Archives Italiennes de Biologie, 142: 285-296, 2004.

DOES HYPNOTIZABILITY AFFECT HUMAN UPRIGHT STANCE?

E.L. SANTARCANGELO[*1], C. RENDO[**], J. CARPANETO[***], P. DARIO[***], S. MICERA[***] AND G. CARLI[**]

[*] *Department of Physiology and Biochemistry, University of Pisa, Italy;* [**] *Department of Physiology, University of Siena, Italy;* [***] *ARTS Lab, Scuola Sant'Anna, Pisa*

INTRODUCTION

Physiological differences between subjects highly (Highs) and low susceptible to hypnosis (Lows) have been demonstrated for motor (12, 13, 55, 56, 57, 58) and vegetative functions (20, 27, 59, 60) as well as for EEG patterns (16, 19, 20, 53, 59) in basal awake conditions. Such differences can be modulated by a hypnotic induction and/or by specific suggestions. In fact, Highs exhibit a peculiar cognitive flexibility (15), based on specific imagery, attentional/disattentional and "absorption" capabilities which can be evaluated through psychological tests (36, 37, 65) and allow them to experience an altered perception. They can easily select the object of their attention, in both awake and hypnotic conditions, and change their physiological setting accordingly. For instance, they can control their vestibular nystagmus (4), lower "involuntarily" their arms during suggestions of heaviness (58), experience suggested fear, happiness (16, 20,59, 60) and analgesia (17, 19, 22, 24, 28, 50) as well as modulate their peripheral responses to pain (7, 18, 21, 23, 32, 54). The Highs' cognitive characteristics, which let them accept suggestions, include a capability to tolerate ambiguous information (66), even at a sensory level (43, 47), likely as a part of a better compliance of Highs towards subjective and environmental events (30, 55, 56, 59, 60, 72).

The hypnotic phenomenology, related to attentional/disattentional mechanisms, is attributed to a particular effectiveness of the frontal executive control system (22, 26, 50, 71), which would be responsible of the selection of specific behavioural modules. It has its anatomical basis in the limbic circuit, particularly in the orbitofrontal and geniculate cortex (25, 33, 61), which are connected with the *nucleus parabrachialis* (5), where vestibular, somatic and visceral information are integrated. On the other side, a role in attentional mechanisms, particularly in the suppression of irrelevant stimuli, has been demonstrated for the *locus coeruleus* (8, 51), which is also widely involved in postural control (49) and exhibits direct and indirect connections with the prefrontal cortex.

Attention can be considered one of the components of equilibrium. In fact, using interference experimental procedures, it has been demonstrated that the upright posture requires more attention that the sitting one (35) and that simultaneous cognitive

[1] Corresponding Author: Dr. E.L. Santarcangelo, Department of Physiology and Biochemistry, University of Pisa, Via San Zeno 31, 56127 Pisa, Italy. Phone: +39-50-2213483; Fax: +39-50-2213527; E-mail: enricals@dfb.unipi.it

tasks modulate the effectiveness of postural control (2, 39, 40, 44, 62), even if it is always prioritised (3). In addition, a sensory alteration experimentally induced (38, 42, 45, 46, 48), or due to ageing (29, 52, 64) and to pathological conditions (3, 10), increases the attention required for a satisfying postural control. It has been also shown that anxiety makes subjects more strictly dependent on the visual input (9, 68, 69) and elicits a body sway characterised by a greater stiffness (14), while the fear of falling magnifies the postural adjustments preceding upper limbs movements (1). Moreover, cognitive factors, like the visual field dependence, interact with the visual contribution to postural control (31).

Thus, as a first step in the investigation on the influences of hypnotizability on postural control, the aim of the present experiment was to study possible differences in the postural adjustments elicited by the eyes closure in Highs and Lows.

METHODS

Subjects

Ninety-eight students joined the experiment. Among them, 25 healthy volunteers (age 18-35), with no vestibular abnormality and no anamnesis of neurological and psychiatric disorder, were selected as for their hypnotic susceptibility through the Stanford Hypnotic Susceptibility Scale, form C (70), after a written informed consent approved by the Ethics Commettee of the University of Siena. They were divided into 2 groups: highly susceptible (Highs, score $\geq 9/12$, $N = 13$) and non susceptible subjects (Lows, score 0/12, $N = 12$).

Experimental procedure

In the first part of the experiment, the subjects cognitive evaluation was performed. The Italian version of the Questionnaire of Visual Imagery (VVIQ), Differential Attentional Processing Questionnaire (DAPQ), Tellegen Scale of Absorption (TAS) and Movement Imagery Questionnaire (MIQ) were administered. In a different day, posture was recorded while subjects stood up barefoot with the arms along the body and feet together. The head, slightly reclined backward (10-20 degrees), could not be fixed, because the collar hid some markers, but its position was monitored through the face markers in order to exclude from analysis subjects unable to keep its position constant across the experiment. Experimental sessions included 1 min of up-right stance with open eyes (OE) and 1 min with closed eyes (CE). The order of OE and CE was randomised among subjects. Body position and movements were monitored through a non-ionising optoelectronic system, AUSCAN, providing 3D displacements of 27 passive markers located on different anatomical repere points. Body landmarks included 17 points placed on the posterior body surface (11 on the spinous process of every second vertebra from C7 to S3, 2 on the acromions), 2 on the lateral surfaces of knees, 2 on the heels (calcaneus spines), and 8 points placed on the anterior body surface (2 on the cheekbones, 1 on the chin, 2 on the sterno-clavicular joints, 1 on the xiphoid process, and 2 on the anterior-superior iliac spines). Data were acquired using 6 CCD infrared cameras with a frequency rate of 50Hz and stored for off-line analysis.

