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The interoception and imagination loop
in hypnotic phenomena

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Running head: INTEROCEPTION AND IMAGINATION LOOP

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Abstract

We tested a working hypothesis that the ideomotor and motor-control suggestions measured by current hypnotizability scales depend on the activation of an interoception-imagination processing loop. In three experiments, participants were exposed to an induction phase, Items 3 (mosquito hallucination) and 8 (arm immobilization) of the Stanford Hypnotic Susceptibility Scale, Form C, and a new version of Item 8 involving the additional activation of imaginative and interoception processes. We found that this modified version of Item 8 elicited greater responsiveness to suggestion, irrespective of its position in the sequence of hypnotic items. We argue that this interoception-imagination loop hypothesis provides a useful information processing analysis for understanding several hypnotic phenomena.

Keywords: interoception, imagination, suggestion, induction, hypnosis

1. Introduction

The development of hypnotizability scales has been an important step in the scientific study of hypnotic phenomena (Laurence, Beaulieu-Prévost, & du Chéné, 2008; Woody & Barnier, 2008). They provide a psychometric measure for identifying those individuals who are most responsive to hypnotic suggestion, also called *highs* (Barnier, Cox, & McConkey, 2014). All built on the same design principles, in which participants are exposed to an induction phase, followed by a series of suggestions, these scales include the Harvard Group Scale of Hypnosis Suggestibility, Form A (HGSHS: A; Shor & Orne, 1962, 1963), the Stanford Hypnotic Susceptibility Scales (SHSS: A and SHSS: B; Wietzenhoffer & Hilgard, 1959; SHSS: C; Wietzenhoffer & Hilgard, 1962), the Carleton University Responsiveness to Suggestion Scale (CURSS; Spanos et al., 1983), and the Waterloo-Stanford Group Scale of Hypnosis Suggestibility, Form C (WSCG; Bowers, 1993). Participants' scores are determined by their responsiveness to each suggestion, and although variations among scales have been reported, these were mainly due to procedural differences and the types of suggestions (Barnes, Lynn, & Pekala, 2009; Spanos, Radtke, Hodgins, Stam, & Bertrand, 1983).

Using these scales, researchers have repeatedly shown that 10-15% of individuals are highly responsive to hypnotic suggestions (i.e., highs), while 10-15% are almost completely unresponsive (i.e., lows), and most of the remaining individuals are able to experience some-but not all-the suggestions (e.g., Hilgard, 1965). Accounting for these variations in responsiveness is a major challenge, and authors have repeatedly reported that no one single factor can explain the distribution of responses (e.g., Nadon, Laurence, & Perry, 1987; Woody, Barnier, & McConkey, 2005). Hypnotic phenomena are likely

resulting from the interaction between several variables, and previous studies have attempted to identify the most important ones.

Several studies attempted to correlate personality traits with hypnotizability scale scores, but the results were inconclusive, indicating that no clear personality trait or combination of traits could account for the distribution of hypnotic responsiveness (Green, 2004; Milling, Miller, Newsome, & Necrason, 2013; Nordenstrom, Council, & Meier, 2002; but see Cardaña & Terhune, 2014). The first consistent relationship was found using the Tellegen Absorption Scale (Tellegen & Atkinson, 1974), with the range of correlations with hypnotizability scales varying from $r = .13$ (Hilgard, Sheehan, Monteiro, & Macdonald, 1981) to $r = .57$ (Crawford, 1982). However, these correlations were subsequently found to decrease when absorption is measured outside the context of a hypnosis study (e.g., Council, Kirsch, & Hafner, 1986; Milling, Kirsch, & Burgess, 2000), indicating that the definition of this theoretical construct probably needs to be reconsidered and linked to a more cognitive explanation (Laurence, Beaulieu-Prévost, & Du Chéné, 2008).

Among the cognitive components related to hypnosis, the ability to focus attention has been shown to account for a proportion of the variance in hypnotic responsiveness (e.g., Crawford, 1994; Karlin, 1979; but see Dienes, Brown, Hutton, Kirsch, Mazzoni, & Wright, 2009) and variations in the neural correlates of attention have been related to the hypnotizability of the participants (Cojan, Piguet, & Vuilleumier, 2015). During both the induction and suggestion phases in current hypnotizability scale protocols, participants are expected to focus on their body sensations. This cognitive operation is closely related to the notion of *interoception*, which conventionally refers to

the processing of signals that originate within the body and refer to bodily state (e.g., Critchley & Garfinkel, 2017; Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Khalsa, Rudrauf, Feinstein, & Tranel, 2009; Ondobaka, Kilner, & Friston, 2017). Interoception is considered to be distinct from both proprioception (i.e., processing of skeletal-motor and vestibular information about the body's position or movement) and the (proximate and distant) sensing of the environment through touch, taste, smell, sight and hearing. Typically, a sense of heaviness or a sense of warmth cannot be considered as proprioceptive or tactile information but belong to interoceptive information.

