

# Hypnotizability and Performance on a Prism Adaptation Test

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**Abstract** The susceptibility to hypnosis, which can be measured by scales, is not merely a cognitive trait. In fact, it is associated with a number of physiological correlates in the ordinary state of consciousness and in the absence of suggestions. The hypnotizability-related differences observed in sensorimotor integration suggested a major role of the cerebellum in the peculiar performance of healthy subjects with high scores of hypnotic susceptibility (*highs*). In order to provide behavioral evidence of this hypothesis, we submitted 20 highs and 21 low hypnotizable participants (*lows*) to the classical cerebellar Prism Adaptation Test (PAT). We found that the highs' performance was significantly less accurate and more variable than the lows' one, even though the two groups shared the same characteristics of adaptation to prismatic lenses. Although further studies are required to interpret these findings, they could account for earlier reports of hypnotizability-related differences in postural control and blink rate, as they indicate that hypnotizability influences the cerebellar control of sensorimotor integration.

**Keywords** Hypnotizability · Accuracy · Prismatic adaptation · Cerebellum · Nitric oxide · Sensorimotor integration

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## Introduction

Hypnotizability (or hypnotic susceptibility) has long been considered a cognitive trait enabling the individuals with high scores of hypnotizability to modify perception, memory, and behavior according to specific suggestions' contents and to perceive the changes as involuntary [1]. This ability, which is widely used to control pain [2], has been classically attributed to peculiar attentional characteristics sustained by a more efficient executive control [3]. In contrast, more recent evidence have shown that the higher ability of highly hypnotizable people (*highs*) to keep their attention focused on a selected object should be interpreted as a reduced capacity to redirect attention from its current focus toward a new object [4, 5]. Imaging studies, however, have revealed that highs display stronger functional connectivity [6, 7] between salience (anterior cingulum, fronto-insular and limbic structures), and executive brain circuits (dorsolateral prefrontal cortex (DLPC), lateral parietal cortices). In addition, highs exhibit stronger connectivity between the left DLPC and posterior areas involved in vision and imagery and lower connectivity between the right fronto-parietal network, associated with somesthesia and pain, and the right lateral thalamus/caudate, receiving peripheral somatosensory input [7].

In the latest decade, a new line of research has suggested that hypnotizability is not merely a cognitive trait and that its assessment may be useful not only to psychologists and psychotherapists but also to clinicians in several medical disciplines. In fact, investigation of the physiological correlates of hypnotic susceptibility has shown that it modulates sensorimotor integration [8, 9] and cardiovascular control [10–12] in the ordinary state of consciousness and in the absence of specific suggestions. Such new view of hypnotizability posits that it may account for part of the variability of the general population in many respects [8, 9]. In fact, highs represent

approximately 15 % of the population [13, 14] and may also share some of their characteristics with the individuals with intermediate scores of hypnotic susceptibility.

In particular, it has been suggested [9] that peculiar cerebellar properties may account for the observation that highs are less prone than people with low hypnotizability scores (*lows*) to buffer the changes in body sway which follow sensory alterations relevant to postural control, such as suppression of vision, leg proprioception modulation [15], and tactile asymmetric foot stimulations [16]. In these conditions, highs exhibit larger and faster body sway with respect to lows, which indicates a less strict control of posture. In contrast, tonic neck rotation has minor effects on the highs' body sway [17]; however, both kinds of postural response can be due to the same mechanism likely based in the cerebellar processing of sensory information [18, 19]. It is noteworthy, in this respect, that a different relevance of the neck proprioceptive information has been also found in other primates. In fact, the activity of rotation-responsive vestibular nuclei neurons is modulated by both vestibular and neck proprioceptive inputs in the squirrel monkey, but only by vestibular stimulation in the rhesus monkey, and even two species within a single genus (*Macaca*) show integration of vestibular and neck information as being different [20].

