

HYPNOTIZABILITY AND IMAGERY MODALITY PREFERENCE: DO HIGHS AND LOWS LIVE IN THE SAME WORLD?

Giancarlo Carli¹, Francesca I. Cavallaro¹, Enrica L. Santarcangelo²

¹Department of Physiology, University of Siena, ²Department of Human Physiology, University of Pisa

Abstract

Imagery plays an important role in hypnotic phenomena. Recent findings have shown, however, that hypnotized subjects with high (Highs) and low (Lows) susceptibility to hypnosis undergoing guided imagery tasks centred on specific sensory modalities share similar visual imagery ability, but Highs obtain better imagery than Lows when tactile instructions are given. The aim of this experiment was to confirm this finding using instructions of globally reduced perception instead of suggestions centred on specific sensory modalities, assuming that the preferred imagery modality would be the least easily suppressed. Changes in body sway (that are sensitive to cognitive activity because postural control requires attention) were used as indices of possible differences in the cognitive task load in Highs and Lows. The results confirmed the hypothesis that Highs and Lows differ in their preferred imagery modalities, and showed that Highs' body sway was not modified by the simultaneous imagery of globally reduced perception, while Lows increased their sway while perceiving the decreased sensory availability. The Discussion focuses on the similar networks involved in imagery and perception and on possible differences between Highs and Lows in the mechanisms of imagery/perception and sensory-motor integration. Copyright © 2007 British Society of Experimental & Clinical Hypnosis. Published by John Wiley & Sons, Ltd.

Key words: body sway, hypnotizability, imagery, sensory modalities, sensory-motor integration

Introduction

Hypnotizability is a cognitive trait allowing subjects to modulate perception, emotion and behaviour according to specific suggestions. It is a multidimensional characteristic including various abilities, i.e. imagery (Crawford, 1982; Glisky, Tataryn and Kihlstrom, 1995; Lyons and Crawford, 1997; Kogon, Jasiukaitis, Berardi, Gupta, Kosslyn and Spiegel, 1998), fantasy-proneness (Wilson and Barber, 1982; Lynn and Ruhe, 1986), expectancy (Council, Kirsch and Hafner, 1986), attention/absorption (Tellegen and Atkins, 1974; Crawford, 1989; 1994; Crawford, Brown and Moon, 1993), acquiescence and consistency motivation (Council and Green, 2004). Imagery, particularly in the visual modality, has been frequently considered to be mainly responsible for hypnotizability (Glisky et al., 1995). Yet studies on the ability to perform various mental imagery tasks have failed to detect a correlation between hypnotizability (Kogon, Jasiukaitis, Berardi et al., 1998) and high scores on visual imagery questionnaires, although this

might depend on the adequacy of these instruments to reveal possible particular strategies adopted in mental imagery tasks (Lequerica, Rapport, Axelrod, Telmer and Whitman, 2002).

Some findings indicate that various levels of hypnotizability are characterized by specific 'preferred' sensory modalities (Agargun, Tekeoglu, Kara, Adak and Ercan, 1998; Gemignani, Tosetti, Montanaro, Biagi, Ghelarducci, Guazzelli and Santarcangelo, 2004). Since imagery and perception share similar cortical patterns of both activation (Bartolomeo, 2002; Bryant and Mallard, 2003; Bensafi, Porter, Pouliot, Mainland, Johnson, Zelano, Young, Bremner, Aframian, Khan and Sobel, 2003; Yoo, Freeman, McCarthy and Jolesz, 2003; Djordjevic, Zatorre, Petrides and Jones-Gotman, 2004; Prather, Votaw and Sathian, 2004; Ganis, Thompson and Kosslyn, 2004; Zatorre and Halpern, 2005) and behavioural effects (Carli, Rendo, Sebastiani and Santarcangelo, 2006), preferred imagery modalities might also exist in Highs and Lows. In fact, recent findings on hypnotizability-related differences in mental imagery have shown differences between subjects with high (Highs) and low (Lows) susceptibility to hypnosis in the experience associated with guided visual and tactile imagery tasks. Highs and Lows obtained similar vividness of visual imagery, although a lesser effort was required in Highs, while tactile imagery was less vivid and more effortful in Lows (Carli, Cavallaro, Rendo and Santarcangelo, 2007).

