^\circ/s$  ( $P < 0.05$ ,  $P < 0.03$ ). Migraine and vestibular migraine subjects demonstrated a wider range of vertical deviance when compared to controls ( $P < 0.02$ ).

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**Conclusions:** This study demonstrates a significant deviation of the perceived static as well as dynamic visual vertical in migraine subjects. Moving stimuli may have a greater influence on migraine and vestibular migraine subjects, which suggests an underlying sensory integration disorder.

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## Introduction

Visual vertical is a gravitational reference that allows the brain to control body orientation and stabilization in space.<sup>1</sup> This reference is developed by the brain through integration of vestibular, visual, and somatosensory cues.<sup>2–4</sup> Static visual vertical (SVV) is the perceived visual vertical without rotation of the visual background, and is a sensitive and widely used tool to detect an imbalance in otolith function.<sup>5,6</sup> Dynamic visual vertical (DVV) is the change in perceived vertical upon rotation of a visual background around the line of sight.<sup>1,7</sup>

Migraineurs often suffer from vestibular symptoms, including vertigo and the feeling of tilting during migraine episodes.<sup>8–12</sup> Despite these vestibular symptoms, only a few studies have the effects of migraine on SVV, with one study showing subclinical deviation of the SVV, and another showing no effect.<sup>13,14</sup> While many studies have looked at the visual contribution to migraines, fewer studies have looked at the potential vestibular pathology and to our knowledge none have looked at subjective visual vertical with a dynamic (rotating) visual background.

A decreased perceptual roll-tilt threshold in vestibular migraineurs in comparison to controls has been demonstrated, suggesting abnormally enhanced perception.<sup>15</sup> Although this is an interesting effect, it is not clear if it is limited to vestibular perception or if it can be more broadly applied to other sensory stimuli.

By using subjective visual vertical for studying otolith function, our study aims to further develop the vestibular contribution to migraine pathophysiology. The dynamic visual vertical is a multisensory integration task which allows us to better understand visual adaptation in vestibular deficits. We hypothesized that subjects with migraine or vestibular migraine will have greater deviations in their SVV and DVV, suggesting both a vestibular component to the pathophysiology, as well as limited capacity for visual compensation.

## Materials and methods

### Participants

Ten subjects with migraine, and six subjects with vestibular migraine were recruited, as well as 10 controls. All migraineurs met International Headache Society criteria for migraine.<sup>16</sup> All vestibular migraine subjects met clinical criteria for diagnosis.<sup>17</sup> Of the migraineurs, 8 had migraine with aura, and 8 had migraine without aura. Subjects were excluded if currently on prophylactic medication for

migraine. All migraineurs were asymptomatic during their testing.

All subjects underwent general screening for history of dizziness and vertigo, as well as hearing and vision problems. History of neurologic and rheumatic disease was also explored. Severity of migraine was assessed in all subjects using the migraine severity scale (MIGSEV).<sup>18</sup> Additional demographic information is available in Table 1.

### Tests and procedures

Subjects were seated in front of an 11.75 × 21 inch computer screen which displayed a 4 mm fluorescent green

**Table 1** Population data. Standard deviation indicated in parentheses.

Demographic	Control	Typical	Vestibular
			migraine
			migraine
Number of subjects	10	10	6
Age	27 (15)	33 (13)	30 (5)
Gender			
Male	6	2	0
Female	4	8	6
Race			
White	7	9	4
Asian	3	1	1
Black	0	0	1
Handedness			
Right	10	8	5
Left	0	1	1
Ambidextrous	0	1	
Migraine type			
Migraine with aura		6	2
Migraine without aura		4	4
MIDAS score	0.875 (2.1)	9 (10.5)	32 (29)
Midas classification			
Little or no disability (0–5)		0	
Mild disability (6–10)		8	3
Moderate disability (11–20)			
Severe disability (>20)		2	3

line. The edges of the line were blurred to eliminate the potential of the pixels to provide a cue. To avoid visual cues, the edges of the screen were masked such that the subject was only able to see a circular screen with the fluorescent line. Tests were performed in a dark room and blinders were worn by the subject to ensure no other visual cues were available.