Data analysis

Neuropsychological tests (TAS, DAPQ, VVIQ, MIQ) were analysed through a multivariate ANOVA. Displacements in the sagittal (Z axis) and frontal plane (X axis) were computed as differences between the values of each position and the initial one. For each joint, separate repeated measures ANOVAs following a 2 Groups (Highs, Lows) x 2 Directions (Forward, Backward or Right, Left) x 2 Conditions (OE, CE) experimental design were performed on maximum displacements through the Statistical Package for Social Science (SPSS.9). Maximum displacement values of consecutive 10 sec periods (6 Intervals for each Condition) were also calculated and the movement time-course obtained was analysed following a 2 Groups (Highs, Lows) x 2 Directions (Forward, Backward or Right, Left) x 2 Conditions (OE, CE) x 6 Intervals (1,2, … 6) experimental design. In addition, in order to evaluate the postural adjustments occurring soon after the eyes closure, separate repeated measures ANOVAs were used to compare the latest 10 sec of the OE condition with the earliest 10 sec of the CE one according to a 2 Groups (Highs, Lows) x 2 Directions (Forward, Backward or Right, Left) x 2 Conditions (OE, CE). Level for significance was set at $p < 0.05$.

RESULTS

Psychological tests

Analysis was performed on 12 Highs and 10 Lows because 3 subjects reported great difficulty in the tests compilation and refused to complete them. ANOVA revealed significant Group differences (df: 1,20) for TAS ($F = 13.725$, $p < 0.001$), DAPQ ($F = 8.031$, $p < 0.01$) and VVIQ ($F = 10.320$, $p < 0.004$). In fact, Highs showed higher scores at TAS, DAPQ and VVIQ indicating their better attentional/disattentional and visual imaginative capabilities. On the contrary, the Highs' scores at MIQ were non significantly different from Lows' ones (Tab. I).

Kinematics

The degrees of freedom reported for each joint are not always corresponding to the total number of subjects because sometimes, during experiments, cameras did not detect all markers.

Zaxis

ANOVA on mean values of OE and CE did not reveal any significant Group effect. A Direction effect for L4 (forward > backward, $F(1,23) = 5.067$, $p < 0.034$) and a Condition effect for the right (CE > OE, $F(1,18) = 4.367$, $p < 0.045$) and left acromion (CE > OE, $F(1,22) = 9.175$, $p < 0.006$) were detected. The former (Fig. 1) showed also a Direction x Condition x Group interaction ($F(1,18) = 5.229$, $p < 0.035$) and follow up analysis revealed significant differences only in Lows (Condition: CE > OE, $F(1,9) = 13.992$, $p < 0.005$). In addition, a Direction x Condition interaction within Lows ($F(1,9) = 12.680$, $p < 0.006$) showed a *quasi*-significant difference in the forward sway (OE > CE, $p < 0.063$) and a significant one in the backward displacement (CE > OE, $F(1,9) = 18.001$, $p < 0.002$).

In spite of the sporadic significances, largely due to a wide inter-subjects variability (Tab. II), the axial joints displacements (T2, L4, S3) show that the trunk oscil-

Tab. I. - Neuropsicological tests (M ± SD).

group	Highs	Lows
TAS*	23.54 + 1.51	14.78 + 1.82
DAPQ*	163.00 + 5.94	136.67 + 7.14
VVIQ*	63.85 + 3.42	46.67 + 4.11
MIQ	32.77 + 6.02	40.89 + 7.24

*: significant difference between Highs and Lows.

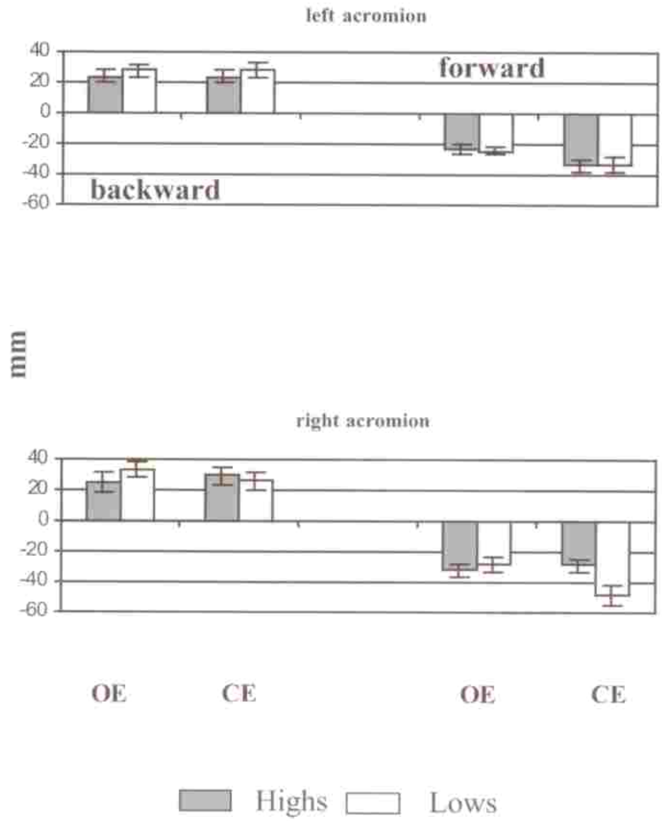

Fig. 1. - *Acromions maximum displacements in the sagittal plane.*

Columns represent the forward (positive numbers) and backward (negative numbers) displacements (M ± SE, mm) of the right and left acromion of highly (Highs, grey columns) and non hypnotizable subjects (Lows, white colunms) with open (OE, 60 sec) and closed eyes (CE, 60 sec). Lows' right acromion exhibits the greatest backward sway, indicating a maximum right-rotation of the body across CE.

lated as a rigid system. In Lows, the right acromion greater backward sway observed during the CE condition indicated a body rotation to the right.

