Visuospatial imagery in healthy individuals with different hypnotizability levels

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Abstract

Hypnotizability is a psychophysiological trait associated with morpho-functional brain differences. Since also cerebellar peculiarities have been reported in individuals with different hypnotizability levels and the cerebellar function is relevant to spatial imagery, the present study was aimed at investigating possible hypnotizability-related differences in the ability of spatial imagery.

Highly (highs, N=31), low (lows, N=17) and medium (mediums, N=16) hypnotizable participants (classified by Stanford Hypnotic Susceptibility Scale, form A) of both genders were submitted to a test of mental rotation, which requires the integrity of both executive and cerebellar structures. In order to disentangle the role of the cerebellum from that of executive circuits as much as possible, visuospatial and verbal working memory tests, which mainly reflect executive processes, were also performed.

Healthy highs exhibited higher scores of mental rotation ability compared to mediums in the absence of significant differences in visual-spatial and verbal working memory. Lows reported intermediate scores not significantly different from both highs’ and mediums’. Different cognitive strategies were observed in the three groups as the correlations between mental rotation, visuospatial and verbal working memory were different in highs, mediums and lows.

In conclusion, present findings represent the first report of hypnotizability-related differences in a mental rotation task, which is relevant to several cognitive functions.

Keywords: hypnotizability, cerebellum, mental rotation, working memory, imagery

Introduction

The susceptibility to hypnosis, or hypnotizability, is a multidimensional trait predicting the ability to modify perception, memory and behavior according to specific instructions named “suggestions” [1]. It is measured by scales, is associated with morpho-functional differences in several cerebral regions (including executive, salience and default mode circuits) and in their functional connectivity [2] as well as with peculiar characteristics of attention [3, 4], imagery [5-7] and functional equivalence between imagery and perception [8-10]. In addition, the individuals with high (highs) and low (lows) hypnotizability scores differ in a few aspects of sensori-motor integration – accuracy of postural and visuo-motor control - suggesting a less strict cerebellar control of posture and movement in highs [11]. In line with these observations, reduced grey matter volume in the cerebellar cortex and, specifically, in the left lobules IV-VI of the cerebellum has been observed in highs compared to lows [12]. Also, it has been shown that highs receiving nociceptive stimulation after anodal cerebellar stimulation report paradoxically increased pain intensity associated with increased amplitude of the cortically evoked potentials [13], in contrast to a sample of lows and medium hypnotizable participants (mediums). Finally, reduced cerebellar inhibition of the cerebral cortex has been suggested as one of the possible factors responsible for facilitating ideomotor responses to sensorimotor suggestions [8-10].

The emerging evidence of the involvement of hypnotizability-related cerebellar differences in sensori-motor functions, particularly in the functional equivalence between imagery and perception, poses questions about possible hypnotizability-related differences in other cognitive functions, such as visuospatial imagery [14-16] and working memory [17,18], in which the cerebellum is involved through its widespread cortical and subcortical connections [19].

Visuospatial imagery is classically investigated through tests of mental rotation [20, 21] and has been found associated with right/bilateral parietal activations [22] and with the activation of the medial left cerebellar lobule VI and VII (Crus II) [23], which correlates with the activity in prefrontal, posterior parietal, and superior and middle temporal association areas, cingulate gyrus and retrosplenial cortex [24,25]. More recently, the activation of lobules VIII and IX has also been reported [17]. The involvement of most of the same cerebral areas has been observed for visuospatial [18] and verbal working memory [26], which are associated also with the bilateral activation of the cerebellar lobules IV-VII, Crus 1 and 2 [27].

The present study was aimed at investigating possible hypnotizability-related differences in the ability of spatial imagery. In fact, on the basis of the reported hypnotizability-related morpho-functional cerebellar differences [12, 13], we may expect differences between highs and lows in both mental rotation (owing to the highs' smaller lobule VI grey matter volume) and working memory (owing to their smaller left lobule IV-VI grey matter volume).

We administered a test of mental rotation, which requires the integrity of both executive and cerebellar structures. In order to disentangle the role of the cerebellum from that of the executive circuits as much as possible, visuospatial and verbal working memory tests which mainly reflect executive processes. Cerebral cortical areas may also co-operate in establishing hypnotizability-related differences in these tasks [18, 22, 26], although there is no available information allowing to predict their role as a function of hypnotizability. We administered the tasks to highs, lows and medium hypnotizable participants (mediums) of both genders since both visuospatial [20-22] and verbal working memory abilities are influenced by gender [26].

Methods

The study was conducted according to the Declaration of Helsinki and approved by the local Ethics committee. All participants signed an informed consent and their privacy was always observed.

