Walking with eyes closed is easier than walking with eyes open without visual cues: The Romberg task versus the goggles task

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Abstract

Background: The Romberg test, with the subject standing and with eyes closed, gives diagnostic arguments for a proprioceptive disorder. Closing the eyes is also used in balance rehabilitation as a main way to stimulate neural plasticity with proprioceptive, vestibular and even cerebellar disorders. Nevertheless, standing and walking with eyes closed or with eyes open in the dark are certainly 2 different tasks. We aimed to compare walking with eyes open, closed and wearing black or white goggles in healthy subjects.

Methods: A total of 50 healthy participants were randomly divided into 2 protocols and asked to walk on a 5-m pressure-sensitive mat, under 3 conditions: (1) eyes open (EO), eyes closed (EC) and eyes open with black goggles (BG) and (2) EO, EO with BG and with white goggles (WG). Gait was described by velocity (m s⁻¹), double support (% gait cycle), gait variability index (GVI/100) and exit from the mat (%).

Analysis involved repeated measures Anova, Holm-Sidak’s multiple comparisons test for parametric parameters (GVI) and Dunn’s multiple comparisons test for non-parametric parameters.

Results: As compared with walking with EC, walking with BG produced lower median velocity, by 6% (EO 1.26; BG 1.01 vs EC 1.07 m s⁻¹, P = 0.0328), and lower mean GVI, by 8% (EO 91.8; BG 66.8 vs EC 72.24, P = 0.009). Parameters did not differ between walking under the BG and WG conditions.

Conclusion: The goggle task increases the difficulty in walking with visual deprivation compared to the Romberg task, so the goggle task can be proposed to gradually increase the difficulty in walking with visual deprivation (from eyes closed to eyes open in black goggles).

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1. Introduction

In neurological examinations, a usual assessment involves a static standing position with or without visual input, the Romberg test. The subject is asked to close the eyes, and the increase in sway (disturbed balance) suggests a proprioceptive disorder (see reference Lanska and Goetz [1] for the history of the Romberg sign). Closing the eyes can give useful diagnostic information.

Closing the eyes is also used in balance rehabilitation as a main way to stimulate neural plasticity in proprioceptive, vestibular and even cerebellar disorders. In this situation, a subject impaired in balance spontaneously increases the use of visual information, when available, as assistive compensation for failure of another sensory input. However, this compensatory strategy may be counterproductive because it can prevent the central nervous system from recovering. This situation was first demonstrated among patients with acute vestibular neuritis, and closing the eyes is one of the main tools in vestibular rehabilitation found effective in unilateral or bilateral vestibular deficit [2].

Moreover, the visual compensatory strategy could lead to a visual dependence (VD) behavior, defined as the priority the subject gives to the visual input for balance control even if the visual signal, compared with other sensory inputs, is poor or erroneous [3,4]. VD can be detected by a perception and orientation task of visual verticality called the rod and frame test, first described by Witkin and Wapner [5], whereby the patient stands on a dynamic force platform as with the Equitest [6] or sits...
on a seesaw platform [7]. Such VD has been described in Parkinson’s disease [8], after peripheral or central vestibular disorders [9,10] or after stroke [4,7]. VD for postural control is also observed in normal older adults [11,12] and can lead to falls, especially in older adults [13–15]. The condition has been described as vestibular omission syndrome [16] in some older adults who complain of dizziness because of their adherence to erroneous visual signals despite normal vestibular and proprioceptive functions. Rehabilitation in visual deprivation in this case can give some excellent results. Moreover, after acute vestibular neuritis, patients with VD have severe and persistent vestibular disorders [17].

When VD is diagnosed, the impact on rehabilitation is obvious: exercises of motor and balance control without visual input will likely provide the best results in improving balance. The usefulness of this technique has been demonstrated after stroke [18,19]. To prevent and reduce VD, 2 ways are commonly used in rehabilitation: to close the eyes or to disturb the visual environment with optokinetic stimulation. The latter is considered difficult and is therefore less often used.

Closing the eyes is supposed to reproduce a dark environment. Nevertheless, standing and walking with the eyes closed or open in the dark are likely two different tasks. In the first task, the subject makes a voluntary effort to cancel the visual input, thus preparing the central nervous system to look for other inputs (proprioceptive, vestibular, tactile and even auditory), knowing that the visual one is unavailable. In the second task, walking with eyes open in the dark, the usual behavior is to improve attention given to the visual input, which could be to the detriment of the other sensorial inputs. So, even if the visual input is poor or difficult to be analyzed, the whole attention process is devoted to this analysis and can be highly detrimental to balance.

Training for standing balance in a dark room is easy but training to walk in a dark room is difficult. Such training needs a large room without any visual signal, even a small ray of light. A mask is often used. There are 2 kinds of masks. The one masking all planes to assist with sleep is close to the eyelids and helps keep the eyes closed. The other allows the eyes to be open, such as goggles for work or for skiing, which are often used to manipulate vision in studies of standing or walking conditions [20–24]. We commonly use these goggles with the visual field masked by black tape for balance rehabilitation [19]. Two different goggles have been used: black goggles simulating the darkness and white goggles simulating fog to observe possible differences. Indeed, the role of the visual input is unclear because a stimulation of the photoreceptors of the retina could by itself affect these possible adaptations.