Attending to the inside of the body can be equated with the notions of both absorption and dissociation. Attending to bodily information diverts the cognitive system from processing information from outside the body and can be interpreted as a form of absorption. Orienting attentional processing resources toward interoceptive information therefore induces a form of dissociation from the environment¹.

Another cognitive component that is central to hypnotic phenomena encompasses imaginative activity (Barber, Spanos, & Chaves, 1974; Hilgard, 1981), goal-directed fantasy (Spanos, 1971), and imaginative involvement (Hilgard, 1979). Authors like Sutcliffe (1961) have viewed the hypnotic situation as providing a context in which individuals who are skilled at make-believe and fantasy are given an opportunity to become engaged in what they are able to do especially well (Sutcliffe, Perry, & Sheehan, 1970). Kirsch and Braffman (2001) argued that imaginative suggestibility is one of the

¹ The term “dissociation” is used here in a non-canonical way to describe a specific mode of information processing in which attention is directed toward bodily information processing. By intensively paying attention to bodily information, our view is that one can indeed experience a form of dissociation toward the external world. Furthermore, this dissociation from the present external world can be further increased if one couples bodily information with imagination. The resulting phenomenal experience can therefore be strongly detached from the immediate environment. Note that using the term “dissociation” in that sense is different from its use in psychopathology (e.g., Dell, 2010).

main psychological constructs underlying hypnotic phenomena. They show that it is related to expectancy, motivation, absorption, and fantasy proneness (Braffman & Kirsch, 1999). The ability to activate imaginative processes therefore appears to be another key feature of the production of hypnotic phenomena (Spanos & Barber, 1974; for a different perspective, see Hargadon, Bowers, & Woody, 1995).

Although other factors have been shown to influence hypnotic responsiveness, in the present study, we focused on the interaction between interoception and imagination processes in specific hypnotic situations. We adopted a different heuristic from studies that have previously tried to account for the variance in hypnotizability scales. Instead of considering the *entire set* of hypnotic items, we looked at the relationships between hypnotic responsiveness and *specific items* in current hypnotizability scales. We worked on the assumption that by studying a restricted set of hypnotic phenomena that are probably supported by the same underlying cognitive mechanisms, we would be able to learn more about these mechanisms.

There are three general types of suggestion that differ in terms of pass rates or difficulty: ideomotor suggestions, motor-control suggestions, and cognitive-perceptual suggestions (Barnes, Lynn, & Pekala, 2009). In the present study, we only considered the simplest items in current hypnotizability scales (i.e., ideomotor and motor-control suggestions), as we hypothesized that the mechanisms behind the occurrence of these hypnotic phenomena are probably related to the establishment of a loop between the interoceptive and imaginative processes that support the transformation of individuals' subjective experience. This working hypothesis is derived from recent theoretical frameworks providing a detailed description of the attentional processes involved in

specific experimental tasks, such as working memory tasks (e.g., Barrouillet, Bernardin, & Camos, 2004; Barrouillet, Portras, Camos, 2011; Perruchet & Vinter, 2002). These theoretical accounts attempt to determine the successive information that participants process or to which they pay attention. In the case of hypnotizability scales, participants are expected to shift progressively from processing external information to internal bodily sensations (i.e., interoceptive information). Hereafter, they are expected to activate imaginative information and to connect this information to bodily sensations, leading to a processing loop between interoceptive and imaginative information. Therefore, according to this working hypothesis, hypnotic phenomena are a by-product of this processing loop. Participants are indeed more likely to produce a hypnotic response if their attention is directed toward their bodily sensations and if they are conjointly engaged in top-down imaginative processes that generate an alternative interpretation of these sensations. Their engagement in this processing loop makes suggestions feel as though they were genuinely experienced, leading to a major change in their subjective experience and the production of a hypnotic response.