Significant effects and interactions for the movement time course of each joint are summarized in Table III. They indicate a greater sway during the CE condition with respect to OE. Subsequent contrast analysis revealed significant differences within groups for S3, left acromion and knee. Both Highs and Lows exhibited a greater displacement of the left acromion (Fig. 2) during CE with respect to OE (Condition: Highs, $F(1,11) = 16.152$, $p < 0.006$; Lows, $F(1,9) = 16.152$, $p < 0.003$). Lows decreased their sway over time in both directions (Cond x Int, $F(5,45) = 3.778$, $p < 0.003$), while Highs showed a decreasing displacement in both directions during CE and an opposite sway, decreasing forward and increasing backward, during OE (Cond x Dir x Int, $F(5,55) = 3.139$, $p < 0.038$). Since no side difference was present in the spines sway, but a significant larger oscillation occurred at the left acromion of both groups at the eyes closure, possible body rotations should involve only the higher part of the back.

In Highs, a Condition effect indicated a greater displacement during CE with respect to OE for S3 ($F(1,12) = 4.826$, $p < 0.048$) and an Interval effect showed for the left knee a decreasing sway over time in both conditions ($F(5,60) = 2.860$, $p < 0.022$).

Tab. II. - Maximum displacement range (M ± SE, mm) along Z and X axis.

group	position	axis/ condition	Z forward	Z backward	X right	X left
Highs	T2	OE	26.13 ± 5.25	17.99 ± 2.04	19.64 ± 3.17	18.91 ± 3.02
		CE	23.53 ± 3.99	20.95 ± 3.97	21.00 ± 3.50	18.86 ± 3.61
Lows		OE	24.14 ± 5.46	17.75 ± 2.12	21.51 ± 3.29	15.39 ± 3.14
		CE	22.52 ± 4.16	29.63 ± 4.13	24.42 ± 3.64	21.40 ± 3.76
Highs	L4	OE	23.71 ± 4.96	13.49 ± 2.09	14.53 ± 2.83	14.73 ± 2.05
		CE	21.79 ± 3.22	15.67 ± 2.48	16.74 ± 2.85	13.91 ± 2.48
Lows		OE	20.82 ± 5.16	14.37 ± 2.18	17.69 ± 2.95	10.66 ± 2.13
		CE	17.62 ± 3.36	17.75 ± 2.57	18.36 ± 2.97	14.67 ± 2.58
Highs	S3	OE	21.42 ± 5.25	14.03 ± 1.77	16.02 ± 2.72	15.99 ± 2.63
		CE	20.31 ± 3.39	15.70 ± 2.43	17.07 ± 3.39	15.89 ± 3.17
Lows		OE	19.99 ± 4.90	13.24 ± 1.43	16.92 ± 2.84	14.42 ± 2.73
		CE	16.36 ± 3.47	18.00 ± 2.61	23.20 ± 3.53	16.41 ± 3.30
Highs	R acromion	OE	24.70 ± 6.35	32.41 ± 3.79	19.86 ± 3.61	16.96 ± 3.18
		CE	29.69 ± 5.63	29.07 ± 5.95	20.56 ± 3.51	19.18 ± 4.25
Lows		OE	33.67 ± 5.46	28.48 ± 4.48	23.64 ± 3.62	19.01 ± 3.18
		CE	25.86 ± 4.61	48.53 ± 6.45	27.77 ± 5.51	22.40 ± 4.25
Highs	L acromion	OE	22.93 ± 4.06	23.04 ± 2.62	18.34 ± 3.62	16.01 ± 2.40
		CE	23.94 ± 4.59	32.11 ± 4.56	23.34 ± 3.29	16.55 ± 3.23
Lows		OE	33.23 ± 4.24	25.62 ± 2.73	21.48 ± 3.78	18.61 ± 2.50
		CE	32.25 ± 4.80	33.59 ± 4.76	24.66 ± 3.44	20.37 ± 3.38
Highs	R spine	OE	17.55 ± 3.07	17.49 ± 2.25	22.23 ± 3.60	20.74 ± 3.77
		CE	20.72 ± 2.71	19.00 ± 2.50	16.42 ± 2.58	19.25 ± 2.46
Lows		OE	21.71 ± 4.12	19.75 ± 3.02	28.48 ± 5.70	20.40 ± 4.08
		CE	16.55 ± 3.63	25.44 ± 3.36	27.81 ± 5.97	19.43 ± 3.89
Highs	L spine	OE	18.49 ± 3.38	17.94 ± 2.22	20.64 ± 3.06	22.65 ± 3.81
		CE	21.15 ± 4.08	17.50 ± 3.07	19.06 ± 3.60	18.49 ± 2.59
Lows		OE	20.72 ± 4.54	18.35 ± 2.98	29.51 ± 6.03	29.12 ± 6.03
		CE	19.39 ± 5.48	21.91 ± 4.12	20.55 ± 5.69	13.30 ± 4.10
Highs	R knee	OE	12.07 ± 2.57	11.04 ± 4.92	10.83 ± 2.64	10.56 ± 5.07
		CE	13.44 ± 2.05	11.29 ± 1.71	10.51 ± 1.67	11.24 ± 1.65
Lows		OE	14.79 ± 2.68	21.68 ± 5.12	14.42 ± 2.75	20.10 ± 5.28
		CE	13.91 ± 2.13	15.54 ± 1.78	14.67 ± 1.73	11.71 ± 1.72
Highs	L knee	OE	11.44 ± 2.00	11.38 ± 1.95	9.60 ± 1.85	8.19 ± 1.26
		CE	10.20 ± 2.26	13.56 ± 1.53	9.22 ± 1.60	8.35 ± 1.44
Lows		OE	13.98 ± 2.83	15.62 ± 2.03	12.88 ± 1.92	6.40 ± 1.32
		CE	14.53 ± 2.35	12.37 ± 1.59	11.88 ± 1.66	8.30 ± 1.50