Our hypothesis is that walking with eyes open with goggles is more difficult than walking with eyes closed. A previous study of standing balance on a platform among healthy subjects showed such differences [25]: keeping the eyes open led to decreased descending drive over the postural muscles, as assessed by the amplitude of the difference between center-of-pressure and vertically projected center-of-gravity movements. This lower tonic muscular activity likely also infers some biomechanical effects over the gait pattern. However, to our knowledge, the relative effect on walking of eyes open while wearing goggles versus eyes closed has not been investigated often. In particular, we investigated whether walking with eyes open in the dark would result in slower velocity and increased time during support phases than with eyes closed.

| Table 1 |

| Characteristics of healthy subjects undergoing walk tests in 2 protocols. |
|-----------------|-----------------|-----------------|
| 50 subjects     | Age (years)     | Height (cm)     | Weight (kg)     |
| First protocol  | 22.7 ± 2.5      | 172 ± 8.3       | 64.4 ± 8.3     |
| Second protocol | 24.6 ± 4.6      | 168 ± 8.3       | 62.5 ± 10.4    |

Data are mean ± SD.

Rehabilitation Medicine. In a first protocol, 25 participants [10 males, mean age 23 ± 2.5 years] walked under 3 conditions: eyes open (EO), eyes closed (EC) and EO with black goggles (BG). In a second protocol, 25 other participants [9 males, mean age 25 ± 4.6 years] walked under 3 other conditions: EO, EO with BG and EO with white goggles (WG) (Table 1).

The clinical investigation was conducted according to the principles expressed in the Declaration of Helsinki. Written informed consent was obtained from all participants. The study was registered with the Commission Nationale Informatique et Liberté (CNIL; no. 1828153).

2.2. Protocol

Participants completed walking assessments on a 5-m pressure-sensitive mat (GaitRite®). First, participants walked with eyes open (EO) looking at a target 7 m ahead. After baseline assessment, participants were randomly assigned in the first protocol to walk first under the BG condition or the EC condition, then under the other condition, and participants in the second protocol walked first using black or white goggles. Participants were instructed to walk at a comfortable velocity until 1 m after the end of the GaitRite® mat as announced by the examiner. To assess deviation from a straight line, the final location of the heel on the carpet was noted if the participant had exited the GaitRite® mat.

2.3. Data analysis

Each condition was recorded 3 times to assess gait parameters with the average over the 3 trials analyzed. Data were collected with the GaitRite® software V4.0. Gait was described with 4 parameters: velocity (m s⁻¹), which quantified the gait performance; double support (% gait cycle), an indicator of gait stability; gait variability index (GVI/100), which assesses the variability in spatiotemporal parameters [26]; and exit from the mat (% of the length of the GaitRite® mat).

2.4. Statistical analysis

The normality of data distribution was tested by the Shapiro-Wilk normality test. To compare the 3 conditions of gait for each study (EO, BG vs EC and EO, BG vs WG), repeated measures ANOVA was used. Holm-Sidak’s multiple comparisons test was used for the parametric parameter (GVI) and Dunn’s multiple comparisons test for non-parametric parameters (velocity, double support and exit from the mat). Depending on the data distribution, data are described with mean (SD) or median (interquartile range). Statistical significance was set at P < 0.05. Data were analyzed with GraphPad Prism V6.

3. Results

At baseline, walking with EO, the 2 protocol groups did not differ in age, gender, velocity, double support, GVI or exit from the mat.

In the first protocol, walking with BG produced the following results (Table 2):

2. Methods

2.1. Subjects

We recruited 50 healthy subjects without neuro-musculoskeletal disorders among students in our department of Physical and

3. Results

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2. Methods

2.1. Subjects

We recruited 50 healthy subjects without neuro-musculoskeletal disorders among students in our department of Physical and
Table 2

First protocol: walking with eyes open (EO), EO with black goggles (BG) and eyes closed (EC).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>EO</th>
<th>BG</th>
<th>EC</th>
<th>P value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVI (/100)</td>
<td>91.8 ± 7.3</td>
<td>66.8 ± 7.1</td>
<td>72.2 ± 6</td>
<td>0.009</td>
</tr>
<tr>
<td>Double stance support (%)</td>
<td>26 [23.5–27.5]</td>
<td>30 [27.5–32]</td>
<td>28 [26.5–30.5]</td>
<td>NS</td>
</tr>
<tr>
<td>Exit from the mat (%)</td>
<td>100 [100]</td>
<td>91 [87–100]</td>
<td>90 [82–100]</td>
<td>NS</td>
</tr>
<tr>
<td>Velocity (m s⁻¹)</td>
<td>1.26 [1.18–1.33]</td>
<td>1.01 [0.86–1.11]</td>
<td>1.07 [0.93–1.15]</td>
<td>0.0328</td>
</tr>
</tbody>
</table>

Data are mean ± SD or median [interquartile range], GVI: gait variability index.