The instructions given to participants during a hypnotic session in a standardized test like the SHSS: C (Wietzenhoffer & Hilgard, 1962) are consistent with this hypothesis. For example, for the *hand lowering* item of the SHSS: C, after the induction phase, participants receive the following instructions: “Now hold your right arm out at shoulder height, with the palm of your hand up. There, that's right. Attend carefully to this hand, how it feels, what is going on in it.” Here, participants are clearly expected to engage in interoceptive processes and to pay attention to the bodily sensations related to their right hand. Soon after, they are instructed to “imagine that you are holding

something heavy in your hand... Maybe a heavy baseball or a billiard ball... Something heavy.” This time, imaginative processes are elicited. Finally, both processes are activated in alternation, as though a loop between interoception and imagination processes had been created: “The weight is so great, the hand is so heavy... You feel the weight more and more...” We hypothesized that participants who create this loop are more likely to produce this hypnotic phenomenon (i.e., observable gradual lowering of their hand).

The percentage of participants who pass the suggestion for the hand lowering item in the HGSHS-A (Shor & Orne, 1962, 1963) or GSHA (Hawkins & Wenzel, 1999) is generally high (around 80%; Barnes et al., 2009). This is probably due to the natural tendency to lower one’s hand in such tiring position, thus facilitating the activation of the interoception-imagination loop. Motor-challenge items generally give rise to far lower scores. For example, only around 30% of participants pass the suggestion in the *arm immobilization* item (Barnes et al., 2009).

In the present study, we hypothesized that ideomotor and motor-control suggestions depend on the presence of this interoception-imagination loop. We also assumed that increasing the activation of imaginative processes strengthens this loop and thus increases the number of participants who pass the suggestion. We tested these hypotheses in three experiments where different groups of participants were exposed to an induction phase (Item 0), Items 3 (mosquito hallucination) and 8 (arm immobilization) of the SHSS: C, and a new version of Item 8 with the additional activation of imaginative processes (Loop Item 8). Both the induction phase (eye closure) and Item 3 were used as behavioral baselines to check that the different groups in Experiments 1-3 did not differ

in their responsiveness to these items. The position of Loop Item 8 varied across the three experiments. It should be noted that the instructions were adapted to avoid the use of the term *hypnosis*. Owing to the different representations of hypnosis among participants, this term could either have facilitated or inhibited their responsiveness to the suggestions, so they were simply told that the experiment was about the roles of imagination, relaxation and introspection in perceptions of the world.

2. Experiment 1

2.1. Participants

A group of 33 native French-speaking students took part in the study (24 women; mean age = 19.97 years, $SD = 2.4$)². Participants provided their informed written consent and were compensated for their participation with course credits. They underwent the experiment in groups of two to six persons.

2.2. Material

We used three items from the SHSS: C (Weitzenhoffer & Hilgard, 1962) to test the hypnotic suggestibility of participants: Item 0 (induction by eye closure), Item 3 (mosquito hallucination), and Item 8 (arm immobilization) (see Appendix for the French versions of these items). Items 0 and 3 were used in Experiments 1-3 as a baseline to compare the performances of the different groups. We created a fourth item (Loop Item 8, based on Item 8) to test our working hypothesis that enhancing the activation of imaginative processes increases the strength of the interoception-imagination loop and therefore heightens responsiveness to suggestion.

² Given that we used a novel way of scoring participants' responses, we did not have any expectations about the effect size. We therefore arbitrarily chose an initial sample size of more than 30 participants.

In the standard version of Item 8, participants receive a series of suggestions about their arm becoming heavier. In the modified version, they were explicitly invited to deeply use their imagination to make the situation as real as possible. They were then asked to feel the heaviness in their arm and to nod when they were able to do it. This expected feedback was used to stimulate their engagement in the interoceptive-imagination loop. Finally, imaginative processes were further activated by asking them to imagine the sensations they would have if they were stuck in this imaginative situation.

Loop Item 8 instructions were administered in three steps:

1- General statement about imagination and first expected response:

“Please stay comfortably seated in your chair. I would like you now to use your imagination as much as possible. Note however that imagining does not just mean thinking. It really means living the experience as if it were real. You can play this game with your eyes either open or closed, but it must be in silence.

If you understand what I mean, please nod.”

2- First imaginative suggestion and second expected response:

“Imagine that your left arm is extremely heavy, so heavy that you are unable to move or lift it. When you succeed in imagining it, please nod and keep on imagining until everybody gets there.”

3- Second imaginary suggestion and third expected response:

“Now, while you are still imagining this, imagine that you are stuck in this situation. Imagine that whatever you are doing you cannot get out of it... Imagine that whatever you are doing your left arm remains so heavy that you are unable to move or lift

it.... When you succeed in imagining it, nod and keep on imagining until everybody gets there.”