In the comparison between the latest 10sec of the OE condition with the earliest 10 sec of the CE condition (Fig. 3), ANOVA did not reveal any Group effect. A greater displacement of the left acromion was found (Side, $F(1,13) = 7.485$, $p < 0.017$). For both acromions, a greater sway occurred in the backward direction (Dir, $F(1,13) = 55.464$, $p < 0.0001$). A Side x Dir interaction ($F(1,13) = 15.701$, $p < 0.002$) indicated a backward sway prevalence on the left side and thus a rotation of the trunk toward the left side in both groups. A greater backward displacement was observed in both groups, conditions and sides for the anterior iliac spine (Dir, $F(1,14) = 7.955$, $p < 0.014$). We argue that, across the CE condition, Lows changed the body left-rotation exhibited during the latest 10 sec of OE into a right-rotated one.

X axis

No Group effect was detected. ANOVA revealed a Condition effect for T2

Tab. III. - Timecourse significant effects and interactions along Z and X axis.

joint	effect	Z	X
T2	cond	F(1,23) = 12.702**	F(1,23) = 16.574***
L4	cond		F(1,21) = 4.064*
S3	dir		F(1,20) = 6.622*
	int	F(5,115) = 2.421*	F(5,100) = 8.052***
	cond x int		F(5,100) = 3.880**
	cond x dir x int		F(5,100) = 2.794*
	group x cond x dir x int	F(115) = 2.331*	
L acromion	cond	F(1,20) = 27.699***	F(1,20) = 15.496**
	int	F(5,100) = 14.382***	
	cond x int	F(5,100) = 13.601***	
	group x cond x dir x int	F(5,100) = 3.339*	
L spine	dir x int x group	F(5,70) = 4.162*	
R spine	cond x dir x int	F(5,80) = 2.443*	
L knee	cond		F(1,23) = 5.584*
	dir		F(1,23) = 7.833*
	int	F(5,115) = 4.605**	F(5,115) = 2.584*
	dir x int	F(5,115) = 3.082*	
	group x cond x dir x int	F(5,115) = 2.850*	
R knee	cond		F(1,22) = 7.541*
	dir		
	int	F(5,110) = 7.541***	

*, $p < 0.05$; **, $p < 0.001$; ***, $p < 0.0001$

(F(1,23) = 6.119, p < 0.021), L4 (F(1,23) = 4.594, p < 0.043), right (F(1,18) = 4.284, p < 0.050) and left acromion (F(1,21) = 6.033, p < 0.023) indicating a larger sway during CE (Tab. II) and a Direction effect for the left knee (F(1,23) = 6.577, p < 0.017) whose maximum displacement was greater toward the right side (Right, 10.89 ± 1.02; Left, 7.81 ± 0.698) for both groups (Tab. II). No significant change in the first 10 sec after the eyes closure and no significant differences in the movement timecourse was observed. However, results indicate a consistent trend toward larger displacements on the right side and during CE, not dependent on hypnotic susceptibility.

DISCUSSION

Results showed that the body sway modulation expected after the eyes closure (6) was different in Highs and Lows. In fact, the maximum displacements observed during OE and CE indicated that Lows were more sensitive to the eyes closure and reacted to it with a greater backward sway. In addition, the analysis of the movement time course proved that earlier posture modifications were similar in both groups and elicited a left-side rotation of the body during the first 10 sec after the eyes closure. Later, across CE, Lows exhibited a larger right-oriented body rotation. It should be remarked, however, that the present findings, referring to maximum displacements and not to preferential stance, are indicators of pre-eminent dynamic postural adjustments instead of preferred postures.