Peculiar cerebellar function inducing reduced inhibition of occipital areas may also account for the higher spontaneous blink rate observed in resting highs with respect to lows [21] in the absence of significant differences in their dopaminergic tone [22, 23]. Thus, we submitted highs and lows to the classical cerebellar Prism Adaptation Test (PAT) [24, 25], which consists of three consecutive phases: baseline (basal), prism (wearing glasses deviating gaze horizontally), after (after glasses removal). During each phase, participants are instructed to fixate on a visual target placed at eye level and to launch small balls toward it. Among healthy adults, during the prism condition of the PAT, the first few throws miss the target in the direction of the distorted visual information; within a few throws, the ball landing position returns to the target. When the glasses are removed (after), the same effect occurs, but in the opposite direction (after effect). Patients with alteration of the cerebellar input do not show adaptation or adapt more slowly than controls [24], whereas similar adaptation, but reduced accuracy, has been observed in children with developmental coordination disorder (DCD), which is considered a condition of cerebellar immaturity [26–28].

The aim of the present study was to assess possible differences in the performance of highs and lows for the Prism Adaptation Test.

## Materials and Methods

The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the

University of Siena. Participants signed informed consent describing the procedure but not the rationale and the aim of the experiment.

## Subjects

Forty-one unpaid participants sorted among 220 healthy people registered in the database of the laboratory of Human Physiology (Dept. of Medical and Surgical Sciences and Neuroscience) of Siena University accepted to join the experiment. They had undergone hypnotic assessment through the Italian version (*Organizzazioni Speciali, Firenze*) of the Stanford Hypnotic Susceptibility Scale, Form A [29] at least 1 year before the experimental session. Twenty of them were highs (SHSS score (mean $\pm$ SD),  $9.6\pm1.4$ , 10 females) and 21 were lows (SHSS,  $1.7\pm1.4$ , 12 females), and there was no significant difference in the SHSS scores between males and females in both the highs and lows groups. All were right handed, according to the Edinburgh Handedness Inventory (EHI score $\geq$ 16); highs and lows did not differ significantly for height (mean $\pm$ SD (cm); highs,  $173.12\pm8.75$  cm; lows,  $174.0\pm8.62$  cm) and arm length (cm) (highs  $54.06\pm1.9$ ; lows,  $53.13\pm3.1$ ). In contrast, males ( $179.26\pm5.93$  cm) were significantly ( $t(1,38)=4.983$ ,  $p=.0001$ ) taller than females ( $168.52\pm7.5$  cm), and their right arm was significantly longer than that of females ( $t(1,38)=2.786$ ,  $p=.008$ ; males,  $55.42\pm2.7$ ; females,  $52.91\pm3.0$ ; cm).

## Experimental Procedures

In order to minimize the possible effects of different launching strategies, standing participants were trained (ten trials) to raise their hand to shoulder level and then launch. During training, however, no ball was really launched. Then, participants were asked to fixate a visual  $2\times2$  cm square target placed on a panel in front of them (250 cm far, at eye level) for 10 s and then to launch small wood balls ( $d=2$  cm, weight=25 g) with their right hand in sequence, without specific temporal constraints and without looking at their hand. After each launch, one of the experimenters placed another ball in participant's hand. The panel consisted of two paper layers placed on a rigid Plexiglas surface. The ball contacted the first layer, where the target was drawn on a white paper sheet; its backward face, marked by millimeter squares, was in contact with the second layer—a carbon paper sheet. Therefore, the ball contact marked a spot on the back of the white sheet; the distances from the central point of the target to the central point of the spot produced by ball contact with the panel (absolute distance), and the distance from the target to the central point to the projection of the spot on the horizontal axis (horizontal error) were measured. The experimental conditions, including 50 launches (trials) each, were as follows: baseline, prism (wearing safety goggles fitted with 3M™

Press-On™ adhesive prismatic lenses deviating gaze horizontally by 30°), and after (after removal of glasses). Sessions lasted about 45–60 min. None of the participants reported fatigue.

