

HYPNOTIZABILITY AND TEMPORAL DYNAMICS OF ATTENTION: A STUDY ON THE ATTENTIONAL BLINK EFFECT

Eleonora Castellani,¹ Luigi D'Alessandro and Laura Sebastiani²

¹*Department of Physiology, University of Siena, Italy;* ²*Department of Human Physiology, University of Pisa, Italy*

Abstract

This study was designed to seek hypnotizability-related differences in attention temporal dynamics. For this purpose, an iconic version of the Attentional Blink Task (AB) was performed on 18 highly (Highs, score 9–12, SHSS form C) and 18 low susceptible individuals (Lows, score 0–3). The procedure consisted of two tasks in which two animal shapes (a coloured animal, Target, and a black butterfly, Probe) appeared in close temporal proximity within a rapid stream of distractors (black animals). In the Single task only Probe detection was required; in the Conditional task, Target identification was also requested. In this case, competition between Target and Probe for limited attentional resources decreases Probe visibility as a function of the time lag from Target (AB effect). A similar AB effect occurred in the two groups; nonetheless, Probe detection scores at the shorter lags were frequently higher in Highs than in Lows. This suggests that time constraints could affect the performance of Highs less than Lows, but also that the two groups could differ in attention capturing mechanisms, i.e. automatic capture by colour at the shorter lag. Moreover, Highs scores on Target identification were lower than Lows' ones indicating an impairment of Highs when engaged in dual tasks.

Key words: attention, Attentional Blink Task (AB), hypnotizability, iconic paradigm

Introduction

Many theories of hypnotic responding have proposed that differences in hypnotic trait/suggestibility correlate with differences in attention functions sustained by frontal cerebral cortex networks (Barber, 1960; Tellegen and Atkinson, 1974; Crawford and Gruzelier, 1992; Woody and Bowers, 1994; Kallio, Revonsuo, Hamalainen, Markela and Gruzelier, 2001; Gruzelier, Gray and Horn, 2002; Jamieson and Sheehan, 2002; Rainville, Hofbauer, Bushnell, Duncan and Price, 2002; Egner, Jamieson and Gruzelier, 2005; Raz, 2005).

The concept of attention is one of the key topics in psychological science (for a review see Posner and Petersen, 1990). The term attention is often employed in the restricted sense of the selective process of concentrating on one thing while ignoring other things. However, attention may also refer to the process of voluntarily allocating resources to a particular task at the expense of other activities, or to the alerting and sustaining process whereby a high receptivity to incoming information is achieved and maintained by regulating vigilance level.

Even in the restricted sense of a focusing process, attention refers to different phenomena such as selectively attending to information presented in a particular modality

(Posner, Nissen and Klein, 1976; Broadbent, 1982; Shapiro, Egerman and Klein, 1984) or position in space (Moray, 1975; Posner, 1980; Shapiro and Johnson, 1987); to stimuli with a particular colour or shape (Francolini and Egeth, 1980; Lambert and Hockey, 1986); or to items belonging to a particular class or category (Posner and Snyder, 1975; Neely, 1977). In spite of these differences, attended information is generally processed more efficiently than unattended ones, with better performances at faster rates. The improvement of performance on increased investment of attention is supported by experimental evidence (for a review see Raz, 2004).

In spite of the great number of experimental paradigms employed with the aim of capturing the range of phenomena encompassed by attention, there is no agreement on whether attention involves separate mechanisms from those used to process data.

So far, several experimental studies, corroborated by recent neuroimaging data (Fan, Flombaum, McCandliss, Thomas and Posner, 2003; Pessoa, Kastner and Ungerleider, 2003) have suggested that attention does not imply a singular mechanism, but rather, it is a complex system made of distinct brain areas, which control a number of separate neuronal circuits each involved in different attention processes. Thus, it is now possible to examine attention as an 'organ system' with its own functional anatomy, circuitry and cellular structure (Posner and Peterson, 1990; Posner and Fan, 2004). According to the trinity model proposed by Posner (Posner and Peterson, 1990; Fan, McCandliss, Sommer, Raz and Posner, 2002; Posner and Fan, 2004), attention networks consisted of: a) the alerting system involved in obtaining and maintaining a state of high sensitivity to incoming stimuli, which greatly relies on thalamic areas, locus coeruleus, and cortical areas; b) the orienting system concerning the selection of information from sensory input, which depends heavily on the activity of the superior parietal lobe and the temporal parietal junction; and c) the executive attention network involved in monitoring and resolving conflict between competing areas of the brain that might be simultaneously active, which relies on anterior cingulate and lateral areas of the prefrontal cortex (for a review see Raz, 2004).

Concerning the involvement of attention in hypnotic phenomena, one of the models mostly supported by experimental evidence is the neuropsychological model of hypnosis introduced by Gruzelier (1988) and Crawford and Gruzelier (1992). The authors argue that highly hypnotizable individuals (Highs) would be engaged in the first stage of hypnotic induction by easily concentrating their attention on the hypnotist's voice/instruction and disregarding distracting stimuli, due to their skillfulness in focusing attention. A general decrease of frontal functioning associated with the suspension of critical evaluation and reality testing would follow, marking the transition into the hypnotic state. The alteration of attentional control characterizing the hypnotic state has been recently attributed to a decoupling between conflict monitoring and cognitive control processes of the frontal lobe (Gruzelier, 1998; Jamieson and Sheehan, 2004; Egner et al., 2005).