The starting position of the line was randomly displaced either to the right or to the left of gravitational vertical by angles that varied as much as  $\pm 30^\circ$ . Using a dial, subjects were instructed to rotate the line until perceived vertical was achieved. At that point, subjects pressed a button on the dial box to advance to the next condition. There was no time constraint. There were eight conditions. Each condition included 8 stimulus presentations. All tests were performed binocularly.

Eight conditions with distinct visual background were presented to the subjects. The task for all conditions was the same, as noted above. The first condition tested the static visual vertical (SVV), and consisted of a blank background. The second condition had a background with fixed, randomly-placed non-moving circles.

Following this, three separate conditions tested the dynamic visual vertical (DVV). The background consisted of similar circles moving at 5 cm/s, 20 cm/s and 80 cm/s around a fixed center in the middle of the circular screen. With each condition, the rotation direction was interleaved between clockwise (positive) and counterclockwise (negative).

## Data acquisition and statistical analysis

Custom software written in Adobe Flash (Adobe Systems, New York, NY) was used to create the stimulus. Data was sent by PHP to a secure server. The student *t*-test (assuming unequal variance) was used for population comparisons. One-way ANOVA was used to test differences amongst multiple populations in a single condition (migraine, vestibular migraine, and controls). Two-way ANOVA with matched pairs was used to test the interaction of conditions and differences amongst populations.

## Results

### Effects of migraine on SVV

Migraine and vestibular migraine subjects had a combined SVV of  $-0.638^\circ$  (SD =  $0.809^\circ$ ), which approached but was not statistically different from controls (mean =  $0.097^\circ$ , SD =  $0.991^\circ$ ,  $P = 0.064$ ).

When separated into two separate populations – migraine and vestibular migraine – the migraine subjects had a significantly lower mean SVV than controls (mean =  $-0.884^\circ$ , SD =  $0.788$ ,  $P = 0.025$ ) while vestibular migraine subjects did not. Individual subject results for both SVV and DVV are highlighted in Fig. 1.

### Effects of migraine on DVV

Individual subject data was refitted around the static mean, and analysis group analysis was performed. As a

single population, migraine and vestibular migraine subjects had a more negative deviation from gravitational vertical than controls when the background rotated at  $-5$  cm/s (mean =  $-1.62$ , SD =  $0.87$ ,  $P = 0.02$ ),  $-20$  cm/s (mean =  $-2.56$ , SD =  $1.19$ ,  $P < 0.001$ ), and  $-80$  cm/s (mean =  $-2.16$ , SD =  $1.29$ ,  $P = 0.006$ ). The greatest deviations from true vertical were generally with a dynamic stimulus of  $-20$  cm/s. The deviation from vertical was not significantly different with positive (clockwise) rotation of the background at  $+5$  cm/s,  $+20$  cm/s, or  $+80$  cm/s. Fig. 2A and B demonstrate the redistribution of DVV around the new SVV in migraine and vestibular migraine subjects.

When separated into two separate populations, the effect was similar. Subjects with migraine had significant deviation from gravitational vertical compared to controls with counterclockwise rotation at  $-80$  cm/s and  $-20$  cm/s, and approached significance at  $-5$  cm/s ( $P = 0.02$ ,  $P = 0.03$ ,  $P = 0.07$ ), but not with clockwise rotation.

Subjects with vestibular migraine deviated in a similar manner to typical migraineurs, with significant deviations from gravitational vertical compared to controls at  $-80$  cm/s,  $-20$  cm/s, and approached significance at  $-5$  cm/s ( $P = 0.03$ ,  $P = 0.01$ ,  $P = 0.06$ ). Again, the differences between vestibular migraineurs and controls in the clockwise rotating stimuli were not significant.