## Variables

During the experimental session, the participants' body position and arm movements were monitored through a non-ionizing optoelectronic system (Elite-BTS, Milano) which measured 3-D displacements of markers placed on each acromion, elbow, and wrist. Since all participants showed changes in the acromion position lower than 2 cm in each direction throughout the entire session, all of them were included in the analysis. No significant difference in gender and hypnotizability was observed in anteroposterior (gender,  $t(1,38)=.555$ ,  $p=.482$ ; hypnotizability,  $t(1,38)=.497$ ,  $p=.445$ ) and latero-lateral body sway (gender,  $t(1,38)=.548$ ,  $p=.392$ ; hypnotizability,  $t(1,38)=.675$ ,  $p=.298$ ).

We studied the participants' throwing accuracy and prismatic adaptation, as recommended by earlier studies [24–26]. In particular, we studied the following: (1) the absolute distance (cm) of ball landing positions from the target center in baseline conditions, which is inversely related to the throwing accuracy (TA), so that longer distances correspond to lower accuracy; (2) the performance coefficient (PC) (cm), as a measure of the throw-to-throw variability (standard deviation (SD)) of the projection of the landing point on the horizontal axis (horizontal error) across the last eight throws of the baseline condition; (3) the presence of after effect (AF), that is whether a significant difference is found between the horizontal error of the first eight throws of the after condition and of the last eight throws of the baseline; (4) the adaptation curve, that is the time course of the horizontal error decay through the adaptation to prismatic glasses.

Beyond the recommended variables, we analyzed the absolute distance, the horizontal error, and their variability throughout all conditions/launches and throughout the earliest and latest eight trials of each condition.

## Statistical Analysis

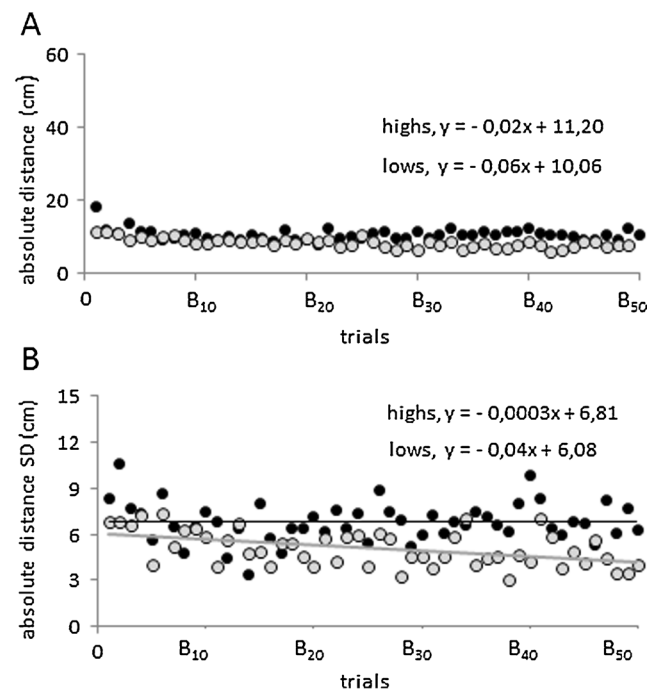
Data distributions were normal, thus allowing parametrical analyses. According to the design of earlier studies [26], we analyzed (SPSS .15 package) through univariate ANOVAs as follows: (a) the baseline absolute distance of balls landing (2 hypnotizability (highs, lows)  $\times$  2 gender (females, males)  $\times$  50 trials ( $B_1, \dots, B_{50}$ ) design); (b) its standard deviation (SD) across trials (2 hypnotizability  $\times$  2 gender design); (c) the performance coefficient, through univariate ANOVA (2 hypnotizability  $\times$  2 gender design); (d) the presence of after effect (2 hypnotizability  $\times$  2 gender  $\times$  2 conditions (after, baseline)  $\times$  8 trials ( $B_{43}, \dots, B_{50}$ ;  $A_1$ – $A_8$ ) design) applied to the horizontal error.

In addition to the recommended analyses [26], we studied the absolute distance and horizontal error in all trials of the three conditions (absolute distance: 2 hypnotizability  $\times$  2 gender  $\times$  3 conditions  $\times$  50 trials design; SD: 2 hypnotizability  $\times$  2 gender  $\times$  3 conditions design). Finally, in order to strengthen our observations, we also report the results of the ANOVAs applied to the absolute distance and horizontal error of the earliest and latest eight trials of each condition (2 hypnotizability  $\times$  2 gender  $\times$  3 condition  $\times$  8 trials). For all analyses, the Greenhouse-Geisser  $\epsilon$  correction for non-sphericity was applied when necessary. Contrast analysis between conditions/trials was performed when appropriate. Significance was set at  $p=.05$ .