Subjects

The participants were 250 healthy students of the University of Pisa (age 19-26 years) who had been informed of the opportunity to have their hypnotic susceptibility measured (by advertisements) and volunteered by e-mail. Hypnotic assessment was performed through the Italian version of the Stanford Hypnotizability Scale (SHSS), form A [28] which allows to classify high (highs, SHSS score > 8 out of 12), low (SHSS score < 4) and medium hypnotizable individuals (mediums, SHSS score: 5-7). After hypnotic assessment, only sixty-eigth subjects accepted to be informed of their hypnotic score after the experimental session, scheduled at least 1 month later (rather than immediately), and completed the Edinburgh Handedness Inventory (EHI) [29, Oldfield 1971]. Since 2 highs and 2 mediums were not strictly right-handed (EHI score < 16), the studied sample consisted of 31 highs, (SHSS score (mean ± SD; 9.86+1.43, 20 females), 17 lows (SHSS score, mean ± SD: .813 + 1.22, 10 females) and 16 mediums (SHSS score, mean ± SD: 5.59 + .82, 10 females). They performed the tests of mental rotation [21], visual-spatial working memory (Psychology Experiment Building Language (PEBL) Block-tapping Task) and verbal working memory (Psychology Experiment Building Language (PEBL) ENB-2, Digit Span). All sessions were performed between 9 and 12 a.m.in a sound attenuated and temperature controlled room.

Tasks

The Mental Rotations Test (MRT) is a paper-and-pencil test of spatial visualization [30] based on the stimuli used by Shepard and Metzler (1971). It contains twenty items in five sets of four items. Each item consists of a criterion stimulus, two correct alternatives (mirrored images), and two incorrect images (non-mirrored) rotated by a given amount of degrees. The assessment of the ability of mental rotation according to the original procedure [31, 32] is based on how accurately the participants distinguish between the mirrored and non-mirrored pairs. Accuracy (score: 0-20) reflects the number of items completed correctly.

MRT was administered in two trials (maximum time allowed for each trial =3 min) with a pause (4 min).

The visual-spatial task was administered by using the Psychology Experiment Building Language (PEBL) a free cross-platform system for designing and running computer-based experiments and tests [32]. PEBL Corsi Block-tapping Task is an implementation of the traditional Corsi's task for visual-spatial working memory task. Nine colored blocks are presented on the computer screen and are lit up according to random sequences. The task requires the participant to observe the sequence of blocks lit up and then reproduce it immediately by clicking on the blocks in the order of presentation. The task starts with a two blocks sequence and gradually increases in length. Inter-trial intervals lasted 1 sec. The test score corresponds to the number of blocks of the longest sequence correctly reproduced (out of 9).

ENB-2 Digit span [33] is a standard digit span task commonly used to measure verbal working memory. Participants listen to a sequence of numerical digits and are asked to verbally repeating it immediately after hearing the digit sequence. In each trial, the sequence gradually increases in length. The participant's span is the number of digits of the longest sequence that can be correctly remembered (out of 8).

Variables and Statistical analysis

The statistical Package for Social Science (SPSS. 15) was used for all analyses. Univariate ANOVAs were performed on Mental rotation, Blocks tapping and Digit span scores. Hypnotizability and Gender were between subjects factors. The Green-house ε correction was applied when necessary. Post-hoc comparisons were conducted through unpaired t-test. The time required by each item was not directly measured. Its mean value (total time/number of performed items) was not studied because the task was interrupted by the experimenters at the end of the 3rd minute [30, 31]in all participants (except 3 highs, 2 lows, 2 mediums who completed the task a few seconds earlier). Pearson correlation coefficients between hypnotizability and tests and between tests were computed on Z-transformed scores. Partial correlation of hypnotizability and accuracy of mental rotation was also studied with Corsi and Digit span as covariates. The level of significance was set at p=.05.

Results

ANOVA revealed a significant Hypnotizability effect (Fig. 1A) only for the mental rotation score (F(1,63) =3.16, p<.05, η^2=.098, α =.583). This difference was sustained by significantly higher scores in highs with respect to mediums (t=2.74, p=.01) whereas lows exhibited scores intermediate between highs and mediums and non significantly different from any of them (lows vs highs: t=1.21, p=.235; lows vs mediums: t=1.629, p=.114). The number of completed items was similar in all hypnotizability/gender subgroups (mean+ SD; high females 8.00+1.92, high males 6.83±1.85; low females 7.30 ±2.11, low males 8.50 ±1.52; medium females 7.50±2.17, medium males 7.21±2.00).

A significant Gender effect (Fig. 1B) was observed for both the mental rotation (males > females, F(1,63) =10.696, p<.002, η^2=.156, α =.895) and the visual memory task 2 (males > females, F(1,63) =8.26, p<.006, η^2=.125, α=.807). No significant interaction between hypnotizability and gender was found for visuospatial imagery (F (1,63) =.078, p=.925, η^2=.002, α=.353) and visual memory (F(1,63)=.220, p=.803, η2=.005, α= .281).

No significant effects and interactions were observed for the Digit span task (Hypnotizability, F (1,63) =3.298, p<.080, η^2= .105, α=.418; Gender, F(1,63)=1.2241, p<.278, η^2= .42, α

=.188; Hypnotizability x Gender, F(1,63)=.842, p=.434, η^2=.019, α=.190). Mean values and SD are shown in Table 1.

No significant linear correlation was found between hypnotizability, Block tapping, Digit span and rotation scores (Fig. 1C). Partial correlation between hypnotizability and rotation accuracy with Block tapping and Digit span scores as covariates was not significant.