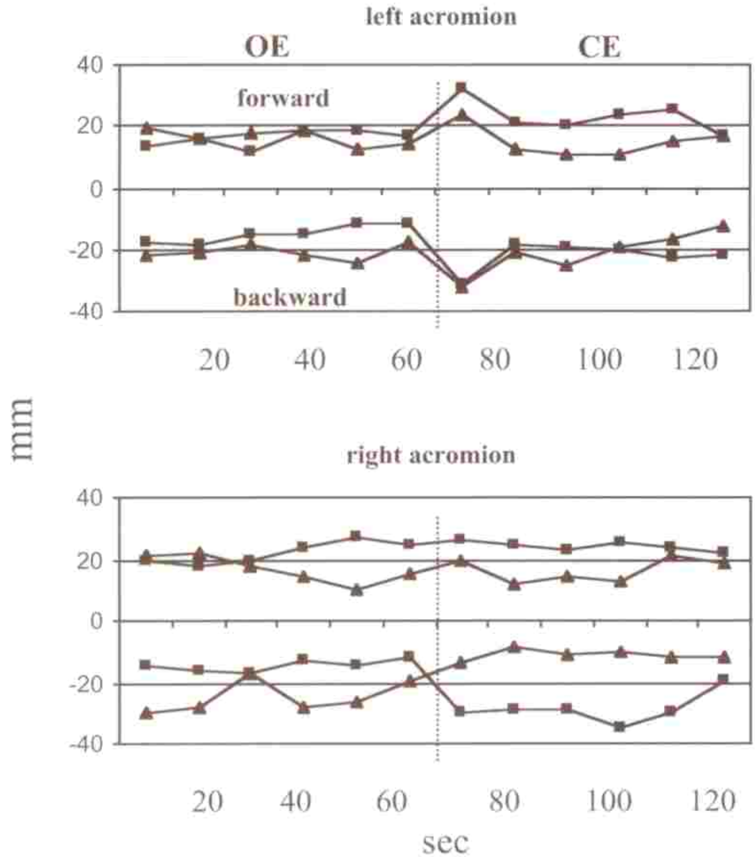

Fig. 2. - *Acromions movement time-course in the sagittal plane.*

Positive and negative values (Highs, square; Lows, triangle) indicate forward and backward displacements (mm), respectively. At the eyes closure (60-120 sec), both groups showed an increased sway of the left acromion, while only Lows exhibited a greater backward sway of the right one.

Highs and Lows exhibited different neuropsychological capabilities, thus their motor behaviours are likely to depend on different internal reference systems for posture control (41). The higher scores reported by Highs at TAS and DAPQ indicate a greater attitude to pay attention to selected objects and to be involved in their own activities and imagery, so that they should be more able than Lows to rely on an internal reference system. In addition, as for imagery capabilities, groups were significantly different at VVIQ, whose score was higher in Highs, but not at MIQ. Thus, a different involvement of visual imagery in the construction of their internal space reference system could be hypothesized (41). From this perspective, the motor outputs observed in Highs and Lows at the eyes closure could be the result of different compensation mechanisms. In the former, the almost complete lack of changes could be based on a high capability to rely on the internal visual reference system (34, 67) when visual input is suppressed by the eyes closure, or on the possibility to obtain an effective postural control even with a lowered sensorial background (11). In the latter, the absence of similar capabilities seems to have allowed slight changes to occur; their anecdotic significance could depend on a particularly

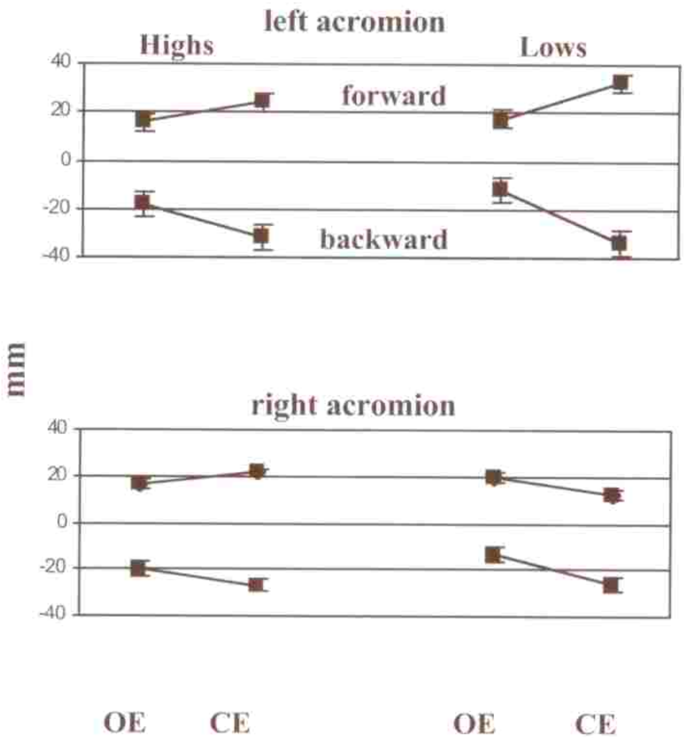

Fig. 3. - *Acromions earlier maximum displacements.*

Forward (positive values) and backward (negative values) sway (M ± SE, mm) of Highs and Lows during the latest 10 sec of the open eyes (OE) and the earliest 10 sec of the closed eyes (CE) condition are shown. A greater backward displacement of the left acromion suggests a left rotation of the body soon after the eyes closure in both groups.

effective compensatory reaction elicited by the perception of an impaired control, which could be more disturbing for Lows. These observations are in line with the postural responses observed in anxious (5, 9, 68, 69) and falling-fearing subjects (1) and with the vestibular ipersensitivity of subjects with a loss of other sensory inputs (2, 3, 38, 42, 45, 46, 48).

In conclusion, the control of upright stance seems to be more effective in Highs and the hypothesis of a hypnotizability-related internal space reference system, in line with the subjects' psychological characteristics, is supported. The cognitive origin of the differences observed between Highs and Lows are underlined by the postural adjustments time-course, which shows mainly late postural differences. As for the structures likely responsible, possible interactions between the *locus coeruleus*, which is largely involved in both arousal (8, 51) and postural mechanisms (49), and the frontal attentional system (26, 50,71), whose activity is considered at the basis of hypnotic phenomenology, could be hypothesised.

SUMMARY

Subjects highly (Highs) and low susceptible to hypnosis (Lows) show different imagery and attentional capabilities and also peculiar somatomotor, vegetative and electroencephalographic differences in basal and task conditions. Since attention is one of the main component of hypnotic susceptibility and also a relevant factor for postural control, the aim of the experiment was to study actual differences between Highs and Lows at the eyes closure during upright stance. Visual and motor imagery as well as attentional/disattentional capabilities were evaluated through psychological tests. Posture was monitored though Elite systems during upright stance with open and closed eyes. At the eyes closure, Highs and Lows exhibited a different body sway modulation. Possible different compensation mechanisms are suggested for the two groups and interactions between attentional/arousal systems responsible of hypnotic phenomenology and postural control are underlined.