Since cognitive activity has been shown to interfere with postural control, which also requires attention (Lajoie, Teasdale, Bard and Fleury, 1993; Teasdale and Simoneau, 2001; Balasubramian and Wing, 2002; McNevin and Wulf, 2002; Woollacott and Shumway-Cook, 2002; Andersson, Hagman, Talianzadeh, Svedberg and Larsen, 2002; Weeks, Forget, Mouchnino, Gravel and Bourbonnais, 2003; Vuillerme and Nougier, 2004), the demonstration of Carli et al. (2007) as performed in standing, non-hypnotized subjects, while changes in body sway associated with the imagery tasks were used as indices of the possible differences in Highs and Lows in cognitive load due to visual and tactile imagery. It was shown that Highs were able to maintain their body sway unaltered during both tasks as well as during mental computation, in contrast to Lows who exhibited reduced body sway during computation, as well as different changes in their acromion mean position during visual and tactile imagery with respect to a basal eyes closed condition. In particular, their acromion mean position changed similarly during tactile imagery and computation, and differentially from visual imagery. This was in line with the experiential results indicating different vividness/effort for the visual and tactile tasks in Lows. The absence of any postural modulation in Highs, which was attributed to an ability to easily perform two tasks simultaneously (imagery/computation and postural control), did not allow determining any peculiar postural correlates of the different experiences of the two imagery modalities (visual versus tactile) in this group of subjects.

Thus, the first goal of the present study was to identify possible postural correlates of visual and tactile imagery that might be obtained also in Highs by using different instructions, consisting of the description of reduced sensory information. This choice was based on the assumption that in a guided imagery task describing a global decrease of sensory availability (visual, tactile, acoustic, gustatory/olfactory), if subjects are required to imagine according to their own preferences, then the preferred imagery modality should be the most difficult to suppress. In addition, if a reduction of sensory availability could be obtained through this kind of imagery, the postural changes associated with it would reveal whether even a global suppression of perception modifies body sway only in Lows, as occurs when visual (Santarcangelo, Rendo, Carpaneto, Dario,

Micera and Carli, 2004) and neck proprioceptive information (Santarcangelo, Scattina, Orsini, Bruschini, Ghelarducci and Manzoni, in press) as well as attention (Carli et al., 2007) were separately modulated by eyes closure, neck rotation and imagery/computation tasks, respectively. A physical reduction of global sensory information is in fact virtually unobtainable outside of special environments, and on the other hand it is known that successful imagery of explicitly and even implicitly suggested altered perception elicits behavioural effects similar to those induced by physically altered perception (Carli et al., 2006).

Methods

Subjects

After written informed consent, 21 healthy females (age, mean \pm SD, 22 ± 1.5) were selected from 189 volunteers and divided into 9 high-hypnotizable (Highs, mean \pm SD, SHSS score 10.2 ± 0.9) and 12 low-hypnotizable females (Lows, SHSS score 1.7 ± 1.1) according to the Stanford Hypnotic Susceptibility Scale, form C (Weitzenhoffer and Hilgard, 1962). Four of the Highs and 5 of the Lows had previously joined another experiment concerning visual and tactile imagery (Carli et al., 2007). Their hypnotizability-related attentional abilities were evaluated by the Differential Attentional Processing Inventory (DAPI: Crawford et al., 1993) and by the Tellegen Absorption Scale (TAS: Tellegen and Atkinson, 1974) while their imagery abilities were studied through a modified version of the Betts' Questionnaire (Betts, 1909). This included 20 items for each modality except the organic one (10 items).

Experimental procedure

The experimental paradigm included instructions of the absence of any perceptual imagery (condition I) and of mental computation (condition C). Both consisted of 3 consecutive conditions lasting 1 minute each: eyes open, eyes closed, imagery (I) or computation (C) with eyes closed. The order of I and C was randomly administered among the subjects. At the beginning of each eyes open condition they were asked to align their head with the trunk and stare at a black circle ($d = 1$ cm) positioned 3 meters away at eye level. Throughout the experiment, the subjects stood barefoot, with the arms along the body and feet together. At the end of the experiment, subjects were interviewed about 1) the main and accessory sensory modalities used to imagine the absence of perception; 2) the vividness of their imagery (range min 1–max 10); 3) the effort required by imagery and computation (range 1–10).

The mental computation (C) task consisted of serial subtraction (of 2 and 5 alternatively) from 223, and multiplication by 2 of the first number smaller than 100 reached through serial subtraction.

Instruction of 'no perception'

This was as follows:

'Now you feel yourself as you were gliding in the air . . . You don't see and hear anything . . . as if your body did not belong to you anymore . . . Everything is damped, weightless, no sounds, no smells. . . Nothing can touch you while you are like this, flying in midair . . . you do not see, you don't hear or touch anything . . . Your body is light, your sight dims, sounds are far away. You do not perceive anything, the world does not exist . . . everything is far, so far . . . you are sailing in nothingness . . . everything is completely void . . .'