Discussion

The present study shows for the first time that the ability of mental rotation is greater in highly hypnotizable individuals, whereas the gender difference advantaging males with respect to females are consistent with previous studies [34, 35]. Importantly, the differences in mental rotation were not associated with differences in visuospatial and verbal working memory and correlational analysis showed that spatial imagery was independent from them.

Higher scores of accuracy in mental rotation have been observed in highs with respect to mediums whereas the lows' score was intermediate between highs' and mediums' and not significantly different from any of them. This finding highlights the fact that not all the characteristics modulated by hypnotizability are linerarly correlated with it, in contrast to variables such as the responsiveness to suggestions for analgesia in chronic pain patients [36], to suggestions of analgesia and to conditioned analgesia in healthy subjects receiving nociceptive stimulation [37] and to the sensitivity of opioid μ1 receptors [38].

Our findings can be interpreted according to the model proposed by Gill and coll. (1998) which claims that mental rotation is obtained by generating and storing visuospatial mental images rather than producing a sequential mental displacement of the perceived object [just gill 39, 40] and that the mental images are successively rotated through operations of the temporal cortex. Speculatively, in highs the earliest process – generating mental images- may be facilitated by the reduced inhibition of the right cerebral cortex by the left cerebellar lobules [11]. In this respect, the larger grey matter volume observed in the highs' temporal planum [2] could contribute to better generation of images. Not alternatively, the better performance of highs at mental rotation could depend on a possible greater ability to utilize a supra-modal processing of sensory information [41,42] consisting of a general model of spatial reasoning.

Gender differences independent of hypnotizability were not the aim of the present study. However, as corollary findings we observed gender-related differences advantaging males in visuospatial memory, in line with part of earlier observations [34, 35, 43, 44].

The finding of higher accuracy in mental rotation without differences in the time of response observed in highs has been reported also among the general population in individuals with greater imagery abilities activating premotor/visual cortices rather than SMA/fronto-parietal networks, which are preferentially activated in low imagers [45]. Other authors have reported down-regulation of the left cerebellar hemisphere by theta burst stimulation (TBS) resulting in lengthened response times with no change in the response accuracy [46], while accuracy was modulated by cerebellar TBS during dual tasks performance [47]. This may indicate that down-regulation of the left cerebellar cortex may influence the accuracy of mental rotation only in highly demanding attentional conditions. It seems reasonable, indeed, that the participants not pressed to complete the mental rotation test [46] can achieve the same accuracy by taking different time. On the other hand, the absence of differences in the time response in the presence of higher accuracy could support a difference between highs and lows in the strategy of mental rotation accounted for by the model of Gill and coll (1998), as suggested by the above reported differences in the correlation between rotation accuracy, verbal and visuospatial working memory observed in highs, mediums and lows.

A limitation of the study is the low effect size of a few comparisons, which could be addressed by recruiting larger samples of participants. The interpretation of the results may be improved by comparing the rotation of objects with the rotation of body parts. In fact, due to the pre-eminent role of kinaesthetic information in highs with respect to lows [7] and to the role of kinaesthetic information in the construction of the body image [48, 49], one may expect that hypnotizability- related differences in mental rotation become more apparent in the rotation of body parts. This further research could contribute to disentangle the sensori-motor ground of mental images, expected to be greater for the rotation of body parts, from possible supra-modal mechanisms involved in mental rotation [50]. In this respect, also that the evaluation of the participants' education [51,52] may allow better understanding of the findings. Finally, present findings should be supported by neuroimaging studies aimed at clarifying whether the hypnotizability-related cerebellar differences are substantially responsible for the observed difference in mental imagery, as cerebral areas influence the studied cognitive functions. Nonetheless, findings represent a novel contribution to the field of hypnotizability and prompt further investigation of hypnotizability-related cognitive characteristics since mental rotation is involved in several cognitive processes.

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Table 1.Mental rotation, Block tapping and Digit span scores

		rotation		block tapping		digit span	
hypn	gender	Mean	SD	Mean	SD	Mean	SD
highs	males	10.25	3.69	5.67	0.78	6.08	0.79
	females	6.55	3.87	5.25	0.64	6.15	0.99
	Total	7.94	4.16	5.4	0.71	6.12	0.91
lows	males	7.67	2.87	5.83	1.17	6.17	1.17
	females	5.4	2.59	5.2	0.63	6.2	0.79
	Total	6.25	2.84	5.44	0.89	6.19	0.91
mediums	males	7.67	3.26	5.92	0.8	5.33	0.82
	females	3.7	3.2	5.25	0.72	5.9	0.99
	Total	5.19	3.69	5.5	0.79	5.69	0.95
males		8.96	3.52	5.77	0.86	5.92	0.93
females		5.55	3.55	5.24	0.64	6.1	0.93

Figure Captions

Fig. 1. Mental rotation, Block tapping and Digit span tests (mean, SEM). A) Scores in: H, highs; L, lows; M, mediums, and B) m, males; f, females. Lines indicate significant differences (see text); C) Distribution of mental rotation scores as a function of the scores reported at Block tapping and Digit span tests.