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RUNNING HEAD: Hypnosis and prospective memory

Hypnosis attenuates executive cost of prospective memory

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Abstract

Prospective memory is defined as the ability to formulate and carry out actions at the appropriate time, or in the appropriate context. The aim of this study was to identify the effect of hypnosis on prospective memory performance and to analyze the involvement of executive control processes in intention realization in a hypnotically altered state of consciousness. In one experiment, manipulating hypnotic instruction in a within-subject fashion, we explored event based prospective memory performance in three conditions – baseline, expectation and execution - of twenty-three volunteers. Our main result is that executing prospective memory responses, at the same accuracy rate, produced a significantly lower cost of ongoing responses in terms of response latency in the hypnotic state than in wake condition.

Keywords: hypnosis, prospective memory, monitoring functions, intention maintenance, executive control

1. Introduction

Enacting planned actions when encountering relevant environmental cues at an appropriate time in the future is a fundamental task for all human beings that enables them to live an independent and socially adaptive lifestyle. Prospective memory (PM) refers to the function of encoding, storage, and delayed retrieval of intended actions (Einstein & McDaniel, 1996; Ellis, 1996; Ellis & Freeman, 2008). Intact functioning of PM relies upon a distributed neural network involving the rostral and dorsolateral part of the frontal cortex, the parietal cortex, the hippocampal complex and also the thalamus (Burgess, Quayle, & Frith, 2001; Burgess et al., 2003; Okuda et al., 2001; West, 2008). The injury of this network can produce a serious dysfunction of PM, as it has been detected following extensive frontal lobe lesion and has been identified in a range of psychiatric conditions with deficit of executive frontal lobe functions (Burgess, 2000; Burgess, Veitch, De Lacy Costello, & Shallice, 2000; Elvevåg, Maylor, & Gilbert, 2003; Fortin, Godbout, & Braun, 2002; Fortin, Godbout, & Braum, 2003; Kliegel, Jager, Altgassen, & Shum, 2008; Kondel, 2002; Kumar, Nizamie, & Jahan, 2005; Racsmány, Demeter, Csigó, Harsányi, & Németh, 2011; Schum, Ungvari, Tang, & Leung, 2004). Prospective remembering involves a number of information processing components, such as formation, retention, execution, and evaluation or monitoring of planned actions (see Kliegel, Martin, McDaniel, & Einstein, 2002).

Recent theoretical models of PM consider the role of executive frontal system in carrying out appropriate prospective responses in several different ways. According to the supervisory attentional system (SAS) model, the executive control system, known to rely on frontal networks, monitors the environment for target events that indicate when it is appropriate to execute the intended prospective response (Burgess & Shallice, 1997; Norman & Shallice, 1986). The multiprocess model proposes that PM is supported by automatic processes when there is a strong association between the PM target event and the intended actions. However, in certain circumstances, for instance when PM target events are not salient, or there is no strong association between the target event and the intended action, the PM response is mediated by more strategic processes (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004). A third influential theory, the preparatory attentional and memory processes model (PAM) proposes that non-automatic attentional processes are always involved in PM retrieval (Smith, 2003; Smith & Bayen, 2004). One component of these preparatory attentional processes is monitoring for PM target events that indicate the appropriate time for PM actions. In sum, the involvement of the frontal executive system in PM is both a fundamental theoretical and a practical question.

As fast and reversible changes of attentional and memory processing are experienced in hypnosis, it was recently suggested that this altered state of consciousness is a useful tool for cognitive neuroscience research (Raz & Shapiro, 2002). It has been widely demonstrated that hypnosis impairs the performance on executive tasks. Participants produced impaired performance on fluency and Stroop tasks in hypnosis, while hypnotic induction left implicit sequence learning, known to rely on fronto-striatal networks, intact or even enhanced (Farvolden & Woody, 2004; Kaiser, Barker, Haenschel, Baldeweg, & Gruzelier, 1997; Kallio, Revonsuo, Hamalainen, Markela, & Gruzelier, 2001; Nemeth, Janacsek, Polner, & Kovacs, 2013; Wagstaff, Cole, Brunas-Wagstaff, 2007). These results are in line with the dissociated-control hypothesis that assumes that hypnosis weakens the executive control of behavior (Woody & Bowers, 1994). This theory has received support from studies demonstrating that hypnosis reduces the connectivity between frontal lobe and other brain areas, most importantly disconnecting frontal lobe from the anterior cingular cortex, a brain structure usually associated with conflict monitoring (Egner, Jamieson, & Gruzelier, 2005; Fingelkurts, Kallio, & Revonsuo, 2007; Gruzelier, 2006). Therefore, hypnosis may serve as an appropriate tool to investigate the role of executive frontal system in performing a PM task.