Data acquisition

Body position and movements were monitored with a non-ionizing optoelectronic system, Elite-AUSCAN (BTS, Milan), which measured 3D displacements of 27 passive markers located on different anatomical reference points (for details, see Santarcangelo, Rendo, Carpaneto et al., 2004; Carli et al., 2006). The data were acquired using 6 CCD infrared cameras with a frequency rate of 50 Hz and were stored for off-line analysis with a Matlab program prepared ad hoc.

Each marker displacement in the frontal (X axis) and sagittal (Y axis) planes were evaluated during the later 30 sec (Interval 2) of the closed eyes condition (CE) and during the earlier (Interval 1: I1, C1) and later (Interval 2: I2, C2) 30 sec of the instructions. The variables considered were the mean position (X_{mean} , Y_{mean}), its standard deviation, (X_{SD} , Y_{SD}) and the maximum sway (X_{max} , Y_{max}), corresponding to the maximum–minimum values observed during each condition (CE, I1/C1, I2/C1).

Data analysis

The statistical package SPSS.13 was used for data analysis. TAS, DAPI and DAPI subscales scores as well as the self-reports collected with the structured interviews (vividness and effort) were evaluated with multivariate ANOVA. The percentage of subjects using each sensory modality as preferred (V, T) or accessory (v, t, others) was evaluated, and the frequencies observed in Highs and Lows were compared through χ^2 test.

Each kinematic variable (X_{mean} , Y_{mean} , X_{SD} , Y_{SD} , X_{max} , Y_{max}) concerning acromia, anterior iliac spines and knees was analysed through repeated measures ANOVAs according to a within Groups 2 Sides \times 2 Instructions (I, C) \times 3 Conditions (CE, I1/C1, I2/C2) experimental design. A between Groups design, in fact, could have under- or overestimated group differences due to possible, although not significant, differences in CE conditions. Contrast analysis and t-tests were used when appropriate. The level of significance was set at $p < 0.05$ as in previous studies (Santarcangelo Rendo, Carpaneto et al., 2004; Carli et al., 2006; 2007) and in line with the inverted pendulum model of body sway (Gage, Winter, Frank and Adkin, 2004). Only data concerning *acromia* are presented.

Results

Neuropsychological questionnaires

Multivariate ANOVA showed significantly higher scores in Highs than in Lows with the DAPI ($F(1,19) = 4.84$, $p < 0.040$) and, although not significantly, with the TAS (mean \pm SD; Highs, 26.11 ± 4.78 ; Lows, 21.58 ± 6.95). Among the DAPI subscales, Highs obtained scores significantly higher than Lows with the Diss1 ($F(1,19) = 6.75$, $p < 0.018$) and *quasi* significantly higher with the ModCogn ($F(1,19) = 4.29$, $p = 0.052$) subscales indicating a greater ability of extremely focused attention and of dissociation between cognitive activities respectively. No significant difference between groups and among imagery modalities was found with the Betts' Questionnaire (mean \pm SD: visual, Highs: 40.71 ± 11.71 ; Lows, 49.14 ± 14.18 ; acoustic, Highs: 44.00 ± 16.16 ; Lows, 55.28 ± 16.79 ; tactile, Highs: 38.85 ± 13.06 ; Lows, 55 ± 31.73 ; kinaesthetic, Highs: 42.28 ± 17.96 ; Lows, 54.00 ± 16.27 ; gustatory, Highs: 37.71 ± 17.84 ; Lows, 52.42 ± 17.20 ; olfactory, Highs: 46.28 ± 19.37 , Lows: 63.57 ± 15.93 ; organic, Highs: 17.85 ± 7.51 , Lows: 27.42 ± 9.86)

Interview

As shown in Figure 1, the main modality of imagery was always the visual one in Lows, while both the visual and tactile modalities were observed in Highs; no other sensory channel (acoustic, olfactory/gustatory) was used as a main modality. Among accessory modalities, 6 subjects in each group used the acoustic one, 2 Lows and 1 of the Highs the kinaesthetic one, and 1 of the Highs reported ‘emotion’. The lack of significant differences between Highs and Lows in the modalities frequency distribution (χ^2 test) might depend on the small number of categories (V, T, v, t, others) and on the similar values of some of them (t, others) in the two groups.

Multivariate ANOVA showed significantly higher values of vividness in Highs ($F(1,19) = 6.82, p < 0.017$). In this group, effort showed a tendency to be lower than in Lows, although not significantly (see Figure 1B).