While there is large neurophysiological, neuroimaging and behavioural evidence that supports the alteration of attention functioning in hypnotized Highs (Blum and Graef, 1971; Sheenan, Donovan and MacLeod, 1988; Gruzelier and Warren, 1993; Kaiser, Barker, Haenschel, Baldeweg and Gruzelier, 1997; Nordby, Hugdahl, Jasiukaitis and Spiegel, 1999; Rainville, Hofbauer, Paus, Duncan, Bushnell and Price, 1999; Halligan, Athwal, Oakley and Frackowiak, 2000; Kallio et al., 2001; Kallio and Revonsuo, 2003; Gruzelier et al., 2002; Rainville et al., 2002; Farvolden and Woody, 2004; Jamieson and Sheehan, 2004; Egner et al., 2005), it is still controversial whether, out of hypnosis, executive functions of Highs are different from those of low hypnotizable individuals

(Lows). In fact, even though many experiments have attempted to clarify which attentional functions are associated with hypnotic susceptibility (i.e. concentrating skills) and which frontal areas are involved, so far evidence of hypnotizability-related attentional abilities has not been conclusive (Dixon, Brunet and Laurence, 1990; Dixon and Laurence, 1992; Crawford, Brown and Moon, 1993; Aikins and Ray, 2001; Kallio et al., 2001; Farvolden and Woody, 2004; Rubichi, Ricci, Padovani and Scaglietti, 2005). Recently, it has been reported that in not hypnotized Highs, suggestion to interpret Stroop words as meaningless symbol reduces both Stroop conflict and neuroimaging signals in specific brain areas involved in attentional control, such as the anterior cingulate cortex (Raz, Shapiro, Fan and Posner, 2002; Raz, Landzberg, Schweizer, Zephrani, Shapiro, Fan and Posner, 2003; Raz, 2004, 2005, 2006). Since the Stroop paradigm is considered as an effective test of frontal attentional functions, these findings are suggestive of peculiar frontal executive abilities attributable to the hypnotic trait.

In a series of Reaction Time (RT) experiments Castellani and colleagues (Castellani, D'Alessandro, Santarcangelo and Sebastiani, 2006; Castellani, D'Alessandro and Sebastiani, 2007; Castellani and Sebastiani, 2008) aimed to seek out possible hypnotizability-related attentional differences by studying the effects of the manipulation of attention. We found that Highs executed good performances with lower costs in response time than Lows. In particular, in one of these studies in which we evaluated the automatic (alerting and orienting) and intentional (executive control) components of spatial attention of Highs and Lows by using a shortened version of the Attention Network Test (ANT; Fan et al., 2002), results yielded that Highs were generally faster than Lows. This tendency was particularly marked in the condition without any warning signal or spatial cue in which the basal level of subject's arousal is considered a relevant factor in conditioning the performance by modulating the speed of response selection (Fan et al., 2002). Noticeably, this capacity was more evident in the most complex condition with incongruent flankers. In this condition, in contrast to Lows whose RTs were getting shorter as cue signals became increasingly more alerting or informative on stimulus location, Highs' RTs were scarcely modulated by the different cues. In accordance with these findings, the specific evaluation of alerting, orienting and executive functions yielded somewhat smaller orienting and significantly lower alerting in Highs than in Lows.

In another experiment designed to study the effects of manipulations of attention on perceptual implicit memory (Word stem completion task) of Highs and Lows (Castellani and Sebastiani, 2008), we found that in spite of similar implicit memory scores, Highs were faster than Lows during the study phase in which word encoding occurs.

In line with our findings, shorter RTs in Highs than in Lows are the frequent finding of other studies concerning simple and choice reaction times (Crawford, Harrison and Kapelis, 1995; Braffman and Kirsch, 2001). Thus, this ability seems to represent a generalized skill of Highs that could be attributed to a particularly high efficiency of the Locus coeruleus-mediated arousal component of attention (Castellani et al., 2007). Indeed, evidence from animal neurophysiological studies indicates the synchronized activation mode of the Locus coeruleus-noradrenergic system as a key factor in promoting rapid neural responses in the cortical projection areas during tasks requiring focused attention (Aston-Jones, Rajkowski and Cohen, 1999; Berridge and Waterhouse, 2003; Bouret and Sara, 2005). This activation mode is likely to be driven by conscious monitoring activity in the anterior cingulate (ACC) and orbito-frontal cortices. Indeed, a negative correlation between ACC activity and RTs is the common finding in simple and choice RTs tasks as assessed by PET, fMRI or event-related potentials studies (Mulert, Gallinat, Pascual-Marqui, Dorn, Frick, Schlattmann, Mientus, Herrmann and Winterer,

2001; Mulert, Gallinat, Dorn, Herrmann and Winterer, 2003; Naito, Kinomura, Geyer, Kawashima, Roland and Zilles, 2000; Winterer, Adams, Jones and Knutson, 2002), and this suggests that Highs' faster RTs could be the outcome of a higher ACC monitoring activity in Highs than in Lows.