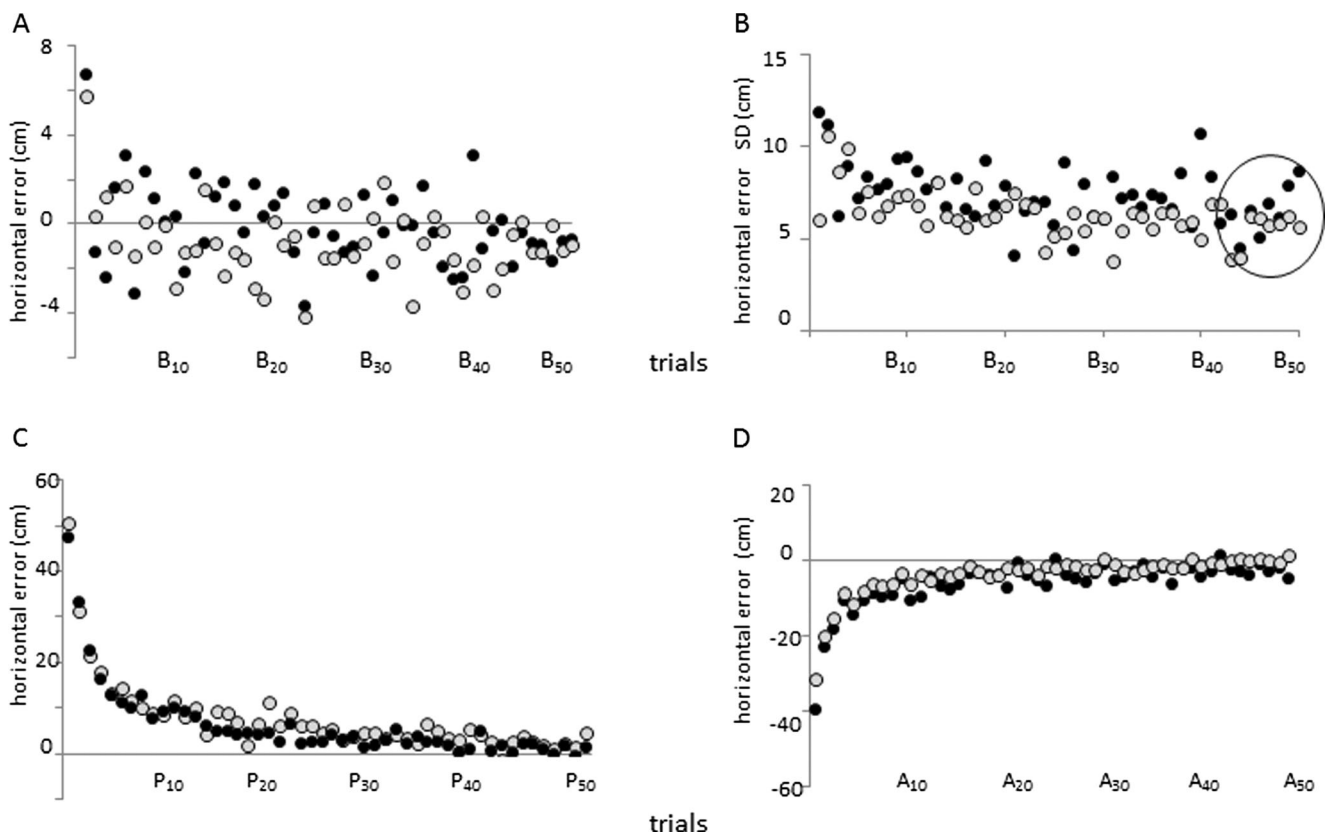
## Results

Results showed that accuracy was lower in highs than in lows (Fig. 1a). In fact, the former exhibited larger baseline absolute distance of landing (hypnotizability effect,  $F(1,37)=6.185$ ,  $p=.0013$ ,  $\eta^2=.157$ ) and larger variability (Fig. 1b) (hypnotizability effect,  $F(1,37)=5.799$ ,  $p=.021$ ,  $\eta^2=.135$ ).