Postural variables

In Highs the ANOVA did not reveal any significant task-related changes.

In Lows (see Table 1), the X_{mean} and Y_{mean} remained unchanged, but significant changes in maximum sway (Figure 2A, B) and SD were observed during the tasks with respect to the eyes closed condition in both planes. In particular, X_{max}, Y_{max}, X_{SD} and Y_{SD} increased during imagery and decreased during mental computation.

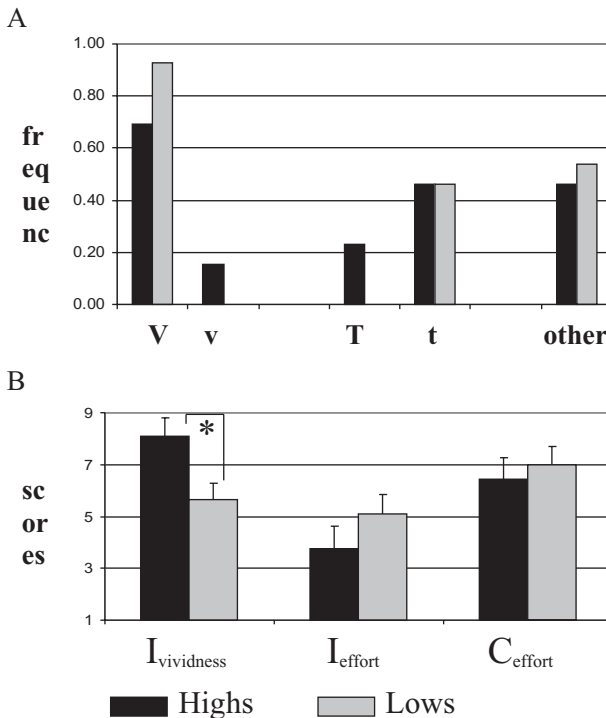


Figure 1. A) frequency of imagery modalities used as preferred (V, visual; T, tactile) and accessory (v, visual; t, tactile, others, acoustic + olfactory). B) Self-reports (mean + SE) of the vividness of the imagery of decreased sensory availability and of the effort required by imagery and by mental computation. CE: basal, closed eyes condition; I: imagery of absence of perception; C: mental computation. Stars indicate significant differences ($p < 0.05$).

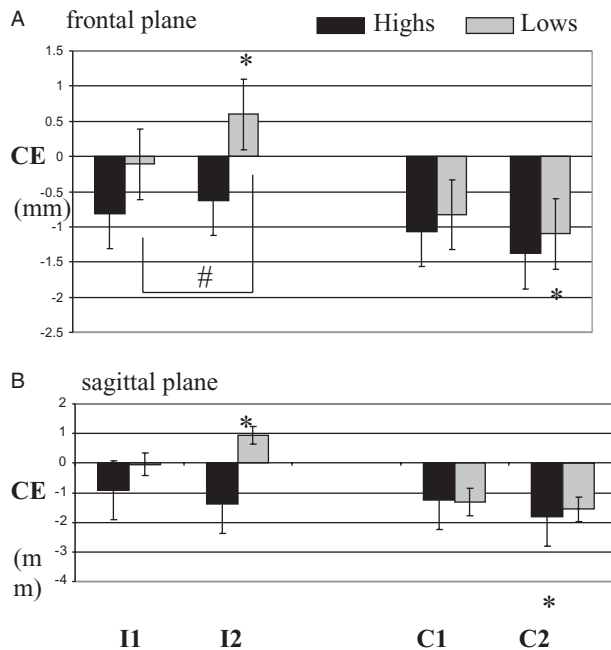


Figure 2. Acromial sway (mean + SE) recorded in the frontal and sagittal planes. Bars represent changes with respect to basal conditions; stars indicate significant differences ($p < 0.05$). CE: basal conditions; I1, I2, C1, C2: values corresponding to the earlier (I1,C1) and later (I2,C2) 30 secs of I (imagery of absence of perception) and C (mental computation), respectively.

Discussion

Goals of the present study were a) to confirm the hypothesis that Highs and Lows differ in their preferred imagery modalities (Carli et al., 2007), and b) to evaluate whether a global suppression of perception obtained through mental imagery modifies body sway only in Lows, as has occurred when visual (Santarcangelo et al., 2004) and neck proprioceptive information (Santarcangelo et al., in press) as well as attention (Carli et al., 2007) were modulated by eyes closure, neck rotation and imagery/computation tasks, respectively.