* Comparing BG and EC.

- lower median velocity, by 6%, than walking with EC (EO 1.26; BG 1.01 vs EC 1.07 m s⁻¹, P = 0.0328); the change in velocity was a decrease ≥ 10% for 6 subjects, < 10% for 15 subjects, unchanged for one subject and a slight increase for only 3 subjects (5–6%);
- lower mean GVI, by 8% (EO 91.8; BG 66.8 vs EC 72.24, P = 0.009); the change in GVI was a decrease ≥ 10% for 11 subjects, < 10% for 7 and an increase ≥ 10% for 1 subject and < 10% for 6;
- no difference in stability of gait assessed by the double support or trajectory assessed by exit from the mat.

In contrast, the second protocol produced no difference between walking with BG or WG: velocity 1.1 versus 1.2 m s⁻¹, double stance support 27% versus 26%, GVI 74.3 versus 76.4 and exit from the mat 88% versus 91% (Table 3).

According to these results, walking with eyes open without visual information seems to be more difficult than walking with eyes closed because subjects were slowing down, with more variable parameters of walking.

4. Discussion

To our knowledge, this is the first study assessing the effect of walking with eyes closed or eyes open in the dark by wearing black goggles in healthy subjects. A significant modification of the organization of gait control was observed and consisted of reduced velocity and increased variability of walk. These results are very consistent because very few (but interesting) subjects had an opposite compartment. This situation suggests greater difficulty walking with eyes open with black goggles than walking with eyes closed. As well, in the control situation, stimulation of the photoreceptors alone did not change anything because walking with white or black goggles gave the same results. In our clinical practice, this behavior has been reported by some patients with bilateral proprioceptive impairment due to polyneuritis, who prefer to walk with eyes closed than eyes open in the dark, as long as the environment is known to be safe, such as at home.

Different investigators have used standing or walking with goggles to manipulate the vision [20–24], but this scenario has not been compared to walking with eyes closed. In some studies, goggles such as swimming goggles, with black tape, are considered identical to the eyes closed condition [27], but we provide evidence that they infer different walking effects.

Our findings have 2 main clinical consequences. The first is for the diagnosis of proprioceptive disorders. The goggle task, which is sensitive and easily used, can be added to the usual Romberg test. Some authors have emphasized the usefulness of a walking Romberg test to improve the sensitivity of this test [28]. We propose another way to easily increase the difficulty of this test. In other words, proprioceptive disorders could be more easily detected by a test based on eyes open without visual cues.

The second consequence of our findings is for balance rehabilitation. Training for balance in visual deprivation is commonly used in vestibular rehabilitation [2] but is less often used for balance disorders related to neurological disorders [29,30]. We previously showed the usefulness of such rehabilitation in hemiplegic patients after chronic stroke [4] and possibly in patients after subacute stroke [19]. Our findings allow for proposing a progression of exercises in visual deprivation: training with eyes open, eyes closed, then eyes open with black goggles. Normal subjects adapt over a short time (< 30 min) to the obscurity particularly by decreasing muscle activity during the upright stance [31]. The more difficult task appears to be walking in a moving surround, which can be produced by a surrounding optical flow [32] but needs specific equipment.

Some explanations can be proposed for the differences we observed across these conditions. The main one is that vision is the main sensory input for controlling the environment, movement of the subject or movement of the environment. Therefore, visual dependence is often observed in healthy subjects, is more frequent in older adults [12] and has been reported in many patients with balance disorders during diseases as different as vestibular [9,10] or neurological disorders [4,7,8]. Moreover, visual dependence has been demonstrated among children [33] and is usually found in adults when confronting a new motor difficulty, pathologic or not, or learning a new balance skill, with increased use of visual information at first. Closing the eyes may also give the subject access to mental imagery of the space, more easily accessible because it is well known, than the perturbed visual input.

Our subjects were both healthy and young. Conducting the same study among disabled and older people for whom rehabilitation protocols are usually devoted would be of interest. It also could be interesting to conduct this task with eye tracking to ensure that subjects keep eyes open while wearing goggles. Indeed for both populations, the main goal of the rehabilitation is to reinforce the contribution of non-visual cues to gait control.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Table 3

Second protocol: walking with EO and EO with black (BG) or white goggles (WG).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>EO</th>
<th>BG</th>
<th>WG</th>
<th>P value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVI (/100)</td>
<td>93.9 ± 9.7</td>
<td>74.3 ± 9.0</td>
<td>76.4 ± 9.1</td>
<td>NS</td>
</tr>
<tr>
<td>Exit from the mat (%)</td>
<td>100 [100]</td>
<td>88 [81–100]</td>
<td>91 [76.5–100]</td>
<td>NS</td>
</tr>
<tr>
<td>Velocity (m s⁻¹)</td>
<td>1.27 [1.16–1.41]</td>
<td>1.10 [0.88–1.24]</td>
<td>1.15 [0.83–1.26]</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data are mean ± SD or median [interquartile range], GVI: gait variability index.

* Comparing BG and WG.
References