On the other hand, we cannot exclude that the shorter reaction times exhibited by Highs with respect to Lows could be related to particularly efficient or more automatic visual perceptual capabilities.

Whatever the reason, one could expect that Highs' performances on attention visual tasks were less affected by time constraints than Lows.

Resting on this last hypothesis, the present study was aimed to verify possible hypnotizability-related differences in the temporal dynamics of visual attention and perception by using the Attentional Blink task, an experimental paradigm in which the perceptual awareness of stimuli was reduced by increasing the temporal attentional load.

Several experimental procedures have shown that highly supraliminal stimuli can be unconsciously perceived if the subject's attention is unavailable at that moment (Shapiro, Arnell and Raymond, 1997; Enns and Di Lollo, 2000; Kim and Blake, 2005) and the Attentional Blink effect (AB) represents one of the most robust phenomena of such 'attentional' blindness. Specifically, the AB refers to the transient reduction in the perceptual awareness of a second target (probe), occurring when subjects are required to select two targets in close succession from a stream of Rapid Serial Visual Presentations (RSVP; Raymond, Shapiro and Arnell, 1992; Chun and Potter 1995; Shapiro et al., 1997). In this dual target /conditional task, probe visibility depends mainly on the amount of attention available at that particular time lag from Target presentation. Typically, correct identification of the Target interferes with the perceptual awareness of a probe appearing between 100 and 500 ms after the Target. This deficit is called 'attentional' blink because no decrement is found when Target detection is not required (single task), suggesting an attentional, opposed to perceptual, basis for the effect (Raymond et al., 1992; Chun and Potter, 1995).

According to the neurocomputational theory of Nieuwenhuis and colleagues (2005), the Locus Coeruleus noradrenergic neuromodulatory system would play a key role in the AB effect. Thus, on the basis of the hypothesized differences in Locus Coeruleus activity between Highs and Lows, hypnotizability-related differences in the amplitude and/or time course of AB could be expected.

In this study we used a modified version of the AB task in which all the stimuli of the sequence were animal shapes. This paradigm had been previously used in our lab in a study on animal phobia, and the results yielded AB effects comparable to those found with verbal stimuli or familiar objects icons (D'Alessandro, Gemignani and Sebastiani, 2005).

Method

Subjects

Participants were 36 volunteers recruited from a pool of students at the University of Pisa, who decided to participate to the experiment to obtain an extra credit for a Physiology Lab (age 23.53 ± 1.99 ; mean $\pm$ SD). Subjects had earlier been individually screened for hypnotizability by a medical psychologist using the Italian version of the Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C; S Weitzenhoffer and Hilgard, 1962), that is one of the scales currently used to measure hypnotic susceptibility. Eighteen individuals scored in the higher range of the hypnotizability scale (Highs, range 9–12,

15 females) and eighteen scored in the lower range (Lows, score 0–3, 15 females). All subjects reported normal or corrected-to-normal vision.

Written informed consent approved by the local Ethical Committee was obtained from all participants.

Stimuli and procedure

Stimuli and the experiment flow chart are shown in Figures 1 and 2. The experiment was run on a FreeBSD PC system (Imago program, feanor.sssup.it/~pv/). Stimuli were projected for 70 ms in the centre of a screen placed at 57 cm from the eyes of the subject so that each image covered an area of $4^{\circ} \times 4^{\circ}$. The inter-stimulus interval (ISI) was set at 30 ms to obtain a frequency of images presentation of 10 Hz. The simultaneous presentation of an acoustic warning cue and the fixation point in the centre of the screen signalled the beginning of the sequence presentation. Each sequence consisted of three types of stimuli: Distractors, Target and Probe.

Distractors consisted of 24 shapes/outlines of different animals, uniformly coloured in black; the Target was an animal shape coloured in blue, randomly chosen from the 24 distractors; the Probe was a black shape of a butterfly and did not belong to the group of distractors.

In the sequence the Target was presented at a distance of 9–13 distractors from the beginning. The Probe was presented 10 times in each of 4 different positions of the