For an appropriate interpretation of the results it is necessary to assume that self-reports are reliable indicators of the subjective experience (Price et al., 2002; Ericsson and Simon, 1993), and that a successfully imagined modulation of perception does correspond to a modulation of the available information, as suggested by previous studies (Carli et al., 2006). This is reasonable given that similar cortical activation has been observed during perception and imagery for various sensory modalities (Bartolomeo, 2002; Bryant and Mallard, 2003; Bensafi, Porter, Pouliot, et al., 2003; Yoo, Freeman, McCarthy and Jolesz, 2003; Djordjevic et al., 2004; Ganis et al., 2004; Prather et al., 2004; Zatorre and Halpern, 2005). In this regard both groups experienced a strong suppression of perception, although it was significantly greater in Highs, and thus may have reduced the sensory availability required for postural control.

It is interesting that no subject realized the contradiction between the suggestion of suppressed perception and the request to evaluate the efficacy of their imagery and the sensory modality used. This might occur because hypnotic trance and imagination share

Table 1. Summary of significant results for acromion

Variable	Effect	X axis		Y axis	
		Highs	Lows	Highs	Lows
SD	instruction	F(1,8) = 7.46* I > C			F(1,11) = 9.88** N > C
	condition		F(2,22) = 4.95*		F(2,22) = 4.67*
	instr x cond			right CE > C1 t(1,11) = 2.83* CE > C2 t(1,11) = 3.54** left CE > C1 t(1,11) = 2.86* CE > C2 t(1,11) = 3.34**	CE > t1 F(1,11) = 6.89* left I1 < I2 t(1,11) = 2.26* CE > C1 t(1,11) = 2.77* CE > C2 t(1,11) = 4.72***
max	instruction	F(1,8) = 7.56* I > C		F(1,8) = 5.47* I > C	F(1,11) = 5.92* I > C
	condition		F(2,22) = 3.79*		F(2,22) = 5.80**
	instr x cond		F(2,22) = 6.79**		right CE < I2 t(1,11) = 2.46* left CE > C1 t(1,11) = 2.14 CE > C2 t(1,11) = 2.87*

Note: X axis, frontal plane; Y axis, sagittal plane; SD, standard deviation of the mean position; max, maximum sway

Instruction: imagery of nothingness (I), mental computation (C); Condition: closed eyes(CE), t1 and t2: earlier and later 30 sec of instructions; I1, I2 and C1, C2: t1 and t2 of imagery and computation, respectively

the possibility of incongruent logic which can be present in both Highs and Lows and also in non-hypnotized individuals (McConkey, Bryant, Bibb and Kihlstrom, 1991).

The present results support previous findings (Carli et al., 2007) indicating that Highs can obtain a satisfying mental imagery through both visual and tactile sensory modalities (point a). The differences between Highs and Lows, in fact, concern mainly the tactile task that was 'easier' for Highs (Carli et al., 2007) and, in the present experiment, contributes to the Highs' imagery either as a main or accessory modality, while Lows mainly obtain the imagery of reduced perception through visual imagery. The similar ability of Highs and Lows to imagine through the visual modality is in line with previous reports (Kogon, Jasiukaitis, Berardi et al., 1998), while the Highs' greater ability with the tactile one might be interpreted on the basis of possible modality-specific, similar processing of imagery and perception. In this perspective, it accords with studies showing lower thresholds for mechanical pain in Highs than in Lows (Agargun et al., 1998), and with the sporadic observation suggesting that Highs, more often than Lows, activate the caudal S1/M1 that receives the most part of the tactile information (Gemignani, Tosetti, Montanaro et al., 2004). A morpho-functional basis of the greater ability of Highs than Lows at tactile imagery/perception might be found, theoretically, in a possible different distribution of the pathways originating from the *locus coeruleus* to sensory cortices (Berridge and Waterhouse, 2003), as well as in the fibres originating from the prefrontal cortex to the thalamic nuclei responsible for attentional regulation for the selection of relevant sensory signals and the suppression of distractors (Zikopoulos and Barbas, 2006) an/or in a different integration of tactile with visual information (Negyessy, Nepusz, Kocsis and Bazso, 2006; Merabet, Swisher, McMain, Halko, Amedi, Pascual-Leone and Somers, 2007).

Also, the present findings agree with criticism about the inadequacy of questionnaires alone to detect imagery abilities (Gliski et al., 1995; Kogon, Jasiukaitis, Berardi et al., 1998; Lequerica et al., 2002); in fact the Betts questionnaire did not enlighten any differences between Highs and Lows.