In the present experiment, we aimed to use hypnosis as a tool to attenuate the involvement of the executive system in performing a PM task. We applied a PM task designed by Burgess et al. (2001) for a positron emission tomography (PET) study. In this procedure, participants were instructed to perform a task under three conditions: a baseline condition where only ongoing activities were performed, a prospective expectation condition where prospective cues were expected but were never presented, and an execution condition where prospective cues were actually presented. Burgess and colleagues found larger activations in the frontal pole (middle frontal gyrus), right parietal lobe, and precuneus region in both the expectation and the execution conditions relative to the baseline condition (Burgess et al., 2001). This result was interpreted as evidence that the activated network supports the maintenance of intentions during the course of ongoing activity. The comparison of the expectation and execution conditions revealed significant differences: the activation of the right thalamus, accompanied by decreases in the right dorsolateral prefrontal cortex (RDLPFC), seemed to be associated with the realization and execution of delayed intentions.

This task was selected because the neural networks that are involved in accomplishing this specific task are known (Burgess et al., 2001). The design of the task allowed us to separately investigate the involvement of the executive system in maintaining and executing a PM response (Racsmány et al., 2011). Based on the results of Burgess et al. (2001) we hypothesized that executive monitoring of prospective cues and shifting between ongoing and prospective responses puts an extra load on ongoing task processing when participants are awake and this will be present in an increase of reaction times of the ongoing task. In accordance with the multiprocess model of PM (McDaniel & Einstein, 2000), we also assumed that hypnosis will decrease the involvement of executive system and participants will accomplish the task in a more automatic and faster way when they are in hypnosis.

2. Method

2.1. Participants

Twenty-three volunteers (mean age = 24.3 years, SD = 1.33; education = 17.04 years, SD = .56) without any psychiatric or neurological disorder took part in the study. They were not paid for participating.

Hypnotizability was measured using the Hungarian version of the Harvard Group Scale of Hypnotic Susceptibility (Shor & Orne, 1962). Statistical scoring procedures from the original English language version were employed. The mean hypnotizability scores were: cognitive scores = .95 (SD = .71), motor scores = 5.83 (SD = 2.66), total scores = 6.78 (SD = 3.03). Because hypnotizability, a stable personal trait, is distributed dimensionally in the population, the categorization of low-high can be artificial and, thus, likely to be distorting. In our study, the distribution of hypnotizability was almost perfectly normal, so the low-high categorization of our sample seemed inappropriate.

Written informed consent was obtained prior to the study. The project was approved by the institutional ethical review board.

2.2. Experimental design and procedure

Susceptibility to hypnosis was measured in groups of 5-9 persons. The hypnosis was led by a qualified, experienced hypnotist, following the standard induction of the Harvard Group Scale of Hypnotic Susceptibility (Shor & Orne, 1962). On the following day, participants performed the event based PM task in alert waking and in hypnotic states of consciousness with the same standard instructions in counterbalanced order. We followed a within subject design and the two experimental conditions were randomized for each subject.

Since we were concerned that the style of the hypnotic induction, its formal elements, and its content could affect the depth of hypnosis achieved, we endeavored to ensure standardization. A skilled therapist with extensive experience with hypnosis tape-recorded the induction, instructions, and dehypnotizing phases. This recording was played to every participant. The type of hypnosis induction was essentially a relaxing one.

Regarding the PM task, we closely adhered to the protocol established by Burgess et al. (2001). An event-based PM task was administered to each participant under three conditions: (1) a baseline condition in which there was no expectation that PM stimuli would occur, and no PM stimuli occurred; (2) an expectation condition in which participants were told that PM stimuli might occur, though none actually did; and (3) an execution condition in which participants were told that PM stimuli might occur, and stimuli did occur. This procedure allowed us to separate and compare the performances associated with intention maintenance and its realization.