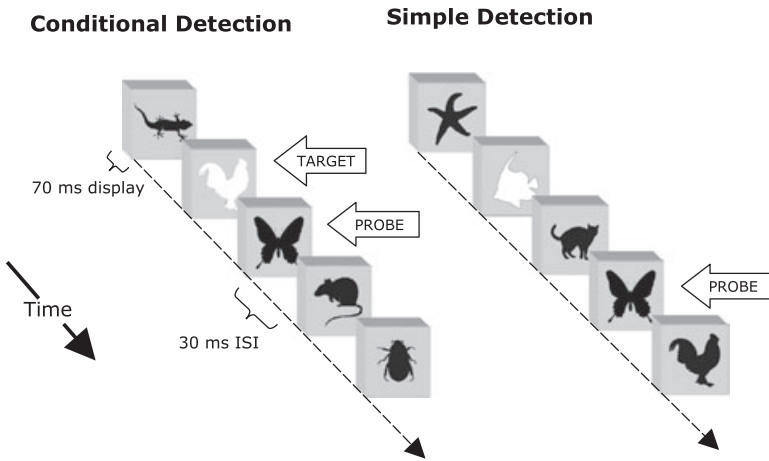


Figure 1. Schematic representation of Stimuli and Temporal Parameters

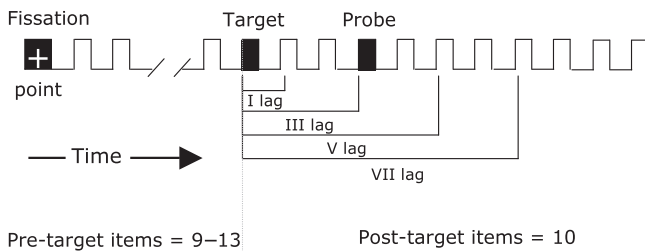


Figure 2. Flow chart of the Attentional Blink paradigm

sequence, namely lag I, lag III, lag V, and lag VII, corresponding, respectively, to latencies of 100, 300, 500 and 700 ms from Target presentation. Twenty catch trials in which the Probe was lacking were also included so that a total of 60 sequences, produced in a randomized order, were presented to each participant.

During the experimental session participants were sitting in front of the monitor in a darkened and sound attenuated room and instructed on the experimental procedure. They were also asked to focus on the fixation point throughout the task, avoiding eye movements. In order to reduce head movements and to maintain the distance from the screen, subjects positioned their head on a suitable support.

The session included 10 training trials followed by two blocks of 60 experimental trials. In the first block the participants' task was to detect the Probe while ignoring all the other stimuli, including the coloured Target (Simple Detection Task); in the second block the participants were asked to identify the coloured Target and detect the Probe (Conditional Detection Task). In both conditions subjects were instructed to respond verbally at the end of each sequence trying to report their visual experience as accurately as possible, avoiding any guess on the presence of the Probe and/or the identity of the Target.

The Attentional Blink task was carried out by one of the authors (EC) in a neurophysiology laboratory at least one month after hypnotizability assessment. Volunteers were not informed that there were any relationships between the task and hypnotizability.

Data analysis

In the Simple Detection task the percentage of correct detections of each Probe in each of the 4 lag/positions (100, 300, 500 and 700 ms) was calculated for each participant. In the Conditional Detection task, for each subject and position, the percentage of correct detection of each Probe was calculated with respect to the number of trials in which the Target was correctly identified. All the trials in which the identification of the Target was incorrect were excluded from the analysis. For analysis percentage data were arcsine transformed according to the Anscombe formula (Anscombe, 1948). Data were analysed by means of Repeated Measures ANOVA with Lag (I, III, V, VII) and Task (Simple Detection, Conditional Detection) as Within Subjects factors and Group (Highs, Lows) as a Between Subjects factor.

During the Conditional Detection task, for each subject, the number of false positive detections on catch trials were computed and analyzed by univariate ANOVA, with Group (Highs, Lows) as a Between Subjects factor. For each subject and for each lag, the number of correct Target identifications were also calculated and analyzed by means of Repeated Measures ANOVA, with Lag (I, III, V, VII) as Within Subjects factors, and Group (Highs, Lows) as a Between Subjects factor.

In order to reveal different patterns of changes between Highs and Lows across the four different lags, planned pair-wise linear comparisons and polynomial contrasts were carried out. Significance was set at $p < 0.05$.

Results

Probe Detection

Figure 3 shows the mean percentage of simple and conditional detections of the Probe scored by the two groups.

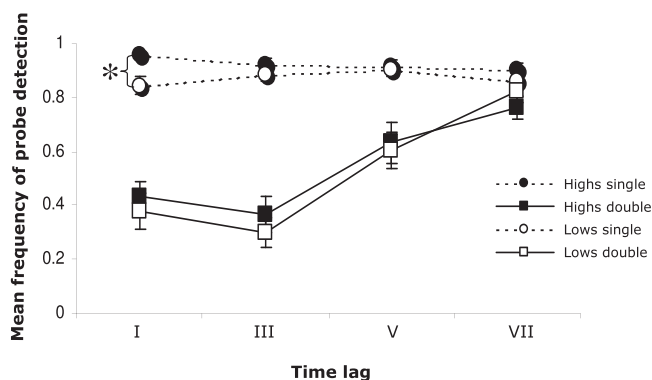


Figure 3. Mean percentage of Probe detections scored by Highs and Lows during Simple and Conditional Tasks. Significant differences are shown (*, $p < 0.05$)

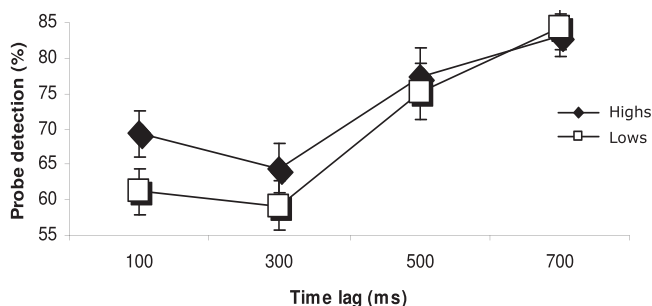


Figure 4. Mean percentage of Probe detections scored by Highs and Lows across the two task conditions

As can be observed, accuracy on simple detection is very high (>80%) for both groups, independently of the Probe lag. On the contrary, the conditional detection of the butterfly is strongly affected by the Probe lag in both groups. When the butterfly is presented within an interval of 500 ms after the Target, its detection falls below 65%, with the lowest score (<40%) at 300 ms, thus suggesting that a similar Attentional Blink (AB) effect occurred in both Highs and Lows.