Our results (point b) indicate that Highs are less vulnerable than Lows to an imagery-induced postural instability, even when global perception is markedly reduced. In fact, Highs did not modify their body sway while in Lows the suppression of perception obtained through imagery modified postural control; in addition, the change was similar to that induced by a real decrease in sensory availability (Santarcangelo, Rendo, Carpaneto et al., 2004), but was different from that induced by cognitive load, as shown in the present and in previous studies (Carli et al., 2007).

Taking together the experiential and behavioural results, it may be concluded that mental imagery was responsible for the suppression of perception in both groups, which might have its basis in the non-significantly different scores reported by Highs and Lows in absorption; in contrast, only Highs could successfully counteract the effects of a decreased sensory availability. This is in line with what was previously shown and with the hypothesis of a particularly effective internal model for postural control (Santarcangelo, Rendo, Carpaneto et al., 2004; 2007; in press; Carli et al., 2007). This is likely to have its morpho-functional basis in the connections among the prefrontal cortex, whose relation with the anterior cingulate cortex is responsible for hypnotic phenomena (Gruzelier, 1998; Woody and Farvolden, 1998; Rainville and Price, 2003; Egner, Jamieson and Gruzelier, 2005; Raz, 2005), while the cerebellum is the site for the adaptation of sensorimotor coupling to behavioural conditions (Ito, 1981; Brodal, Bjaalie and Aas, 1991; Manzoni, 2005; Ramnani, 2006), and the *locus coeruleus* involved in both postural control (Pompeiano, 2001) and attentional mechanisms (Berridge and Waterhouse, 2003).

In our opinion, the present findings are of interest for several reasons. The possibility to markedly reduce perception could be useful, e.g., to avoid motion sickness. This is an autonomic impairment induced by a discrepancy between ego- and space-referenced information, conveyed by proprioceptive and visual inputs respectively, in motion environments and in microgravity, and it is less serious when the conflict is reduced by avoiding movements, i.e. sensory information (Heer and Paloski, 2006).

However, the possibility that hypnotizability represents a physiological model in psychological and philosophical research is even more intriguing. In fact, Highs and Lows exhibiting specific preferred sensory (Agargun et al., 1998; Gemignani, Tosetti, Montanaro et al., 2004) and imagery modalities (Carli et al., 2007) are likely to experience their environment in different ways, which might lead to different styles of communication and judgment. This suggests that hypnotizability might be an unexpectedly pervasive trait and prompts investigation of the physiological correlates of the differences observed between Highs and Lows in imagery/perception, which are less indirect than posture (EEG, neuroimaging), and of other fields (i.e. language) possibly related to them and likely to influence daily life.

Acknowledgments

The research was supported by the Italian Space Agency (ASI). Postural data collection was made possible by BTS-Engineering (Elite-Auscan System). We are grateful to Dr. A. Huber for helpful criticism and discussion and to Dr P. Christie for the revision of the English text.

References

- Agargun MY, Tekeoglu I, Kara H, Adak B, Ercan M (1998) Hypnotizability, pain threshold, and dissociative experiences. *Biological Psychiatry* 44: 69–71.
- Andersson G, Hagman J, Talianzadeh R, Svedberg A, Larsen HC (2002) Effect of cognitive load on postural control. *Brain Research Bulletin* 58: 135–9.
- Balasubramaniam R, Wing AM (2002) The dynamics of standing balance. *Trends in Cognitive Sciences* 6: 531–6.
- Bartolomeo P (2002) The relationship between visual perception and visual mental imagery: a reappraisal of the neuropsychological evidence. *Cortex* 38: 357–78.
- Bensafi WM, Porter J, Pouliot S, Mainland J, Johnson B, Zelano C, Young N, Bremner E, Aframian D, Khan R, Sobel N (2003) Olfactory activity during imagery mimics that during perception. *Nature Neuroscience* 6: 1142–44.
- Berridge CW, Waterhouse BD (2003) The locus coeruleus-noradrenergic system: modulation of behavioral state and state-dependent cognitive processes. *Brain Research Review* 42: 33–84.
- Betts GH (1909) *The Distribution and Functions of Mental Imagery*. New York: Teachers College, Columbia University.
- Brodal P, Bjaalie JG, Aas JE (1991) Organization of cingulo-ponto-cerebellar connections in the cat. *Anatomy and Embryology* 184: 245–54.
- Bryant RA, Mallard R (2003) Seeing is believing: the reality of hypnotic hallucinations. *Consciousness and Cognition* 12: 219–30.
- Carli G, Cavallaro FI, Rendo CA, Santarcangelo EL (2007) Imagery of different sensory modalities: hypnotizability and body sway. *Experimental Brain Research* (in press).
- Carli G, Rendo CA, Sebastiani L, Santarcangelo EL (2006) Suggestions of altered balance: possible equivalence of imagery and perception. *International Journal of Clinical and Experimental Hypnosis* 54: 206–23.