4- Test:

“Now, while you are still imagining this, try to raise your arm.”

The experimenter then waited for 10 seconds and observed the participants’ response. The protocol was administered to all the groups by the same experimenter (AP), and each session was recorded with a camcorder.

2.3. Procedure

Each session lasted approximately 20 minutes. Silence was required throughout the experiment.

The experimenter administered the protocol in the following order:

- 1- Induction by eye closure (Item 0 of SHSS: C);
- 2- Mosquito hallucination (Item 3 of SHSS: C);
- 3- Arm immobilization (Item 8 of SHSS: C);
- 4- Wake up: coming back to normal awareness;
- 5- Loop Item 8.

In the current version of the SHSS: C, a binary decision is made on each item, and a score is obtained by summing the items that are passed by the participant (Weitzenhoffer & Hilgard, 1962). Based on the response booklet of the HGSHS: A (Shor & Orne, 1962), we introduced a more continuous scoring of participants’ responsiveness. The scoring scale for each item ranged from 0 to 3 (instead of being 0 or 1). A score of 0 or 1 corresponded to failure, while a score of 2 or 3 corresponded to success.

For Item 0 (induction by eye closure), we scored participants' responsiveness according to when they closed their eyes. Participants were awarded a score of 3 if their eyes were closed by the end of Paragraph 2, 2 if their eyes were closed by the end of Paragraph 3, 1 if their eyes were closed by the end of Paragraph 4, and 0 if their eyes were closed by the end of Paragraph 5.

For Item 3 (mosquito hallucination), we adopted a similar continuous measure. Participants scored 3 if they made a large movement in response to the suggestion, 2 if they made a small movement or a grimace in response to the suggestion, 1 if they displayed any sort of minor reaction during the instructions but nothing in response to the suggestion, and 0 for no response.

For Item 8 (arm immobilization), participants scored 3 if they made no movement, 2 if they produced a movement of less than 3 cm, 1 if they made a movement of 3-10 cm, and 0 if they made a movement of more than 10 cm. The same scoring scale was used for Loop Item 8.

At the end of each experimental session, the video recordings were cut into smaller video files, each containing one item. Three judges then scored the participants' responses while viewing these video files without any sound (they could therefore not distinguish Item 8 from Loop Item 8). The three judges' scores were closely correlated, indicating that there was little ambiguity in the scoring (*kappa* values for Item 0, Item 3, Item 8, and Loop Item 8 were respectively: 1, .87, .86, and .98).

2.4. Results

Mean responsiveness scores for each item and 95% confidence intervals (CI) are reported in Table 1. We found that the mean score on Loop Item 8 (2.42, *SD* = 0.97) was

significantly greater than the mean score on the original Item 8 (1.42, $SD = 1.17$), with a difference of 1 between the two conditions (95% CI: .57 – 1.43, Cohen's $d = .79$). To compare our scores with those reported in the literature for Item 8 of the SHSS: C, we converted our continuous score from 0 to 3 to a binary score. Scores 0 and 1 became 0, and Scores 2 and 3 became 1. This allowed us to obtain the percentages of participants who passed each item, as in the current SHSS: C. The results reported in Table 2 are consistent with those obtained in other studies (Hilgard, 1965; De Pascalis, Bellusci, & Russo, 2000; Lamas, del Valle-Inclan, & Diaz, 1996).

2.5. Discussion

Our results showed that the new Loop Item 8 significantly increased participants' suggestion responsiveness. While 48% of them passed the original Item 8, 88.5% of them passed it in its Loop version. This indicates that enhancing the activation of imaginative processes has possibly strengthened the interoception-imagination loop and has increased responsiveness to suggestion. We obtained this result with a group of participants who obtained standard scores on Items 3 and 8, going by previous studies, indicating that this group was representative of the population.

However, although these results tended to support our working hypothesis, the structure of this experiment left the door open to alternative explanations. In Experiment 1, Loop Item 8 appeared just after the presentation of the original Item 8. The increase in responsiveness to suggestion could therefore be explained by some sort of repetition or priming effect of the presence of Item 8 just before Loop Item 8. In Experiment 2, therefore, a different group of participants was tested in a very similar way to Experiment

1, except that they were not exposed to Item 8 prior to Loop Item 8. If the scores obtained in this situation were similar to those from Experiment 1, it would allow us to rule out a repetition or priming effect.

3. Experiment 2

3.1. Participants

A different group of 19 native French-speaking students took part in the study (16 women; mean age = 19.63 years, $SD = 1.2$)³. Participants provided their written informed consent and were compensated for their participation with course credits.