Statistical analyses are in line with these observations revealing significant Task ($F(1,34) = 208.44$, $p < 0.001$), Lag ($F(3,102) = 28.62$, $p < 0.001$) effects as well as a significant Lag X Task interaction ($F(3,102) = 29.52$, $p < 0.001$). Pair-wise comparisons between simple and conditional detection scores showed significant differences ($p < 0.01$) at all lags. No difference between Groups or Group X Task/Lag interactions was found, thus confirming a similar AB effect in Highs and Lows. In spite of this, polynomial contrasts analysis (useful to predict patterns of change across an ordered sequence of testing conditions) yielded a significant linear trend for the interaction between Lag and Group ($F(1,34) = 4.71$, $p = 0.038$); that is, the difference between Highs and Lows changed linearly across the successive lags. In fact, as shown in Figure 4, the percentage of Probe detection is greater in Highs than in Lows at Lag I; this difference gradually reduces across lag III and V and reverses at lag VII.

Analysis carried out on the two tasks separately reveals the same general trend. In fact, Probe detection scores of Highs were generally higher than those of Lows during both tasks; this difference tended to be greater at lags I and III even though it was significant only during the single detection task at lag I ($F(1,34) = 8.803$, $p < 0.005$). In addition, during conditional detection the difference between Highs and Lows reverses at lag VII.

Concerning false positive detection during catch trials no significant effects were found.

Target identification

Figure 5 shows the mean percentage of Target identification scored by the two groups during conditional detection.

Analysis of variance yielded significant Lag ($F(3,102) = 16.57$, $p < 0.001$) and Group effects ($F(1,34) = 7.30$, $p = 0.011$), with Highs' identification scores generally lower than those of Lows. A significant quadratic trend for the interaction between Lag and Group ($F(1,34) = 5.41$, $p = 0.026$) was also found, indicating that in the two groups the pattern of changes across lags is quite different. In fact, as can be observed in Figure 5, the percentage of Target identification at lag I is similar in Highs and Lows (91% and 93%, respectively); however, in contrast to Lows whose scores remain high (range 88–99%) across lags, Highs' performance gradually declines, reaching its minimum at lag V (79%), to recover at lag VII (97%). This different pattern of changes is also confirmed by pair wise comparisons that showed significant differences between groups at lag III ($F(1,34) = 5.82$, $p = 0.021$) and V ($F(1,34) = 5.83$, $p = 0.021$).

Discussion

This study showed that the AB effect, namely, the transient impairment of attention that typically occurs when two targets to be detected (Target and Probe) are presented in close temporal proximity, is similar in Highs and Lows. This finding suggests *per se* that the attention capabilities of Highs and Lows are likely to share similar temporal dynamics. However, Probe detection scores, independently of the experimental session, tended to be generally higher in Highs than in Lows (see Fig. 4). This finding could be ascribed

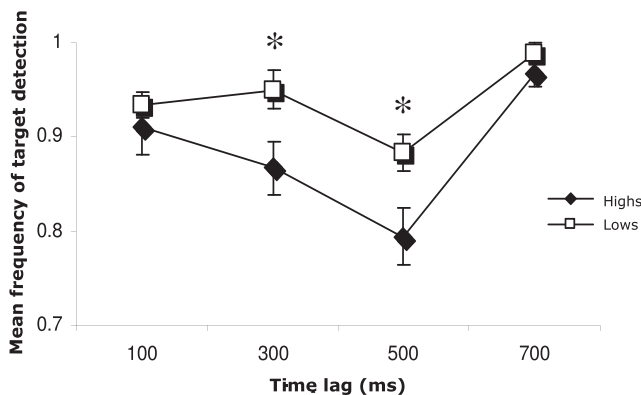


Figure 5. Mean percentage of Target identification scored by Highs and Lows during conditional detection. Significant differences are shown (*, $p < 0.05$)

to general better visual perceptual capabilities of Highs than Lows but could also be explained by hypothesizing that time constraints, which limit the access to attentional resources, affect Highs' visual detection to a lesser extent than Lows. Indeed, the higher efficiency of Locus Coeruleus-mediated arousal component of attention in Highs than in Lows that we have previously hypothesized, could produce an improvement of Highs' performance on Probe detection by increasing noradrenergic-dependent responsiveness of efferent neurons in cortical projections areas.