Sixty stimuli were presented in the baseline and expectation conditions and eighty in the execution condition. The execution condition contained PM stimuli that were pseudorandomly distributed, amounting to 25% of the stimuli. In each condition, the first six stimuli were practice items and were not included in the analysis.

The order of the conditions (baseline, expectation, and execution) followed this protocol: the baseline for each task was always given first, but the order of the expectation and execution conditions was randomized, to prevent subjects from being able to work out an established strategy.

Stimuli presentation strictly adhered to the Burgess et al. (2001) procedure and was subject-paced (i.e., the onset of the next stimulus was cued by the subject’s response, and the stimuli remained visible until that response occurred). A 2000 msec blank white screen interval was inserted between presentations.

In each trial, two arrows were presented on the display. One arrow was always black, and its position varied pseudorandomly. In both the baseline and expectation conditions, stimuli included 30 items in which the black arrow pointed to the left and an additional 30 items in which it pointed to the right. The same ratio in the execution condition was 40/40. Two color bars also appeared on the screen and were located at equal distances above and below the arrows. The color of the horizontal bars were red, blue, green, yellow, or orange (see Figure 1).

- Figure 1 about here –

Participants were positioned with the forefinger, middle finger, and third finger of their right hand on the three arrow keys of the computer keyboard. Written instructions were read to the participants immediately before each experimental block was administered. Participants were asked to press the key with their forefinger if the arrow was to the left of a fixation point and with their third finger if it was to the right. In the expectation and execution conditions participants were told to respond with their middle finger if the two color bars above and below the fixation point were the same color on any trial, this instruction served as a PM task.

3. Results

Mean RTs for the ongoing task were analyzed in a Group (Alert waking state and Hypnotic state) X Condition (baseline, expectation, execution) repeated measures ANOVA. Analysis of RTs was based on errorless trials. The Group (Alert waking state and Hypnotic state) X Condition (baseline, expectation, execution) repeated measures ANOVA for the participants' mean RTs in the ongoing task showed a significant main effect of condition [$F(2,44) = 228.14$, $p < .001$, $\eta^2_{partial} = .91$] and no significant effect of group [$F < 1$]. There was a significant group X condition interaction, [$F(2,44) = 5.71$, $p < .01$, $\eta^2_{partial} = .21$]. We found a significant difference between the two groups [$t(22) = 2.11$, $p < .05$, r = .25] only in the ongoing task of the execution condition. There was no significant difference in the baseline condition [$t(22) = .84$, $p > .05$, $r = .09$], and in the expectation condition [$t(22) = -.25$, $p > .05$ $r = -.03$] (see Figure 2). Comparison of the waking and the hypnotic group RTs in the PM task of the execution condition [$t(22) = .25$, $p > .05$, $r = .03$] revealed no significant differences (see Figure 3). In sum, subjects performed significantly faster in the ongoing task of the execution condition in hypnotic state compared to the alert waking state.

- Figures 2 and 3 about here –

To further analyze our data, a "cost of PM instruction" was calculated for both the expectation condition (mean ongoing task RT in the expectation condition – mean ongoing task RT in the baseline condition) and the execution condition (mean ongoing task RT in the execution condition – mean ongoing task RT in the baseline condition). Comparison of alert waking and hypnotic group expectation costs revealed no significant difference [$t(22) = -1.22$, $p > .05$, $r = -$

.18], while the same comparison yielded a significant difference for execution costs [$t(22) = 2.4$, $p < .05$, $r = .26$] (see Table 1).

- Table 1 about here –

Similarly to the Burgess et al. (2001) study, errors for non-PM and PM stimuli were rare. Hit rate was above 90 % in the PM task, and above 99 % in the ongoing tasks in all the three experimental conditions in both states of consciousness.

4. Discussion

This study examined the effect of hypnosis on PM. Particularly, it tested the hypothesis that hypnosis attenuates the time cost of executing prospective responses embedded in a stream of ongoing responses. Our findings confirmed this hypothesis. Earlier, it was demonstrated that hypnosis decreased the involvement of executive control in complex cognitive tasks (Farvolden & Woody, 2004; Kaiser et al., 1997; Kallio et al., 2001; Wagstaff et al., 2007). Based on this, we suggest that the beneficial effect of hypnosis on RTs of the ongoing task was the consequence of attenuated executive control of the PM task.