Acknowledgments. - Research supported by a grant "Grandi Attrezzature" of Siena University and by a contribution of Azienda Sanitaria Locale (ASL 7), Siena. We are particularly grateful to BTS Bioingegneria - Tecnologia e Sistemi for updating data collection programs.

REFERENCES

1. ADKIN, A.L., FRANK, J.S., CARPENTER, M.G. AND PEYSAR, G.W. Fear of falling modifies anticipatory postural control. *Exp. Brain Res.*, **143:** 160-170, 2002.
2. ANDERSSON, G., HAGMAN, J., TALIANZADEH, R., SVEDBERG, A. AND LARSEN, H.C. Effect of cognitive load on postural control. *Brain Res. Bull.*, **58:** 135-139, 2002.
3. ANDERSSON, G., HAGMAN, J., TALIANZADEH, R., SVEDBERG, A. AND LARSEN, H.C. Dual-task study of cognitive and postural interference in patients with vestibular disorders. *Otol. & Neurol.*, **24:** 289-293, 2003.
4. ASCHAN, G., FINER, B.L. AND HAGBARTH, K.E. The influence of hypnotic suggestion on vestibular nystagmus. *Acta Otolaryng.*, **55:** 97-110, 1962.
5. BALABAN, C.D. AND THAYE, J. Neurological basis for balance-anxiety links. *J. Anxiety Disord.*, **15:** 53-79, 2001.
6. BALASUBRAMANIAM, R. AND D WING, A.M. The dynamics of standing balance. *Trends Cogn. Sci.*, **6:** 531-536, 2002.
7. BENHAIEM, J.M., ATTAL, N., CHAUVIN, M., BRASSEUR, L. AND BOUHASSIRA, D. Local and remote effects of hypnotic suggestions of analgesia. *Pain*, **89:** 167-173, 2001.
8. BERRIDGE, C.W. AND WATERHOUSE, B.D. The locus coeuruleus-noradrenergic system: modulation of behavioral state and state-dependent cognitive processes. *Brain Res. Rev.*, **42:** 33-84, 2003
9. BOLMONT, B., GANGLOFF, P., VOURIOT, A. AND PERRIN, P.P. Mood states and anxiety influence abilities to maintain balance control in healthy human subjects. *Neurosci. Lett.*, **329:** 96-100, 2002.
10. BROWN, L.A., SLEIK, R.J. AND WINDER, T.R. Attentional demands for static postural control after stroke. *Arch. Phys. Med. Rehabil.*, **83:** 1732-1735, 2002.
11. BRYANT, R.A. AND MALLARD, D. Seeing is believing: the reality of hypnotic hallucinations. *Conscious Cogn.*, **12:** 219-230, 2003.
12. BUSSE, K., SANTARCANGELO, E.L. AND CARLI, G. Suscettibilità ipnotica ed eccitabilità del midollo spinale. *Abstr. 3° Congr. Soc. Ital. Psicofisiol.*, **7:** 1993.
13. CARLI, G. AND SANTARCANGELO, E.L. Supraspinal control of flexor motoneurones excitability during relaxation as a function of hypnotizability and hypnosis. *Abstr. 9° Congr. Eur. Soc. Hypn.*, **31:** 2002.

14. CARPENTER, M.G., FRANCK, J.S., SILCHER, C.P. AND PEYSAR, G.W. The influence of postural threat on the control of upright stance. Exp. Brain Res., **138:** 210-218, 2001.
15. CRAWFORD, H.J. Brain dynamics and hypnosis: attentional and disattentional processes. *Int. J. Clin. Exp. Hypn.*, **42:** 204-32, 1994.
16. CRAWFORD, H.J. CLARKE, H.J. AND KITTNER-TRIOLO, M. Self-generated happy and sad emotions in low and highly hypnotizable persons during wake and hypnosis: laterality and regional EEG activity differences. *Int. J. Psychophysiol.*, **24:** 239-266,1996.
17. CRAWFORD, H. J., KNEBEL, T., KAPLAN, L., VENDEMIA, J.M., XIE, M., JAMISON, S. AND PRIBRAM, K.H. Hypnotic analgesia: 1.Somatosensory event-related potential changes to noxious stimuli and 2. transfer learning to reduce chronic low back pain. *Int. J. Clin. Hypn.*, **46:** 92-132, 1998.
18. DANZIGER, N., FOURNIER, E., BOUHASSIRA, D., MICHAUD, D., DE BROUCKER, T., SANTARCANGELO, E., CARLI, G., CHERTOCK, L. AND WILLER, J.C. Different strategies of modulation can be operative during hypnotic analgesia: a neurophysiological study. *Pain*, **75:** 85-92, 1998.
19. DE PASCALIS, V. Somatosensory event-related potential and autonomic activity to varying pain reduction cognitive strategies in hypnosis. *Clin. Neurophysiol.*, **112:** 1475-1485, 2001.
20. DE PASCALIS, V., RAY, W.J., TRANQUILLO, I. AND D'AMICO, D. EEG activity and heart rate during recall of emotional events in hypnosis: relationships with hypnotizability and suggestibility. *Int. J. Psychophysiol.*, **29:** 255-275, 1998.
21. FARTHING, G.W., VENTURINO, M., BROWN, S.W. AND LAZAR, J.D. Internal and external distraction in the control of cold-pressor pain as a function of hypnotisability. *Int.J. Clin. Exp. Hypn.*, **46:** 433-446, 1997.
22. FAYMONVILLE, M.E., LAUREYS, S., DEGUELDRE, C., DEL FIORE, G., LUXEN, A., FRANCK, G., LAMY, M. AND MAQUET, P. Neural mechanisms of antinociceptive effects of hypnosis. *Anesthesiology*, **92:** 1257-1267, 2000.
23. FINER, B. AND GRAF, K. Mechanisms of circulatory changes accompanying hypnotic imagination of hyperalgesia and hypoalgesia in causalgic limbs. *Z. Gesamte Exp. Med.*, **148:** 1-21, 1968.
24. FRIEDERICH, M., TRIPPE, R.H, OZCAN, M., WEISS, T., HECHT, H. AND MILTNER, W.H. Laser-evoked potentials to noxious stimulation during hypnotic analgesia and distraction of attention suggest different brain mechanisms of pain control. *Psychophysiol.*, **38:** 768-776, 2001.
25. FUSTER, J.M. *The prefrontal cortex: Anatomy, physiology and neuropsychology of the frontal lobe*. 3rd ed. Lippicott-Raven, Philadelphia, 1997.
26. GRUZELIER, J. A working model of the neurophysiology of hypnosis: a review of evidence. *Contemporary Hypnosis*, **5:** 3-21, 1998.
27. HARRIS, R.M., PORGES, S.W., CARPENTER, M.C. AND VINCENZ, L.M. Hypnotic susceptibility, mood state and cardiovascular reactivity. *Am. J. Clin. Hypn.*, **36:** 15-25, 1993.
28. HOFBAUER, R.K., RAINVILLE, P., DUNCAN, G.H. AND BUSHNELL, M.C. (2000) Cortical representation of the sensory dimension of pain. *J. Neurophysiol.*, **86:** 402-411, 2001.
29. HORAK, F.B. AND HLAVACKA, F. Somatosensory loss increases vestibulospinal sensitivity. *J. Neurophysiol.*, **86:** 575-585, 2001.
30. JAMBRIK, Z., SEBASTIANI, L., PICANO, E., GHELARDUCCI, B. AND SANTARCANGELO, E.L. Hypnotic modulation of flow-mediated endothelial response to mental stress. *Int. J. Psychophysiol.*, in press, 2004.
31. ISABLEAU, B., OHLMANN, T., CREMIEUX, J. AND AMBLARD, B. Selection of spatial frame of reference and postural control variability. *Exp. Brain Res.*, **114:** 584-589, 1997.
32. KIERNAN, B.D., DANE, J.R., PHILLIPS, L.H. AND PRICE, D.D. Hypnotic analgesia reduces