- Council JR, Green JP (2004) Examining the absorption-hypnotizability link: the roles of acquiescence and consistency motivation. *International Journal of Clinical and Experimental Hypnosis* 52: 364–77.
- Council JR, Kirsch I, Hafner LP (1986) Expectancy versus absorption in the prediction of hypnotic responding. *Journal of Personality and Social Psychology* 50: 182–9.
- Crawford HJ, Brown AM, Moon CE (1993) Sustained attentional and disattentional abilities: differences between low- and high hypnotizable persons. *Journal of Abnormal Psychology* 102: 534–43.
- Crawford HJ (1982) Hypnotizability, daydreaming styles, imagery vividness, and absorption: a multidimensional study. *Journal of Personality and Social Psychology* 42: 915–26.
- Crawford HJ (1994) Brain dynamics and hypnosis: attentional and disattentional processes. *International Journal of Clinical and Experimental Hypnosis* 42: 204–32.
- Crawford HJ (1989) Cognitive and physiological flexibility: multiple pathways to hypnotic responsiveness. In V Gheorgiu, P Nette, H Eysenck, R Rosenthal (eds) *Suggestion and Suggestibility: Theory and Research*. New York: Plenum Press, 155–68.
- Djordjevic J, Zatorre RJ, Petrides M, Jones-Gotman M (2004) The mind's nose: effects of odor and visual imagery on odor detection. *Psychological Sciences* 15: 143–8.
- Egner T, Jamieson G, Gruzelier J (2005) Hypnosis decouples cognitive control from conflict monitoring processes of the frontal lobe. *NeuroImage* 27: 969–78.
- Ericsson AK, Simon HA (1993) *Protocol Analysis: Verbal Reports as Data*. Boston, MA: MIT Press.
- Gage WH, Winter DA, Frank JS, Adkin AL (2004) Kinematic and kinetic validity of the inverted pendulum model in quiet standing. *Gait & Posture* 19: 124–32.
- Ganis G, Thompson WL, Kosslyn SM (2004) Brain areas underlying visual mental imagery and visual perception: an fMRI study. *Cognitive Brain Research* 20: 226–41.
- Gemignani A, Tosetti M, Montanaro D, Biagi L, Ghelarducci B, Guazzelli M, Santarcangelo EL (2004) Sensory-motor cortex activity modulation by hypnotic susceptibility and hypnosis during finger movement. *Archives Italiennes de Biologie* 142: 77–85.
- Glisky ML, Tataryn DJ, Kihlstrom J (1995) Hypnotizability and mental imagery. *International Journal of Clinical and Experimental Hypnosis* 43: 34–54.
- Gruzelier JH (1998) Working model of the neurophysiology of hypnosis: a review of evidence. *Contemporary Hypnosis* 5: 3–21.
- Heer M, Paloski WH, (2006) Spatial motion sickness: incidence, etiology, and countermeasures. *Automatic neuroscience: Basic and Clinical*, 129: 77–79.
- Ito M (1981) *The Cerebellum and Neural Control*. New York: Raven Press.
- Kogon MM, Jasiukaitis P, Berardi A, Gupta M, Kosslyn SM, Spiegel D (1998) Imagery and hypnotizability revisited. *International Journal of Clinical and Experimental Hypnosis* 46: 363–70.
- Lajoie Y, Teasdale H, Bard C, Fleury M (1993) Attentional demands for static and dynamic equilibrium. *Experimental Brain Research* 97: 139–44.
- Lequerica A, Rapport L, Axelrod BN, Telmer K, Whitman RD (2002) Subjective and objective assessment methods of mental imagery control: construct validation of self-report measures. *Journal of Clinical and Experimental Neuropsychology* 24: 1103–16.
- Lynn SJ, Ruhe JW (1986) The fantasy-prone person: hypnosis, imagination, and creativity. *Journal of Personality and Social Psychology* 5: 404–8.
- Lyons LC, Crawford HJ (1997) Sustained attentional and disattentional abilities and arousability: factor analysis and relationships to hypnotic susceptibility. *Personality and Individual Differences* 23: 652–4.
- Manzoni D (2005) The cerebellum may implement the appropriate coupling of sensory inputs and motor responses: evidence from vestibular physiology. *Cerebellum* 4: 78–88.
- McConkey KM, Bryant RA, Bibb BC, Kihlstrom JF (1991) Trance logic in hypnosis and imagination. *Journal of Abnormal Psychology* 10: 464–72.