## Comparison of SVV and DVV by migraine type, presentation, and severity

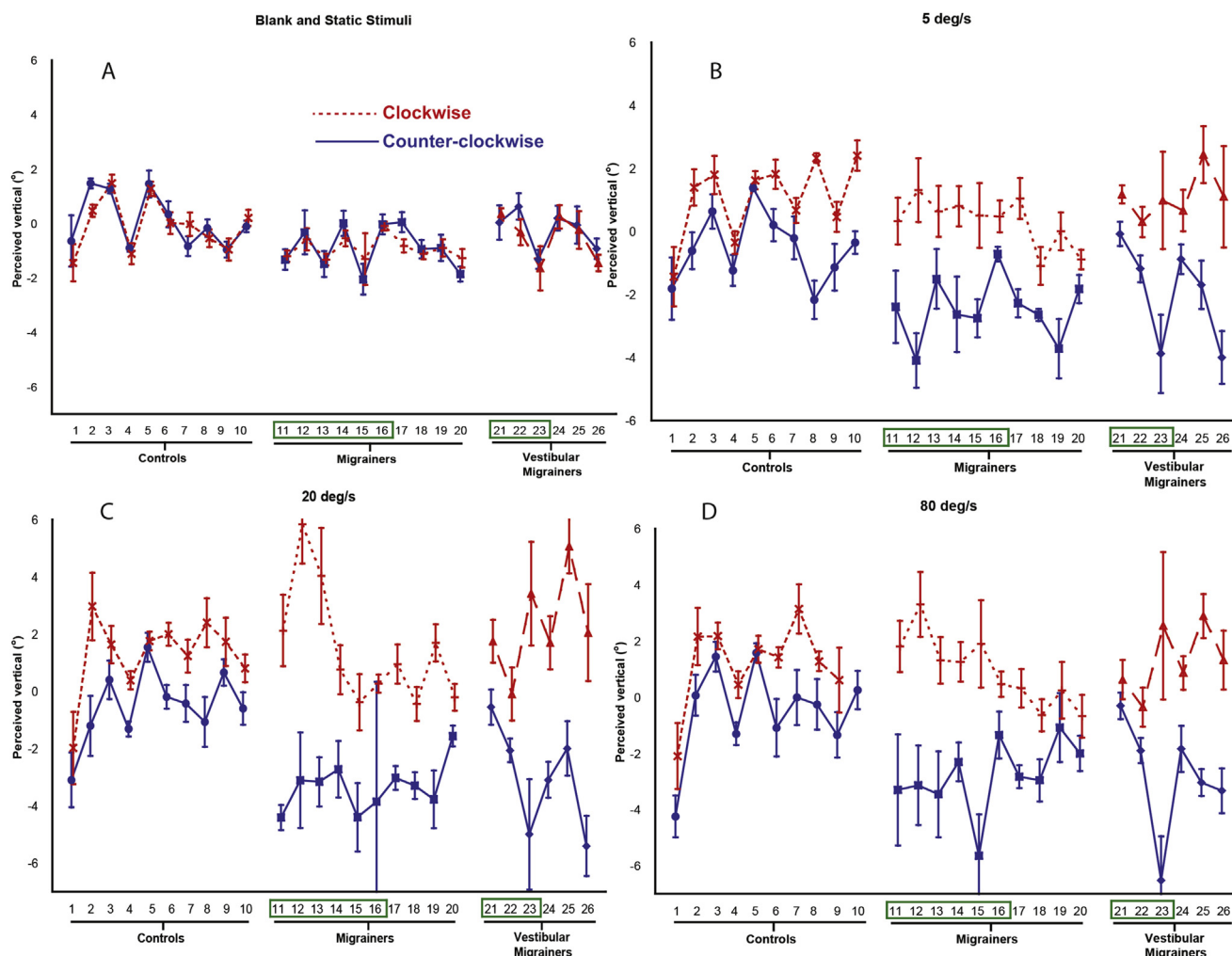
The subjective visual vertical of typical migraine subjects was not significantly different from vestibular migraine subjects. Similarly, the interaction of migraine type and DVV stimulus was not statistically significant. Migraine subjects were stratified by their aura symptoms. Those without aura did not have statistically different SVV or DVV than those with aura. Migraine subjects were also stratified by the severity of symptoms. There was no statistically significant effect on visual vertical perception based on migraine severity.