3.2. Material and Procedure

Everything was the same as in Experiment 1 except that Item 8 was not used. The experiment featured the following sequence of items:

- 1- Hypnosis induction by eye closure (Item 0 of SHSS: C);
- 2- Mosquito hallucination (Item 3 of SHSS: C);
- 3- Wake up (return to normal awareness);
- 4- Loop Item 8.

The video recordings were processed the same way as in Experiment 1. Scores produced by the three judges were again highly correlated (*kappa* values for Item 0, Item 3, and Loop Item 8 were respectively: 1, .80, and .81).

3.3. Results

³ In Experiments 2 and 3, we optionally stopped our random sampling of participants when we reached a number close to 20.

Mean responsiveness scores for each item and 95% CI are reported in Table 1. We found that the mean score on Loop Item 8 (2.63, $SD = 0.83$) was approximately the same as in Experiment 1 (2.42, $SD = 0.97$). This strong score could not be attributed to a group effect, as the scores in the two baseline control conditions were also very similar. The score for induction by eye closure was 1.52 in Experiment 1 ($SD = 0.87$) and 1.42 in Experiment 2 ($SD = 0.84$). The score for Item 3 was 1.42 in Experiment 1 ($SD = 1.25$) and 1.47 in Experiment 2 ($SD = 1.12$).

3.4. Discussion

To rule out the possibility that the effect observed in Experiment 1 was the result of a repetition or priming effect, Experiment 2 tested the same protocol as in Experiment 1, but without the original Item 8. Responsiveness for Loop Item 8 was of a similar magnitude to that in Experiment 1. Given that the scores in the control conditions (i.e., Items 0 and 3) were identical to those in Experiment 1, we can confidently state that there was no difference between the two groups and that the effect for Loop Item 8 was not a group effect.

Experiment 3 was designed to address a final concern. Several studies have shown that responsiveness to suggestion can be observed in a nonhypnotic context, and hypnotic induction is not needed to produce imaginative suggestibility (Augustinova & Ferrand, 2012, 2013; Braffman & Kirsch, 1999, 2001; Hull, 1933; Kirsch et al., 2011; Kirsch, Mazzoni, & Montgomery, 2007; Mazzoni et al., 2009; Parris & Dienes, 2013). Hypnotic induction may simply *facilitate* the production of hypnotic responses (Barber, 1999; Barnier, Dienes, Mitchell, 2008; Brown & Oakley, 2004; Kallio & Revonsuo, 2003;

Terhune & Cardeña. 2010). In this final experiment, we therefore tested whether the increase in suggestion responsiveness observed in Experiments 1 and 2 could also be obtained when Loop Item 8 was administered prior to Item 0 (i.e., induction phase).

4. Experiment 3

4.1. Participants

A different group of 19 native French-speaking students took part in the study (16 women; mean age = 20.68 years, $SD = 2.5$). Participants provided their written informed consent and were compensated for their participation with course credits.

4.2. Material and Procedure

Everything was the same as in Experiment 2, except that Loop Item 8 was placed at the beginning of the experiment. Participants were therefore exposed to the following sequence of items:

- 1- Loop Item 8;
- 2- Hypnosis induction by eye closure (Item 0 of SHSS: C);
- 3- Mosquito hallucination (Item 3 of SHSS: C);
- 4- Wake up (return to normal awareness).

The video recordings were processed in the same way as in Experiments 1 and 2. Scores produced by the three judges were again highly correlated (*kappa* values for Item 0, Item 3, and Loop Item 8 were respectively: 1, .91, and .87).

4.3. Results

Mean responsiveness scores for each item and 95% CI are reported in Table 1. The mean score on Loop Item 8 (2.16, $SD = 1.21$) was slightly lower than in Experiments 1 (2.42) and 2 (2.63), indicating that the presence of previous items (i.e., Items 0 and 3) may have influenced the responsiveness score on Loop Item 8. Interestingly, there was a slight increase in responsiveness for Item 0 (1.84, $SD = 0.83$), compared with Experiments 1 (1.52) and 2 (1.42) but even the largest difference between Experiments 2 and 3 (i.e., $1.84 - 1.42 = .42$) was not significant ($t(36) = 1.55$, $p = .12$, Cohen's $d = .5$). The score for Item 3 was relatively stable across the three experiments (1.42, 1.47, and 1.42), indicating that the three groups were comparable for this control condition.