- McNevin NH, Wulf G (2002) Attentional focus on supra-postural tasks affects postural control. *Human Movement Sciences* 21: 187–202.
- Merabet LB, Swisher JD, McMains SA, Halko MA, Amedi A, Pascual-Leone A, Somers DC (2007) Combined activation and deactivation of visual cortex during tactile sensory processing. *Journal of Neurophysiology* 97: 1633–41.
- Negyessy L, Nepusz T, Kocsis L, Bazso F (2006) Prediction of the main cortical areas and connections involved in the tactile function of the visual cortex by network analysis. *European Journal of Neuroscience* 23: 1919–30.
- Pompeiano O (2001) Role of the locus coeruleus in the static and dynamic control of posture. *Archives Italiennes de Biologie* 139: 109–24.
- Prather SC, Votaw JR, Sathian K (2004) Task-specific recruitment of dorsal and ventral visual areas during tactile perception. *Neuropsychologia* 42: 1079–87.
- Price DD, Barrell JJ, Rainville P (2002) Integrating experiential-phenomenological methods and neuroscience to study neural mechanism of pain and consciousness. *Consciousness and Cognition* 11: 593–608.
- Rainville P, Price DD (2003) Hypnosis phenomenology and the neurobiology of consciousness. *International Journal of Clinical and Experimental Hypnosis* 51: 105–29.
- Ramrani N (2006) The primate cortico-cerebellar system: anatomy and function. *Nature Reviews of Neuroscience* 7: 511–22.
- Raz A (2005) Attention and hypnosis: neural substrates and genetic associations of two converging processes. *International Journal of Clinical and Experimental Hypnosis* 53: 237–58.
- Santarcangelo EL, Rendo C, Carpaneto J, Dario P, Micera S, Carli G (2004) Does hypnotizability affect human upright stance? *Archives Italiennes de Biologie* 142: 285–96.
- Santarcangelo EL, Scattina E, Orsini P, Bruschini L, Ghelarducci B, Manzoni D (2007) Effects of vestibular and neck proprioceptive stimulation on posture as a function of hypnotizability. *International Journal of Clinical and Experimental Hypnosis*, in press
- Teasdale N, Simoneau M (2001) Attentional demand for postural control: the effects of ageing and sensory reintegration. *Gait & Posture* 14: 203–21.
- Tellegen A, Atkinson G (1974) Openness to absorbing and self-altering experiences ('absorption'), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology* 83: 268–77.
- Vuillerme N, Nougier V (2004) Demand for regulating postural sway: the effect of expertise in gymnastics. *Brain Research Bulletin* 63: 161–5.
- Weeks DL, Forget R, Mouchnino L, Gravel D, Bourbonnais D (2003) Interaction between attention demanding motor and cognitive tasks and static postural stability. *Gerontology* 49: 225–32.
- Weitzenhoffer AM, Hilgar E (1962) *Stanford Hypnotic Susceptibility Scale, form C*. Palo Alto, CA: Consulting Psychologist Press.
- Wilson SC, Barber TX (1982) The fantasy-prone personality: implications for understanding imagery, hypnosis, and parapsychological phenomena. *Psychological Research* 1: 94–116.
- Woody E, Farvolden P (1998) Dissociation in hypnosis and frontal executive function. *American Journal of Clinical Hypnosis* 40: 206–16.
- Wollacott MH, Shumway-Cook A (2002) Attention and the control of posture and gait: a review of an emerging area of research. *Gait & Posture* 16: 1–14.
- Yoo SS, Freeman DK, McCarthy JJ^{III}, Jolesz FA (2003) Neural substrates of tactile imagery: a functional MRI study. *NeuroReport* 14: 581–5.
- Zatorre RJ, Halpern AR (2005) Mental concerts: musical imagery and auditory cortex. *Neuron* 47: 9–12.
- Zikopoulos B, Barbas H (2006) Prefrontal projections to the thalamic reticular nucleus form a unique circuit for attentional mechanisms. *Journal of Neuroscience* 26: 7348–61.

Address for correspondence:
Dr Enrica L. Santarcangelo
Department of Human Physiology
University of Pisa
Via San Zeno 31- 56127
Pisa
Italy
Phone: +39 050 2213465
Fax: +39 050 2213527
Email: **enricals@dfb.unipi.it**