On the horizontal axis (Fig. 2a), the performance coefficient (Fig. 2b) was not significantly different between the two groups (mean  $\pm$  SD (cm); highs,  $5.91 \pm 2.75$ ; lows,  $4.93 \pm 1.79$ ), but this was likely due to the low effect size of this comparison ( $\eta^2=.053$ ).



**Fig. 1** Throwing accuracy and its variability. The absolute distance between the target and the ball mean landing position (a) and its standard deviation (b) are shown for each trial of the basal condition in highs (black dots) and lows (gray dots). Abscissae: trials sequence ( $B_1, \dots, B_{50}$ ); Ordinate: absolute distance. Longer distances correspond to lower throwing accuracy (a). Trend lines show that the absolute distance variability (SD) decreases across trials only in lows (b)



**Fig. 2** Horizontal error and its variability. Distribution of the mean horizontal error (**a**) and of its standard deviation (**b**). The performance coefficient is computed on the latest eight trials of the basal condition (within the circle). Mean values of the horizontal error in the prism (**c**) and

after conditions (**d**). Highs are represented by *black dots*; lows are represented by *gray dots*. *Abscissae*: trials sequence in the basal ( $B_1, \dots, B_{50}$ ), prism ( $P_1, \dots, P_{50}$ ) and after ( $A_1, \dots, A_{50}$ ) conditions. *Ordinate*: horizontal error

In contrast to different launching accuracy, highs and lows exhibited the same adaptation characteristics. Indeed, there was a significant after effect which was independent of hypnotizability (condition effect,  $F(1,37)=181.77$ ,  $p=.0001$ ,  $\eta^2=.831$ ), and the highs' and lows' superimposed error decay curves (highs,  $y=31,24e^{-0,17x}$ ; lows,  $y=30,19e^{-0,17x}$ ) indicated the same adaptation rate (Fig. 2c). Also, the recovery curves of the horizontal error during After (Fig. 2d) were similar.

In line with other authors' reports [24], longer absolute distance, that is lower throwing accuracy (gender effect,  $F(1,37)=10.114$ ,  $p=.003$ ,  $\eta^2=.215$ ) and higher performance coefficient (gender effect,  $F(1,37)=6.735$ ,  $p=.013$ ,  $\eta^2=.147$ ) were observed in females. This finding, however, should be cautiously interpreted since the females' arms were significantly shorter than the males'.

### Analyses Applied to the Entire Session and to the Earliest/Latest 8 Trials

Absolute distance and horizontal error mean values and variability (SD) in highs/lows and females/males for all trials/conditions are reported in the Supplemental Electronic Material (Table 1).

Longer absolute distances of landing were observed in highs (hypnotizability effect,  $F(1,40)=8.618$ ,  $p=.005$ ,  $\eta^2=.177$ ) and in females (gender effect,  $F(1,40)=9.532$ ,  $p=.004$ ,  $\eta^2=.192$ ) across all conditions. No significant interaction of hypnotizability with condition and trials was observed. Conditions were different among each other ( $F(2,80)=79.325$ ,  $p=.0001$ ,  $\eta^2=.665$ ) in that lower absolute distances of landing were observed in baseline conditions with respect to prism (contrast analysis,  $F(1,40)=30.831$ ,  $p=.0001$ ,  $\eta^2=.435$ ) and after ( $F(1,40)=119.035$ ,  $p=.0001$ ,  $\eta^2=.748$ ) and during prism with respect to after ( $F(1,40)=59.25$ ,  $p=.0001$ ,  $\eta^2=.597$ ). Decomposition of the significant condition  $\times$  trials interaction ( $F(2,3626)=9.630$ ,  $p<.0001$ ) is reported in Table 2 of the Supplementary Electronic Material. It shows that in baseline conditions, all trials were different from the first one, but no difference was observed between consecutive trials after the second; in the prism condition, all trials were different from the first one, but no difference was observed between consecutive trials after the fifth one; all trials are different from the first one, but no difference is observed between consecutive trials after the fourth one.