Interestingly, this difference was greater at lag I and lag III and reduced linearly across the successive intervals, suggesting that at short lags Highs' detection processes could benefit from a sort of facilitation. This was particularly marked in the single detection task where the difference between Highs and Lows reached significance at lag I from the Target. In effect, the coloured Target appeared in both the single and conditional task with the difference that, in the first case, the voluntary engagement of attention on Target was not required. The notion that coloured targets/distractors are able to automatically attract attention is widely acknowledged (Folk, Leber and Egeth, 2002; Maki, Bussard, Lopez and Digby, 2003; Maki and Mebane, 2006; Snowden, 2002). However, as suggested by Maki and Mebane (2006) by employing coloured distractors, attention drawn by colour is rapidly disengaged and is not sufficient *per se* to produce an AB effect that, indeed, occurs only to the extent that the distractor is task relevant. It is also known (Potter, Staub and O'Connor, 2002; Visser, Zuvic, Bischof and Di Lollo, 1999) that if two competitors are equally strong (i.e. two targets), their presentation in close temporal succession may lead to the joint integration of the two events into a single episodic trace so that they both get access to attention resources. This phenomenon that causes the partial sparing of performance on the Probe at the shorter lag, has been labelled *Lag 1 sparing*. This effect is consistent with the predictions of the Locus Coeruleus model of Nieuwenhuis, Gilzenrat, Holmes and Cohen (2005). Namely, when the Probe immediately follows the Target it may benefit from the noradrenaline release elicited by the LC phasic response to Target.

Thus, differences between Highs and Lows in the automatic capture of attention by colour, as well as in LC phasic activity, could explain the difference between Highs and Lows in Probe detection at lag I. More specifically, in Highs Probe detection could have gained prioritized access to attentional resources due to a stronger engagement of attention by the nearby (lag I) coloured shape than in Lows.

During the conditional task, another interesting finding concerns Target identification. While Lows' scores on Target identification were maintained at over 90%, with the exception of lag V (88%), in Highs they were generally worse than in Lows, especially at lags III and V where differences between Highs and Lows reached significance. This finding is in accord with previous findings that indicated strong conflict effects in Highs during tasks that require attending simultaneously to different characteristics of a target stimulus (Castellani et al., 2006; Castellani and Sebastiani, 2008). Thus, the poor performance of Highs when engaged in dual tasks suggests that they could be more exposed than Lows to interference effects during concurrent activities.

Conclusion

In conclusion, our study did not confirm our hypothesis of hypnotizability-related differences in the temporal dynamics of attention. However, the high scores of Highs on Probe detection at short lags seem to indicate differences in automatic capturing of attention as one of the possible mechanisms involved in perceptual awareness differences

between Highs and Lows. Moreover, the poor performance of Highs on Target identification suggests compromise when attention is engaged in concomitant activities.

Acknowledgements

This work was funded by the Italian Ministry of University, Scientific Research and Technology. We gratefully acknowledge Dr E.L. Santarcangelo for hypnotic assessment of volunteers and Dr A. Gemignani for his helpful comments.

References

- Aikins D, Ray WJ (2001) Frontal lobe contributions to hypnotic susceptibility: a neuropsychological screening of executive functioning. *International Journal of Clinical & Experimental Hypnosis* 49: 320–39.
- Anscombe FJ (1948) The transformation of Poisson, binomial, and negative-binomial data. *Biometrika* 35: 246–54.
- Aston-Jones G, Rajkowski J, Cohen J (1999) Role of Locus Coeruleus in attention and behavioral flexibility. *Biological Psychiatry* 46: 1309–20.
- Barber TX (1960) The necessary and sufficient conditions for hypnotic behavior. *International Journal of Clinical & Experimental Hypnosis* 3: 31–42.
- 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.
- Blum GS, Graef JR (1971) The detection over time of subjects simulating hypnosis. *International Journal of Clinical & Experimental Hypnosis* 19: 211–24.
- Bouret S, Sara SJ (2005) Network reset: a simplified overarching theory of locus coeruleus noradrenaline function. *Trends in Neuroscience* 28: 574–82.
- Braffman W, Kirsch I (2001) Reaction time as a predictor of imaginative suggestibility and hypnotizability. *Contemporary Hypnosis* 18: 107–19.
- Broadbent DE (1982) Task combination and selective intake of information. *Acta Psychologica* 50: 253–90.
- Castellani E, D'Alessandro L, Santarcangelo EL, Sebastiani L (2006) Hypnotizability-related attentional characteristics. *International Journal of Psychophysiology* 54:176.
- Castellani E, D'Alessandro L, Sebastiani L (2007) Hypnotizability and spatial attentional functions. *Archives Italiennes de Biologie* 145: 23–37.
- Castellani E, Sebastiani L (2008) Manipulation of attention in highly and low hypnotizable individuals: a study on verbal priming. *Archives Italiennes de Biologie* 146: 21–33.
- Chun MM, Potter MC (1995) A two-stage model for multiple target decision in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception & Performance* 21: 109–27.
- Crawford HJ, Gruzelier JH (1992) A midstream view of the neuropsychophysiology of hypnosis: recent research and future directions. In: E Fromm, MR Nash (eds) *Contemporary Hypnosis Research*. London: Guilford.
- Crawford HJ, Brown AM, Moon CE (1993) Sustained attentional and disattentional abilities: differences between low and highly hypnotizable persons. *Journal of Abnormal Psychology* 102: 534–43.
- Crawford HJ, Harrison DW, Kapelis L (1995) Visual field asymmetry in facial affect perception: moderating effects of hypnosis, hypnotic susceptibility level, absorption, and sustained attentional abilities. *International Journal of Neuroscience* 82: 11–23.
- Dixon M, Brunet A, Laurence JR (1990) Hypnotizability and automaticity: toward a parallel distributed processing model of hypnotic responding. *Journal of Abnormal Psychology* 99: 336–43.