Importantly, hypnotic and alert conditions did not differ significantly in the baseline condition, suggesting that hypnotic induction did not alter the average reaction time in the ongoing task. The cost of executing a prospective cue while carrying out an ongoing task differed significantly in the hypnotic and alert conditions. This result suggests that hypnosis attenuates the executive control of monitoring of prospective cues during the ongoing task. Participants responded significantly faster for the ongoing cues while they were in a hypnotic state and we argue that this result is not due to a speed/accuracy trade off as accuracy rates did not differ in the hypnotic and the alert conditions. This latter finding runs against a simple alternative explanation that participants did not follow prospective instructions following hypnotic induction.

One way to explain these findings is suggested by the results of the Burgess et al. (2001) study that introduced the experimental task we used. They found that the prospective responses in the execution condition were underlined by a significant change in activity of the DLPFC and the thalamus in comparison to the expectation condition. Importantly, comparing the expectation and execution conditions to the baseline condition, there was a significant increase of regional cerebral blood flow (rCBF) in a range of cortical areas, including the frontal pole (BA10) bilaterally and the right lateral frontal cortex. This means that maintaining and realizing a prospective intention is differentiable only by the activity change of the DLPFC and the thalamus. Interestingly, according to Burgess et al. (2001) this difference reflects that the involvement of this region is not associated with target recognition itself or with post-detection retrieval processes, but with some form of anticipatory processing. This anticipatory process can involve checking the current stimulus against the stored representation of the target or perhaps some abstract decision strategy concerning the sequence of processing of ongoing and prospective stimuli (Burgess et al., 2001). However, this conclusion was based on the fact that Burgess et al. (2001) did not find an increase in RTs in the execution condition compared to the expectation condition. In the current study, however, we found a significant RT difference between expectation and execution conditions, in both the alert [$t(22) = -14.09$, $p < .001$, $r = .95$] and the hypnotic [$t(22) = -9.99$, $p < .001$, $r = .90$] conditions. Regarding this difference between the two studies, it might be the case that executing the PM responses involved a kind of post-detection monitoring process in the current study, and this monitoring process caused the increase of RTs in the execution condition.

The present findings seem to be important from the point of view of contemporary theories of PM. Both SAS and PAM assume that the involvement of the executive system or controlled attention is critical in carrying out adequate PM responses (Burgess & Shallice, 1997; Norman & Shallice, 1986; Smith, 2003; Smith & Bayen, 2004), whereas the multiprocess model proposes that automatic processes can trigger PM responses if the PM cue and the response are strongly associated (McDaniel & Einstein, 2000; McDaniel et al., 2004). Our findings give support to all these assumptions, because decreasing the level of attentional control by hypnosis did not change the accuracy of PM responses, but attenuated the extra load of attentional control measured by RTs. As a consequence, our results showed that executive control processes were involved in checking and responding to PM cues in the awake condition, however, their involvement was not necessary for successful and fast production of PM responses, probably because PM cues were salient and easily detectable.

Our findings suggest that hypnosis affected the executive control of prospective memory responses. It might be the case that, following hypnotic induction, participants were less frequently monitoring PM cues in the execution condition. Presumably they responded to PM cues in a more associative way, without executive control, compared to the condition when they were in an alert state of consciousness. Our findings are in line with earlier results showing that hypnosis mainly altered the executive functions associated with the activity of the lateral prefrontal cortex (Egner et al., 2008). These results are also in line with results demonstrating that lesion in the DLPFC did not result in PM deficit in contrast to the injury of the rostral frontal (frontopolar) cortex (Burgess et al., 2000, 2008). Executive control processes associated to the

DLPFC might play a role in complex PM functions, in which monitoring of context change in a task is crucial for adaptive solution of the task. Without executive control, PM responses might be more rigid and prone to false alarms especially in situations where, infrequently, inhibition of correct response is required. How hypnosis alters the execution of complex PM functions is the question of future investigations.

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Figure 1

Description of the tasks: a) Ongoing task: Press the key (left or right) in the direction of black arrow. b) PM task: if the two color bars are the same color, press the up-arrow key.