Also, the absolute distance SD across all trials of each condition (Fig. 3) was higher in highs (hypnotizability effect,  $F(1,43)=7.323$ ,  $p=.010$ ,  $\eta^2=.146$ ) and in females (gender



effect,  $F(1,43)=9.350$ ,  $p=.004$ ,  $\eta^2=.179$ ) and exhibited a condition effect ( $F(2,86)=139.68$ ,  $p=.0001$ ,  $\eta^2=.765$ ). In fact, lower variability in baseline than in prism (contrast analysis,  $F(1,43)=257.144$ ,  $p=.0001$ ,  $\eta^2=.857$ ) and after condition ( $F(1,43)=69.538$ ,  $p=.0001$ ,  $\eta^2=.650$ ) and lower variability in after than in prism ( $F(1,43)=76.434$ ,  $p=.0001$ ,  $\eta^2=.640$ ) were observed.

The horizontal error was not significantly different between highs and lows and between females and males, but the low effect size may account for these findings (hypnotizability effect,  $\eta^2=.012$ ; gender,  $\eta^2=.066$ ). The horizontal error SD (Fig. 3) was significantly higher in highs (hypnotizability effect,  $F(1,37)=8.44$ ,  $p=.005$ ,  $\eta^2=.193$ ) and in females (gender effect,  $F(1,37)=11.111$ ,  $\eta^2=.p=.002$ ,  $\eta^2=.243$ ) and significantly different between conditions ( $F(2,74)=147.29$ ,  $p=.0001$ ,  $\eta^2=.799$ ), with higher values in prism than in Baseline (contrast analysis,  $F(1,37)=252.75$ ,  $p=.0001$ ,  $\eta^2=.756$ ) and after conditions ( $F(1,37)=75.08$ ,  $p=.0001$ ,  $\eta^2=.670$ ) and higher values in after than in baseline conditions (contrast analysis,  $F(1,37)=85.98$ ,  $p=.0001$ ,  $\eta^2=.697$ ).

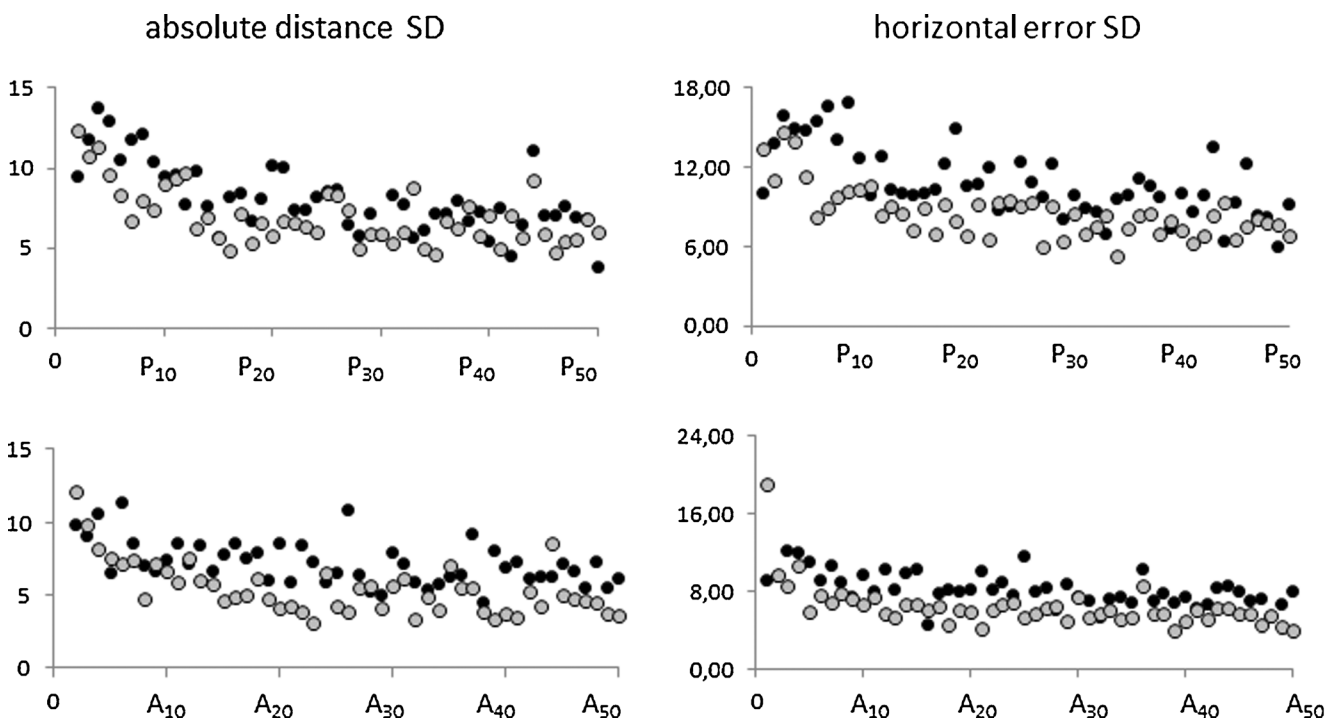
In order to strengthen the reliability of the described findings, we also separately analyzed absolute distance and horizontal error for the earliest and latest eight trials of all conditions. In the earliest eight trials, the absolute distance was larger in highs ( $F(1,37)=6.140$ ,  $p<.018$ ) and in females ( $F(1,37)=5.72$ ,  $p<.022$ ) than in lows and males, respectively;