## Range of perceived vertical by subject across conditions

Subject data was collected for each condition, and a range of averages for each condition was collected. Overall, subjects with migraine and vestibular migraine had a significantly greater range than controls, when viewed as a single population (mean =  $5.58$ ,  $P = 0.002$ ; control mean =  $2.964$ ). As a separate population, migraine subjects also demonstrated greater variation than controls (mean =  $5.401$ ,  $P = 0.015$ ). Vestibular migraine subjects approached significance (mean =  $5.878$ ,  $P = 0.071$ ).

## Discussion

In this study we report a large and novel deviation of the dynamic visual vertical in migraine and vestibular migraine subjects. Additionally, our results confirm the relatively small but significant deviation in static visual vertical in migraineurs.<sup>13</sup>



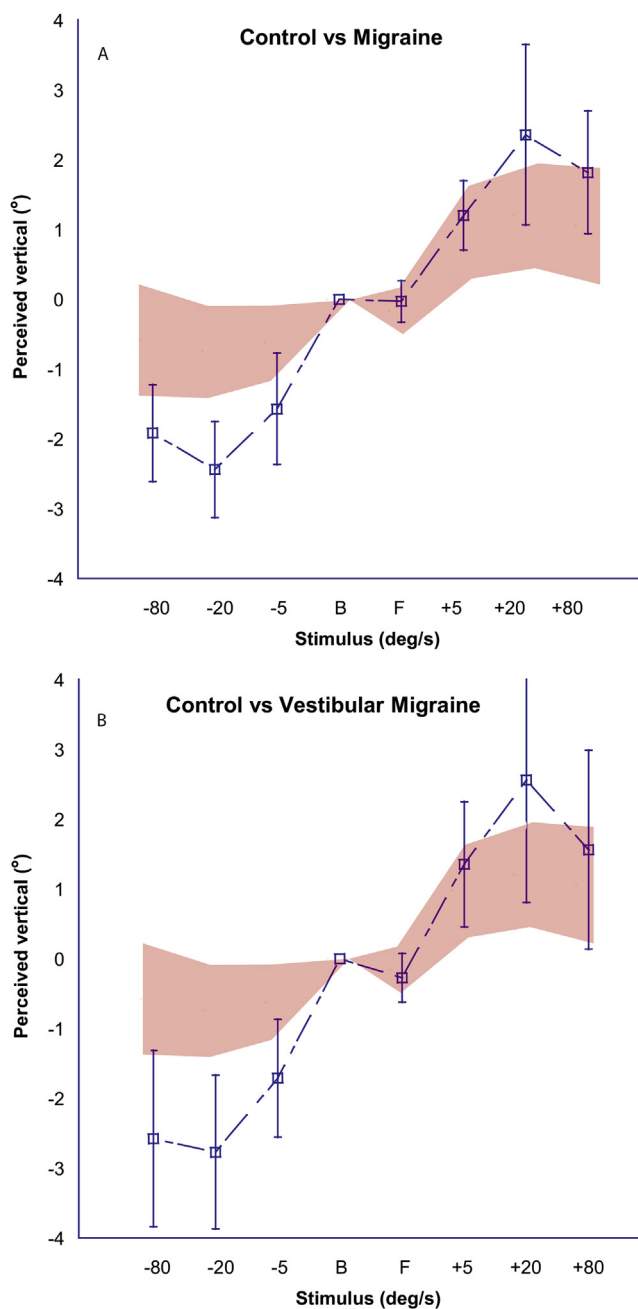
**Fig. 1** Individual subject data. The perceived visual vertical (in degrees) for each patient is shown with 95% confidence intervals represented by error bars. Individual subjects and population are represented in x-axis, with migraine patients with aura outlined in green. A: The blank stimulus is represented by the red line, static stimulus represented by blue line. B–D: Positive or clockwise rotation stimuli are represented by the red line. Negative or counter-clockwise are shown with the blue line. B–D represent individual subject data at 5 deg/s, 20 deg/s, and 80 deg/s, respectively.