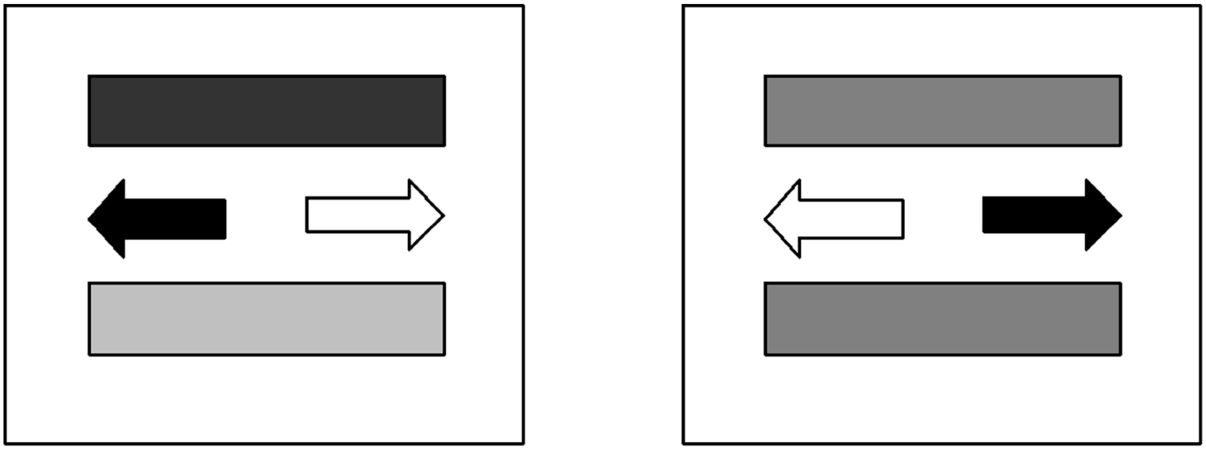

Figure 2

Mean reaction times by condition for the ongoing task. Note: Error bars show standard error of the mean.