R-III nociceptive reflex: further evidence concerning the multifactorial nature of hypnotic analgesia. *Pain*, **63:** 391-392, 1995.

33. KNIGHT, R.T., STAUNES, R., SWICK, D. AND CHAO, L.L. Prefrontal cortex regulates inhibition and excitation in distributed neural networks. *Acta Psychol.*, **101:** 156-178, 1999.
34. KUMAR, V.K., PEKALA, R.J. AND CUMMINGS, J. Trait factors, state effects, and hypnotizability. *Int. J. Clin. Exp. Hypn.*, **44:** 232-249, 1996.
35. LAJOIE, Y., TEASDALE, H., BARD, C. AND FLEURY, M. Attentional demands for static and dynamic equilibrium. *Exp. Brain Res.*, **97:** 139-144, 1993.
36. LYONS, L.C. AND CRAWFORD, H.J. Sustained attentional and disattentional abilities and arousability: factor analysis and relationships to hypnotic susceptibility. *Person. Individ. Diff.*, **23:** 1071-1084, 1997.
37. MARKS, D.F. Visual Imagery differences in the recall of pictures. *Br. J. Psychol.*, **64:** 17-24, 1973.
38. MAURER, C., MERGNER, T., BOLHA, B. AND HLAVACKA, F. Human balance control during cutaneous stimulation of the plantar soles. *Neurosci. Lett.*, **302:** 45-48, 2001.
39. MAYLOR, E.A., ALLISON, S. AND WING, A.M. Effects of spatial and nonspatial cognitive activity on postural stability. *Br. J. Psychol.*, **92:** 319-338, 2001.
40. MCNEVIN, N.H. AND WULF, G. Attentional focus on supra-postural tasks affects postural control. *Hum. Mov. Sci.*, **21:** 187-202, 2002.
41. MERGNER, T. The Matryoshka Dolls principle in human dynamic behavior in space: a theory of linked references for multisensory perception and control of action. *Current Psychology of Cognition*, **21:** 129-212, 2002.
42. MERGNER, T., MAURER, C. AND PETERKA, R.J. A multisensory posture control model of human upright stance. *Prog. Brain Res.*, **142:** 189-201, 2003.
43. NORDBY, H., HUGDAHL, K., JASIUKAITIS, P. AND SPIEGEL, D. Effects of hypnotizability on performance of a Stroop task and event-related potentials. *Percept. Mot. Skills*, **88:** 819-830, 1999.
44. NORRIE, R.G., BRIAN, E.M., RICHARD-STAINES, W. AND MCILROY, W.E. The time course of attention shifts following perturbation of upright stance. *Exp. Brain Res.*, **146:** 315-321, 2002.
45. OIE, K.S., KIEMEL, T. AND JEKA, J.J. Human multisensory fusion of vision and touch: detecting non-linearity with small changes in the sensory environment. *Neurosci. Lett.*, **315:** 113-116, 2001.
46. OIE, K.S., KIEMEL, T. AND JEKA, J.J. Multisensory fusion: simultaneous re-weighting of vision and touch for the control of human posture. *Cogn. Brain Res.*, **14:** 164-176, 2002.
47. OZEKI, T., TAKAHASHI, K. AND TSUJI, K. Autokinetic illusion as affected by suggestions of experimenter and observer. *Percept. Mot. Skills*, **72:** 515-526, 1991.
48. PETERKA, R.J. Sensorimotor integration in human postural control. *J. Neurophysiol.*, **88:** 1097-1118, 2002.
49. POMPEIANO, O. Role of the locus coeruleus in the static and dynamic control of posture. *Arch. Ital. Biol.*, **139:** 109-24, 2001.
50. RAINVILLE, P., HOFBAUER, R.K., BUSHNELL, M.C., DUNCAN, G.H. AND PRICE, D.D. Hypnosis modulates activity in brain structures involved in the regulation of consciousness. *J. Cogn. Neurosci.*, **14:** 887-901, 2002.
51. RAINVILLE, P. AND PRICE D.D. Hypnosis phenomenology and the neurobiology of consciousness. *Int. J. Clin. Exp. Hypn.*, **51:** 105-129, 2003
52. REDFERN, M.S., JENNINGS, J.R., MARTIN, C. AND FURMAN, J.M. Attention influences sensory integration for postural control in older adults. *Gait & Posture*, **14:** 211-216, 2001.
53. SABOURIN, M. E., CUTCOMB, S. D., CRAWFORD, H.J. AND PRIBRAM, K. EEG correlates of