- D'Alessandro L, Gemignani A, Sebastiani L (2005) Visual awareness of feared object: temporal attentional dynamics and emotional arousing processes. Paper presented at the XIII Congresso della Società Italiana di Psicofisiologia, Carrara, Italy.
- Dixon M, Laurence JR (1992) Hypnotic susceptibility and verbal automaticity: automatic and strategic processing differences in the Stroop color-naming task. *Journal of Abnormal Psychology* 101: 344–47.
- Egner T, Jamieson G, Gruzelier JH (2005) Hypnosis decouples cognitive control from conflict monitoring processes of the frontal lobe. *NeuroImage* 27: 969–78.
- Enns JT, Di Lollo V (2000) What's new in visual masking? *Trends in Cognitive Sciences* 4(9): 345–52.
- Fan J, McCandliss BD, Sommer T, Raz A, Posner MI (2002) Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience* 14: 340–7.
- Fan J, Flombaum JI, McCandliss BD, Thomas KM, Posner MI (2003) Cognitive and brain consequences of conflict. *Neuroimage* 18: 42–57.
- Farvolden P, Woody EZ (2004) Hypnosis, memory, and frontal executive functioning. *International Journal of Clinical & Experimental Hypnosis* 52: 3–26.
- Folk CL, Leber AB, Egeth HE (2002) Made you blink! Contingent attentional capture produces a spatial blink. *Perception & Psychophysics* 64: 741–53.
- Francolini CM, Egeth HE (1980) On the nonautomaticity of 'automatic' activation: evidence of selective seeing. *Perceptual Psychophysiology* 27: 331–42.
- Gruzelier JH (1988) The neuropsychology of hypnosis. In: M Heap (eds) *Hypnosis: current clinical, experimental and forensic practices*. London: Croom Helm.
- Gruzelier JH, Warren K (1993) Neuropsychological evidence of reductions of left frontal tests with hypnosis. *Psychological Medicine* 23: 93–101.
- Gruzelier JH (1998) A working model of the neurophysiology of hypnosis: a review of evidence. *Contemporary Hypnosis* 15: 3–21.
- Gruzelier JH, Gray M, Horn P (2002) The involvement of frontally modulated attention in hypnosis and hypnotic susceptibility: cortical evoked potential evidence. *Contemporary Hypnosis* 19: 179–89.
- Halligan PW, Athwal BS, Oakley DA, Frackowiak RS (2000) Imaging hypnotic paralysis: implications for conversion hysteria. *Lancet* 355: 986–7.
- Jamieson GA, Sheehan PW (2002) A critical evaluation of the relationship between sustained attentional abilities and hypnotic susceptibility. *Contemporary Hypnosis* 19: 62–74.
- Jamieson GA, Sheehan PW (2004) An empirical test of Woody and Bowers' dissociated-control theory of hypnosis. *International Journal of Clinical & Experimental Hypnosis* 52: 232–49.
- Kaiser J, Barker R, Haenschel C, Baldeweg T, Gruzelier JH (1997) Hypnosis and event-related potential correlates of error processing in a Stroop-type paradigm: a test of the frontal hypothesis. *International Journal of Psychophysiology* 27: 215–22.
- Kallio S, Revonsuo A, Hamalainen H, Markela J, Gruzelier JH (2001) Anterior brain functions and hypnosis: A test of the frontal hypothesis. *International Journal of Clinical & Experimental Hypnosis* 49: 95–108.
- Kallio S, Revonsuo A (2003) Hypnotic phenomena and altered states of consciousness: a multi-level framework of description and explanation. *Contemporary Hypnosis* 20: 111–64.
- Kim CY, Blake R (2005) Psychophysical magic: rendering the visible 'invisible'. *Trends in Cognitive Sciences* 9: 381–8.
- Lambert A, Hockey R (1986) Selective attention and performance with a multidimensional visual display. *Journal of Experimental Psychology: Human Perception and Performance* 12: 484–95.
- Maki WS, Bussard G, Lopez K, Digby B (2003) Sources of interference in the attentional blink: target-distractor similarity revisited. *Perception and Psychophysics* 65: 188–201.
- Maki WS, Mebane MW (2006) Attentional capture triggers an attentional blink. *Psychonomic Bulletin & Review* 13: 125–31.