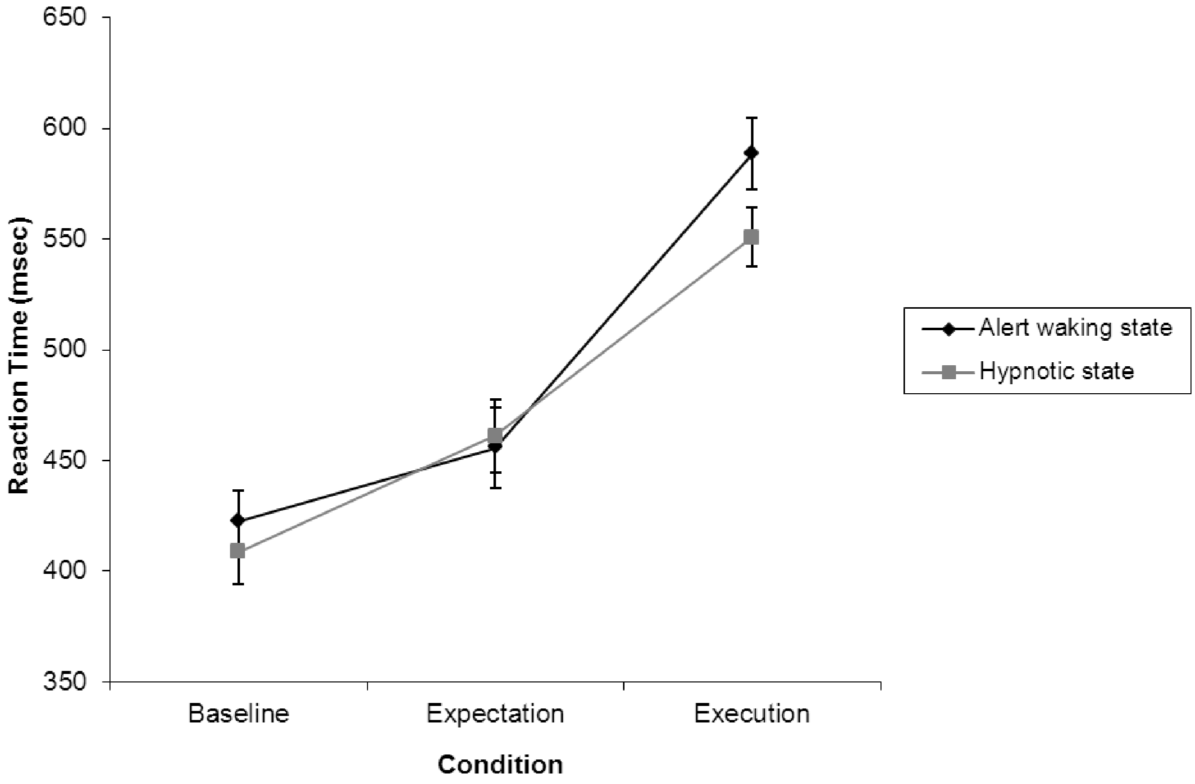

Figure 3

Mean reaction times for the ongoing and PM tasks in the execution condition. Note: Error bars show standard error of the mean.

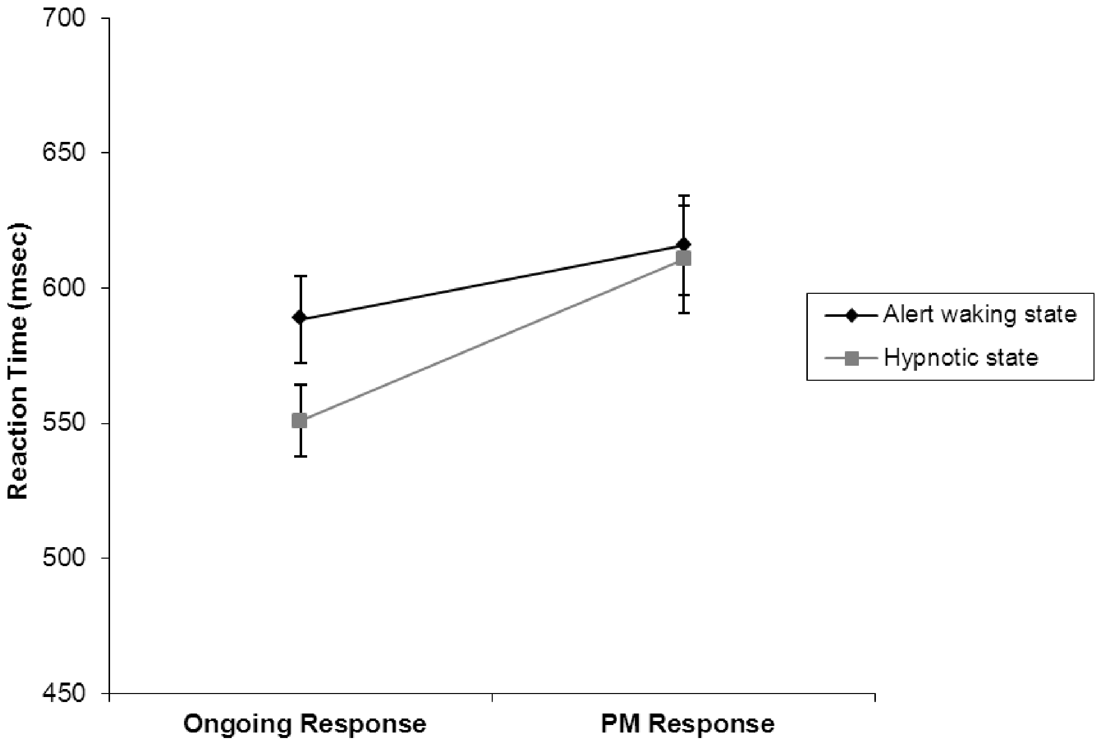

Table 1

The expectation and execution costs in the alert waking and hypnotic state

State	Alert waking state		Hypnotic state		Paired Comparison	
	Mean	SD	Mean	SD	t	p
Expectation cost	33.28	59.37	52.14	41.28	-1.22	n.s.
Execution cost	166.01	51.83	142.01	37.49	2.40	.025

Note. SD, standard deviation; RT, reaction time (msec); Expectation cost = Mean RTs expectation condition - Mean RTs baseline condition; Execution cost = Mean RTs ongoing task execution condition – Mean RTs baseline condition, n.s., not significant