hypnotic susceptibility AND hypnotic trance: spectral analysis and coherence. *Int. J. Psychophysiol.*, **10:** 125-142, 1990.

54. SANDRINI, G., MILANOV, I., MALAGUTI, S., NIGRELLI, M.P., MOGLIA, A. AND NAPPI, G. Effects of hypnosis on diffuse inhibitory controls. *Physiol. Behav.*, **69:** 295-300, 2000.
55. SANTARCANGELO, E.L., BUSSE, K. AND CARLI, G. Changes in electromyographically recorded human monosynaptic reflex in relation to hypnotic susceptibility and hypnosis. *Neurosci. Lett.*, **104:** 157-160, 1989.
56. SANTARCANGELO, E.L., JAMBRIK, Z., SEBASTIANI, L., GHELARDUCCI, B. AND PICANO, E. Hypnotic susceptibility and hypnosis modulate the endothelial response to acute stress, *J. Biol. Res.*, in press, 2004.
57. SANTARCANGELO, E.L., BUSSE, K. AND CARLI, G. Frequency of occurrence of the F wave in distal flexor muscles as a function of hypnotic susceptibility and hypnosis. *Cogn. Brain Res.*, **16:** 99-103, 2003.
58. SANTARCANGELO, E.L., MARANO, E., GHELARDUCCI, B., SEBASTIANI, L., CAVALLARO, E., MAZZOLENI, S., DARIO, P. AND MICERA, S. Hypnotic movement involuntariness during arm heaviness suggestions: a real-simulator design. *Abstr. Congr. Soc. Ital. Neurosci.*, **12:** 2003.
59. SANTARCANGELO E.L. AND SEBASTIANI L. Hypnotizability as an adaptive trait. *Contemporary Hypnosis*, **21:** 3-13, 2004.
60. SEBASTIANI, L., SIMONI, A., GEMIGNANI, A., GHELARDUCCI, B. AND SANTARCANGELO, E.L. Autonomic and EEG correlates of emotional imagery in subjects with different hypnotic susceptibility. *Brain Res. Bull.*, **60:** 151-160, 2003.
61. SHALLICE, T. AND BURGESS, P.W. Deficits in strategy application following frontal lobe damage in man. *Brain*, **114:** 727-741, 1991.
62. SHUMWAY-COOK, A. AND WOOLLACOTT, M. Attentional demands and postural control: the effect of sensory context. *J. Gerontol. A. Biol. Sci. Med. Sci.*, **55:** 10-16, 2000.
63. SINGH, K.K. AND GUDJONSSON, G.H. Interrogative suggestibility among adolescent boys and its relationship with intelligence, memory and cognitive set. *J. Adolesc.*, **15:** 155-161, 1992.
64. TEASDALE, N. AND SIMONEAU, M. Attentional demands for postural control: the effects of aging and sensory reintegration. *Gait & Posture*, **14:** 203-210, 2001.
65. TELLEGEN, A. AND ATKINSON, G. Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *J. Abnorm. Psychol.*, **83:** 268-277, 1974.
66. VAN HOOK, C.W. AND STEELE, C. Individual personality characteristics related to suggestibility. *Psychol. Rep.*, **91:** 1007-1010, 2002.
67. VARGA, K., JOZSA, E., BANYAI, E.I., GOSI-GREGUSS, A.C. AND KUMAR, V.K. Phenomenological experiences associated with hypnotic susceptibility. *Int. J. Clin. Exp. Hypn.*, **49:** 19-29, 2001.
68. VIAUD-DELMON, I., IVANENKO, J.P., BERTHOZ, A. AND JOUVENT, R. Adaptation as a sensorial profile in trait anxiety: a study with virtual reality. *J. Anxiety Disord.*, **14:** 583-601, 2000.
69. WADA, M., SUNAGA, N. AND NAGAI, M. Anxiety affects the postural sway of the antero-posterior axis in college students. *Neurosci. Lett.*, **302:** 157-159, 2001.
70. WEITZENHOFFER, M. AND HILGARD, E.R. *Stanford Hypnotic Susceptibility Scale, Form C.* Consulting Psychologists Press, Palo Alto, 1962.
71. WOODY, E. AND FARVOLDEN, P. Dissociation in hypnosis and frontal executive function. *Am. J. Clin. Hypn.*, **40:** 206-216, 1998.
72. YAPKO, M. Hypnotic intervention for ambiguity as a depressive risk factor. *Am. J. Clin. Hypn.*, **44:** 109-117, 2001.