- Moray N (1975) A data base for theories of selective listening. In: PMA Rabbit, S Dornic (eds) *Attention and Performance. V*. New York: Academic Press.
- Mulert C, Gallinat J, Pascual-Marqui R, Dorn H, Frick K, Schlattmann P, Mientus S, Herrmann WM, Winterer G (2001) Reduced event-related current density in the anterior cingulate cortex in schizophrenia. *NeuroImage* 13: 589–600.
- Mulert C, Gallinat J, Dorn H, Herrmann WM, Winterer G (2003) The relationship between reaction time, error rate and anterior cingulate cortex activity. *International Journal of Psychophysiology* 47: 175–83.
- Naito E, Kinomura S, Geyer S, Kawashima R, Roland PE, Zilles K (2000) Fast reaction time to different sensory modalities activates common fields in the motor areas, but the anterior cingulate cortex is involved in the speed of reaction. *Journal of Neurophysiology* 83: 1701–9.
- Neely JH (1977) Semantic priming and retrieval from lexical memory: roles of inhibitionless spreading activation and limited capacity attention. *Journal of Experimental Psychology* 106: 226–54.
- Nieuwenhuis S, Gilzenrat MS, Holmes BD, Cohen JD (2005) The role of Locus Coeruleus in mediating the attentional blink: a neurocomputational theory. *Journal of experimental psychology: general* 3: 291–307
- Nordby H, Hugdahl K, Jasiukaitis P, Spiegel D (1999) Effects of hypnotizability on performance of a Stroop task and event-related potentials. *Perceptual & Motor Skills* 88: 819–30.
- Pessoa L, Kastner S, Ungerleider LG (2003) Neuroimaging studies of attention: from modulation of sensory processing to top-down control. *Journal of Neuroscience* 23: 3990–8.
- Posner MI, Snyder C (1975) Attention and cognitive control. In: R Solso (eds) *Information processing and cognition*. Hillsdale, NJ: Erlbaum.
- Posner MI, Nissen MJ, Klein R (1976) Visual dominance: an information-processing account of its origin and significance. *Psychological Review* 83: 157–71.
- Posner MI (1980) Orienting of attention. *Quarterly Journal of Experimental Psychology* 31(1): 3–25.
- Posner MI, Petersen SE (1990) The attention system of the human brain. *Annual Review of Neuroscience* 13: 25–42.
- Posner MI, Fan J (2004) Attention as an organ system. In: JR Pomeranz, MC Crai (eds) *Topics in integrative neuroscience: from cells to cognition*. Cambridge, UK: Cambridge University Press.
- Potter MC, Staub A, O'Connor DH (2002) The time course of competition for attention: attention is initially labile. *Journal of Experimental Psychology: Human Perception & Performance* 28: 1149–62.
- Rainville P, Hofbauer RK, Paus T, Duncan GH, Bushnell MC, Price DD (1999) Cerebral mechanisms of hypnotic induction and suggestion. *Journal of Cognitive Neuroscience* 11: 110–25.
- Rainville P, Hofbauer RK, Bushnell MC, Duncan GH, Price DD (2002) Hypnosis modulates activity in brain structures involved in the regulation of consciousness. *Journal of Cognitive Neuroscience* 14: 887–901.
- Raymond JE, Shapiro KL, Arnell KM (1992) Temporary suppression of visual processing in a RSVP task: an attentional blink? *Journal of Experimental Psychology: Human Perception & Performance* 18: 849–60.
- Raz A, Shapiro T, Fan J, Posner MI (2002) Hypnotic suggestion and modulation of Stroop interference. *Archives of General Psychiatry* 59: 1155–61.
- Raz A, Landzberg KS, Schweizer HR, Zephrani ZR, Shapiro T, Fan J, Posner MI (2003) Post-hypnotic suggestion and the modulation of Stroop interference under Cycloplegia. *Consciousness and Cognition* 12: 332–46.
- Raz A (2004) Anatomy of attentional networks. *Anatomical Record* 281B: 21–36.
- Raz A (2005) Attention and hypnosis: neural substrates and genetic associations of two converging processes. *International Journal of Clinical & Experimental Hypnosis* 53: 237–58.
- Raz A (2006) Individual differences and attentional varieties. *Eura Medicophysica* 42(1): 53–8.

- Rubichi S, Ricci F, Padovani R, Scaglietti L (2005) Hypnotic susceptibility, baseline attentional functioning, and the Stroop task. *Consciousness & Cognition* 14: 296–303.
- Shapiro KL, Egerman B, Klein RM (1984) Effects of arousal on human visual dominance. *Perception and Psychophysics* 35(6): 547–52.
- Shapiro KL, Johnson TL (1987) Effects of arousal on attention to central and peripheral visual stimuli. *Acta Psychologica* 66: 157–72.
- Shapiro KL, Arnell KM, Raymond JM (1997) The attentional blink. *Trends in Cognitive Science* 1: 291–6.
- Sheehan PW, Donovan P, MacLeod CM (1988) Strategy manipulation and the Stroop effect in hypnosis. *Journal of Abnormal Psychology* 94: 249–5.
- Snowden RJ (2002) Visual attention to color: parvocellular guidance of attentional resources? *Psychological Science* 13: 180–4.
- Tellegen A, Atkinson G (1974) Openness to absorbing and self-altering experience (‘absorption’), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology* 83: 268–77.
- Visser TA, Zuvic SM, Bischof WF, Di Lollo V (1999) The attentional blink with targets in different spatial locations. *Psychonomic Bulletin & Review* 6: 432–6.
- Weitzenhoffer AM, Hilgard ER (1962) *Stanford Hypnotic Susceptibility Scale, Form C*. Palo Alto, CA: Consulting Psychologists Press.
- Winterer G, Adams CM, Jones DW, Knutson B (2002) Volition to action—an event-related fMRI study. *NeuroImage* 17: 851–8.
- Woody E, Bowers K (1994) A frontal assault on dissociated control. In: SJ Lynn, JW Rhue (eds) *Dissociation: Clinical and Theoretical Perspectives*. New York: Guilford.