the same occurred in the latest eight trials (highs>lows,  $F(1,37)=16.09$ ,  $p<.0001$ ; females>males,  $F(1,37)=11.60$ ,  $p<.002$ ); no interaction of hypnotizability with condition and trials was found (Table 2). The horizontal error was not modulated by hypnotizability. In the Supplementary Electronic Material (Table 2), we report the decomposition of the significant condition $\times$ trial interaction observed in the earliest eight trials for absolute distance ( $F(2,518)=17.304$ ,  $p<.0001$ ) and horizontal error ( $F(2,518)=66.98$ ,  $p<.0001$ ).

## Discussion

Our findings show similar adaptation to prismatic lenses in highs and lows. In contrast, they reveal lower launching accuracy (larger absolute distances) and larger landing variability in highs in all the studied conditions (baseline, prism, after), not associated with significant differences in horizontal error. In addition, a trend to increase the absolute distance of landing and its variability in highs and a trend to decrease them in lows were observed in baseline conditions.

The first finding—showing that adaptation to prismatic lenses occurs in both highs and lows is similar in the two groups and develops across trials as it does in the general population [24]—indicates that the cerebellar activity responsible for adaptation of participants is within the normal range



**Fig. 3** Variability of the absolute distance and of the horizontal error in prism and after conditions. *Upper panels:* standard deviation (SD) of the absolute distance (*left*) and of the horizontal error (*right*) in the prism condition. *Lower panels:* SD of the absolute distance (*left*) and of the horizontal error (*right*) in the after condition. Highs are represented by

black dots; lows are represented by gray dots. *Abscissae:* trials sequence in the basal ( $B_1, \dots, B_{50}$ ), prism ( $P_1, \dots, P_{50}$ ) and after ( $A_1, \dots, A_{50}$ ) conditions. *Ordinate:* absolute distance SD (*left panels*) and horizontal error SD (*right panels*)

and is not influenced by hypnotizability. However, the different trends of throwing accuracy and its variability in highs and lows in the baseline condition suggest that the former are less prone to improve their performance through learning mechanisms, in contrast to lows. A similar absence of learning behavior across trials has been observed in highs standing on a stabilometric platform and undergoing repeated eye closure [15]. In those conditions, highs increased the mean velocity of their body sway and maintained the same velocity through consecutive trials, whereas lows tended to decrease it. In brief, in highs, the sensorimotor performance appeared more automatic, as suggested for their cognitive activity [30].