4.4. Discussion

In Experiment 3, when Loop Item 8 was presented at the beginning of the experiment, the mean responsiveness score remained high, indicating that prior exposure to an induction phase was not mandatory to produce a high degree of suggestion responsiveness (63%), compared with the original Item 8 (52% in Experiment 1). Results also indicated that responsiveness to Item 0 was slightly affected by the prior presence of Loop Item 8.

Nonetheless, the score for Loop Item 8 was lower in this last experiment than in Experiments 1 (85%) and 2 (89%). Given that the score for Item 3 was stable across all three experiments, we can assume that the three groups were comparable. Therefore, any difference between these groups in the target condition should be attributed to the place of Loop Item 8 in the sequence of items. These results clearly suggest that the induction phase (i.e., Item 0) had a facilitating effect on Loop Item 8 in Experiments 1 and 2.

5. General discussion

In three experiments, we found that a modified version of Item 8 (i.e., arm immobilization) of the SHSS: C designed to promote imaginative and interoception processes elicited a higher responsiveness to suggestion score. Loop Item 8 was presented after the standard Item 8 in Experiment 1, but we found a similar effect when we removed Item 8 from the experimental protocol in Experiment 2. A smaller effect was observed in Experiment 3, where Loop Item 8 was presented at the beginning of the experiment. Item 3 of the SHSS: C was used as a control, and similar results were obtained for this item across the three experiments, indicating that the three groups were comparable. Their performances were also within the same range as previous standardized versions of the same hypnosis protocol (Hilgard, 1965; Lamas et al., 1996; De Pascalis et al., 2000), suggesting that our samples were representative of the population.

This result can be interpreted within an information processing model of hypnotic responsiveness that explains the transformation of participants' subjective experience in terms of a strengthened processing loop between interoceptive and imaginative processes. We hypothesized that this loop provides a description of the main processes involved during a hypnotic session, specifically for ideomotor and motor-control suggestions. In these situations, attentional resources are usually directed toward the processing of interoceptive information in conjunction with the processing of imaginative information. Participants who manage to enter this processing loop are more likely to experience the related hypnotic phenomena and produce the related observable behavior (e.g., arm

immobilization). The instructions for Loop Item 8 were constructed precisely to encourage participants to enter this processing loop, thereby generating a stronger hypnotic phenomenon.

The present data shed light on a major debate in hypnosis research about whether or not suggestion responsiveness is resistant to change (Lynn & Rhue, 1991). Some have argued that it can be enhanced by only a small degree (e.g., Benham, Bowers, Nash, & Muenchen, 1998), whereas others have claimed that large increases can be reliably produced (e.g., Gorassini & Spanos, 1986; Spanos, 1986). Regarding ideomotor and motor-control suggestions, the present results indicate that responsiveness can be significantly increased by modifying the instructions to stimulate the activation of imaginative processes. We assumed that responses to these suggestions are strongly dependent on the ability (or willingness) of participants to enter in the interoception-imagination loop. Asking participants to join in this *game* of imagining and asking them also to imagine that they are stuck in this situation were simple instructions that influenced many participants who were not initially responsive to Item 8. Asking them to confirm that they are really imagining the situation contributed also to the present effects and certainly influenced their willingness or motivation to enter in the interoception-imagination loop (Barber & Calverley, 1963; Spanos & Barber, 1974). In terms of change, these participants simply altered the way they processed the information provided by the instruction. This change was transient and probably fully reversible, so the question of whether more lasting change is possible will need further experimental exploration.

The present data also suggest that the induction phase (i.e., Item 0) had an effect on the magnitude of suggestion responsiveness in Loop Item 8. We see two reasons for this influence. First, the induction procedure prepares participants to cooperate by increasing their willingness to prioritize suggestion over reality and pay attention to interoceptive information (Barnier et al., 2008; McConkey 1991; Sheehan, 1991, 1992; Shor, 1959, 1962). Second, the induction tends to banish all thoughts that interfere with the imaginative process and increases the focus on the hypnotist's voice and suggestions (Logan 1994, 2002). Thus, the induction procedure promotes engagement in the interoception-imagination loop (see Terhune & Cardeña, 2016, for a detailed analysis of the critical components of the induction phase). The present data therefore indicate that induction procedures facilitate this mode of processing, which seems important for ideomotor and motor-control suggestions. This is consistent with the idea that the induction procedure is the first suggestion in the hypnosis protocol (Nash, 2005), during which participants are expected to pay attention to their sensorimotor experience (Wagstaff, 1998). By focusing participants' attention on interoceptive information, as opposed to information from the external world, it stimulates the interoception component of the interoception-imagination loop and makes hypnotic phenomena easier to produce (Barnier et al., 2008). Note finally that a major feature of induction procedures is to ask participants to close their eyes. This simple instruction is a good way to prevent counterfactual visual information to work against the activation of imaginative information and to push participants away from the interoceptive-imagination loop.