Creating a visual representation of vertical requires integration of vestibular, visual, and proprioceptive senses.<sup>19</sup> In studying the SVV and DVV, we utilized a primarily vestibular task in order to assess otolith function while minimizing the proprioceptive and visual cues. The finding of significant changes in DVV in migraine and vestibular migraine subjects corroborates with previous studies that suggest that increased task difficulty in DVV results in diminished visual compensation and greater deviation of visual vertical from normal.<sup>3</sup> Our finding of an overall increased variance of range demonstrated by subjects with migraine also supports this conclusion.

Migraine and vestibular migraine are relatively chronic disorders. Bronstein found that subjects with bilateral chronic labyrinthine deficits have a normal SVV with increased deviations from normal upon roll-plane visual motion stimuli, which is similar to DVV. Patients with acute unilateral vestibular lesions, however, had normal SVV.<sup>3</sup> In this study by Lopez, subjects demonstrated normal SVV

prior to unilateral vestibular neurectomy. These subjects' returned to normal by the one-year follow-up. In contrast to these studies, our study demonstrated a significant deviation in SVV in migraineurs. This suggests that adaptation or sensory compensation may be impaired in migraineurs.

The static (i.e. no moving background) visual vertical was previously measured in migraine patients in two studies.<sup>13,14</sup> One study found greater variation in visual vertical in patients with migraine as well as other types of headaches,<sup>13</sup> but both studies found no overall bias in average visual vertical perception.<sup>13,14</sup> The static visual acuity task used currently was similar to the prior studies and similar to the prior studies there was no major difference between migraine and controls for this task other than greater variation in the migraine group. However, the current study builds on this prior work by also including a dynamic visual vertical task. We felt this task might be more relevant because patients with migraine are often bothered by visual motion, suggesting a possible abnormal transfer of



**Fig. 2** Population data. The perceived visual vertical (in degrees) for each DVV stimulus are shown, with results normalized to the SVV. Typical migraine patients are represented in blue in Panel A (95% CI represented by error bars). Vestibular migraine patients are represented in blue in Panel B. The x-axis represents the different stimuli. The pink shaded area is the 95% confidence interval for control populations for each condition.

visual motion to perceptions of tilt. Our study found that for this dynamic task did significantly increase deviation at least for counterclockwise rotation. It was somewhat surprising to us that this effect only occurred in the counterclockwise direction. All of the controls and 13/16 migraine patients were right handed. Although it is possible that the effect seen was related it handedness, the dial was located

near the midline and is unclear how this would be the case. It is not possible to investigate within the current dataset because only 2 individuals in the current study were left handed.

Migraine and vestibular migraine subjects in our study had dynamic visual verticals that deviated more with counterclockwise stimuli than clockwise. Previous studies have shown deviations in visual vertical in subjects with unilateral vestibular neurotomy, vestibular schwannoma, and Meniere’s disease, with the deviation corresponding to the unilateral pathology.<sup>1,20,21</sup> The majority of migraine subjects in the current study also deviated in one direction, suggesting asymmetric vestibular tone.

**Conclusions**

Migraine and vestibular migraine subjects reported significant deviations in dynamic visual vertical. Static visual vertical changes in migraine subjects were also reported. Moving stimuli may have a greater influence on migraine and vestibular migraine subjects, which suggests an underlying sensory integration disorder.

**Conflict of interest disclosure**

None of the authors have a significant conflict of interest related to this work.

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