Despite the cerebellum ability to compensate the effects of prismatic lenses in all our participants, the highs' lower accuracy of landing and its larger variability with respect to lows indicate less accurate cerebellar control. This result is in line with the findings obtained through the diffusional stabilogram [31] in standing highs at eye closure and after destabilization of the supporting platform, which revealed larger body sway in highs than in lows before the occurrence of any correction of body sway by the peripheral re-afference. It also accords with the observation that neck muscle information [17] appears not to be integrated with vestibular input in highs (which induces less accurate postural control) and that asymmetric foot information influences body sway more in highs than in lows [16], which indicates highs' lower ability to compensate sensory alteration. Therefore, although present findings do not provide any direct evidence that the cerebellar functional characteristics highlighted by the Prism Adaptation Test in highs are causatively involved in earlier observation on postural control, they suggest that less precise cerebellar processing and/or lower cerebellar responsivity to sensory changes may be responsible for them.

Finally, the larger absolute distances of landing observed in highs with respect to lows not associated with significantly larger horizontal error (in the absence of significant differences in the mean height and in mean arm length between the two groups) indicate that the highs' launches are less accurate at the vertical direction rather than at horizontal and reinforce the hypothesis that different sensorimotor integration modes operate in the two groups.

PAT findings similar to the present ones have been reported in children suffering from developmental coordination disorder (DCD), a condition of cerebellar immaturity observed in 1.4–19 % of school-aged children, which may continue into adulthood. DCD is associated with greater activation in frontal, parietal, and temporal brain regions but reduced activation of areas associated with motor control, motor learning, and error processing, and is considered a consequence of delayed cerebellar development [2, 26, 28]. Although basal ganglia and parietal cortex alterations could play a role in DCD [26], they may exert it through their connections with the cerebellum [32, 33].

There are peculiar properties of the highs' vascular endothelium which could sustain the association of high hypnotizability and cerebellar immaturity. In fact, studies of post occlusion, flow-mediated dilation of the brachial artery (FMD) have shown that nociceptive stimulation and mental stress reduce FMD in lows [11, 12] and in the general population [34], but not in highs [11, 12]. FMD depends on the release of endothelial nitric oxide (NO). Thus, we may speculate that, in these individuals, non-modulated endothelial NO release and diffusion to the extracellular compartment could be detrimental for cerebellar maturation. In fact, NO is neurotoxic under conditions of excessive production [35]; in particular, abnormal NO availability impairs the regulation of granule maturation and, consequently, of the activity of Purkinje cells [36].

Our NO-based cerebellar hypothesis of the differences observed between the highs' and lows' sensorimotor integration modes could be extended to the cognitive aspects of hypnotizability [8, 9]. In fact, cerebellar targets [37] include executive regions (dorsolateral prefrontal cortex), whose functional connectivity with structures of the salience circuit (dorsal anterior cingulum) is stronger in highs [6], and vestibular nuclei, whose reduced inhibition by the cerebellum may enhance the activity of the locus coeruleus [38] and, consequently, the highs' noradrenergic tone. The latter may be involved in the highs' higher arousal [39] possibly in cooperation with NO-dependent higher brain acetylcholine release in basal ganglia [40]. In addition, reduced cerebellar inhibition of sensory areas may be involved in the highs' greater proneness to perceive imagined physical stimuli as real [41, 42] and to modulate the activity of sensorimotor circuits responsible for reflex movements independent of volition [43]. Finally, reduced inhibition of associative areas may contribute to the highs' perception of involuntariness in action, as suggested by the overactivity of the parietal cortex associated with the feeling that active movements are externally controlled in delusions of alien control [44, 45]. In other words, the cognitive and sensorimotor correlates of hypnotizability may be two facets of the same cerebellar coin [14, 37, 46].

## Conclusion

The present study reports the first behavioral evidence of hypnotizability-related differences in a cerebellar task and provides a possible interpretation of earlier findings on postural control [15–17] and blink rate [21]. It supports the view that hypnotizability is relevant in sensorimotor integration.

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**Conflict of Interest** Authors declare no conflict of interest.

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