The data from Experiment 3 also suggest that the processing of Loop Item 8 before the induction procedure (i.e., Item 0) had an influence on the speed of eye closure

behavior in Item 0. Setting aside the distinction between induction and suggestion, we can focus on the cognitive mechanisms involved in these different types of suggestions and try to disentangle their differences and similarities, together with the way they influence one another (Halligan & Oakley, 2014). In the present case, for both Loop Item 8 and Item 0, participants were expected to attend to interoceptive information, and both suggestions therefore engaged participants in this mode of attentional processing. The data indicate that when one suggestion preceded the other, it tended to facilitate participants' response to the second suggestion, owing to the activation of the same attentional processes as during the first suggestion.

In the present study, our heuristic was to adopt an information processing perspective on some of the items used in a standard hypnosis protocol (e.g., Item 8 of the SHSS: C). Each of these items required participants to engage in some specific form of information processing, and a better description of these processes is certainly a good strategy for better understanding hypnotic responses. Due to the heterogeneity in hypnotic phenomena and in the items used in current hypnotizability scales, our view was that they should be studied not as a single phenomenon called *hypnosis*, but as a set of phenomena that probably involve different cognitive processes (e.g., Woody et al., 2005). Regarding Item 8, our working hypothesis was that participants may experience and produce that hypnotic response if they manage (or agree) to enter a processing loop between interoceptive and imaginative processes. By stimulating imaginative processes related to the sensation of heaviness, participants retrieve these sensations from memory by activating the neural assemblies that supported these sensations in past experiences⁴. If

⁴ This idea can be considered as an extension of the general notion of expectancy developed by Kirsch (1985). Indeed, expectancies are usually considered to code for unidirectional cooccurrences between two

their imaginative processes are further activated in order to feel these sensations as though they were real, and if participants focus their attention on this interoceptive information, then it will increase this self-generated, illusory perception cycle and the hypnotic phenomenon is likely to be observed. In that situation, paying attention to interoceptive information is a way to amplify the (by definition) weak imaginative sensations.

The present description in terms of a processing loop can be connected to the abundant literature on motor and mental imagery together with the role of visualization in sports and motor expertise (for a review, see Ridderinkhof & Brass, 2015). Based on the idea that motor mental imagery and overt action execution recruit partially overlapping neural circuits (leading to the notion of “functional equivalence”), theoretical frameworks have been developed to reach maximal effectiveness of mental imagery in sport training (e.g., the PETTLEP model by Holmes and Collins, 2001). The general goal is to activate as much as possible all the dimensions involved in the real action (i.e., the Physical experience, the Environment, the Task, the Timing, the Learning, related Emotions, and Perspective). The logic is therefore very similar to ours by using various ways of amplifying the imaginative signal to make it as strong as the real one (Pearson, Naselaris, Holmes, & Kosslyn, 2015).

While the present experimental manipulation seemed to support this information-processing description of ideomotor and motor-control hypnotic phenomena, can we extend this logic to other hypnotic items, such as the cognitive/perceptual items that involve seeing, hearing, smelling, feeling, or tasting something that is not actually

events. The notion of a loop between sensations and imaginative perceptions is more consistent with more dynamical descriptions of the perceptive awareness cycle (e.g., Dehaene & Changeux, 2011; Lamme, 2006).

physically present? These suggestions are known to be the most difficult to experience (Barnier & McConkey, 2004; Heap, Brown, & Oakley, 2004), and the recent literature on the cancellation of the Stroop effect in highly hypnotizable participants (i.e., *highs*) provides another set of empirical evidence indicating qualitative differences between participants regarding certain suggestions (e.g., Raz, Shapiro, Fan, & Posner, 2002). The *highs* who succeed on the most difficult items in current hypnotizability scales may indeed be characterized by unusual information-processing capabilities.

Highs do not seem to have any distinctive cognitive feature regarding inhibitory or executive control processes, or attentional capacity (Dienes et al., 2009). For example, there is no difference between *highs* and *lows* on Stroop or Flanker tasks in the normal waking state (Iani, Ricci, Gherri, & Rubichi, 2006; Kallio, Revonsuo, Hämäläinen, Markela, & Gruzelier, 2001). Even under hypnosis, and without any suggestion concerning their reading performance, *highs* perform no better than *lows* on the Stroop task (Aikins & Ray, 2001; Egner, Jamieson, & Gruzelier, 2005; Kaiser, Barker, Haenschel, Baldeweg, & Gruzelier, 1997; Kallio et al., 2001; Jamieson & Sheehan, 2004; Raz & Campbell, 2011; Raz et al., 2003; Raz et al., 2002, 2005; Sheehan, Donovan, & MacLeod, 1988). Thus, *highs* do not seem to produce any specific pattern of performance when tested with standard cognitive protocols. Differences seem to appear when they are specifically tested on their imagination and their ability to distinguish the real world from their imagination.

Highs' pattern of responses to hypnotic (Kihlstrom, 2015; Terhune, 2015) or post-hypnotic (McConkey & Barnier, 2004) suggestions is heterogeneous. Terhune, Cardeña, and Lindgren (2011a) recently proposed dividing *highs* into two subcategories with

distinct cognitive profiles and different mechanisms behind their responses (see also Terhune, Cardeña, & Lindgren, 2011b). Some high appear to have superior imaginative abilities, while others are more liable to judge as real, things that are just imagined, meaning that they are more likely to confuse imagination and reality when monitoring interoceptive or perceptual information (Barber, 1999; Brown & Oakley, 2004; Kunzendorf & Boisvert, 1996).

Santarcangelo (2014) also argued that highs may rely on a preferential employment of the kinesthetic modality of imagery. Following this reasoning, highs could be more sensitive to bodily sensations (or more trained to process them) and be more inclined to pay attention to this internal information. Amplification of the weak imaginative signal could therefore be more efficacious for them.

Returning to the issue of how to increase participants' pass rate on cognitive/perceptual items by applying the logic we used in the present set of experiments, studies of highs suggest that experimental manipulations could be targeted to further enhance imaginative processes or reduce the monitoring of interoceptive or perceptual information, in order to increase the confusion between imagination and reality. However, one major hurdle, compared with ideomotor and motor-control items, is how to generate sufficiently strong imaginative activity to override sensory inputs. While it seems reasonably feasible to retrieve from memory the sensorimotor activity related to heaviness, for example, and to activate these sensations as though they were real, applying the same logic to the visual perception of a red apple by trying to imagine it green seems much harder for most people, owing to the sensory strength of colors and visual information.

As a limitation of the present study, we did not test our participants with a full hypnotizability scale to determine the number of highs, mediums or lows enrolled in each experiment. We also did not measure interoceptive abilities in our sample nor the level of engagement or compliance in the tasks. However, by using Item 0 and 3 as baseline controls, we verified that our three samples of participants from Experiment 1-3 had comparable hypnotic performances and were performing in the same range as the one reported in previous independent studies (see Table 2). More specifically, the fact that the scores for Item 3 were relatively stable across experiments indicate that the level of compliance was not affected by the instructions provided in Loop Item 8.

A reviewer also noticed that Loop Item 8 was systematically preceded by a wake-up instruction in Experiment 1 and 2. Therefore the observed effect could be due to this instruction that would make participants more responsive to the suggestion. This interpretation does not hold for Experiment 3, unless it is considered that the participants were also in a wake-up state before receiving the suggestion. However, if being in a wake-up state was inducing greater responsiveness to suggestions then participants should be less responsive to Item 0 in Experiment 3 compared to Experiment 1 or 2, which is inconsistent with the present results.

To conclude, the present study was based on an information processing approach and a working hypothesis that interoceptive and imaginative processes strongly interact when participants are exposed to ideomotor and motor-control suggestions from standardized hypnotic protocols. When we focused on one specific item from a standardized hypnotizability scale (i.e., Item 8 of the SHSS: C; Wietzenhoffer & Hilgard, 1962), we found that responsiveness to this item could be increased by further activating

this processing loop. Whether the same strategy could be used to increase responsiveness for more difficult items (i.e., cognitive-perceptual items) is still an open question. Meanwhile, adopting an information processing approach to study each item in the standard hypnosis protocols is definitely a worthwhile strategy for studying the ability of participants to generate hypnotic responses.

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Conflict of Interest

AP and AR declare that they have no conflict of interest.

Ethical approval

All procedures performed in the present studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.


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Table 1. Mean responsiveness scores for each item and for the group in Experiments 1-3.

	Item 0	Item 3	Item 8	Loop Item 8
Experiment 1	1.52 (1.22-1.81)	1.42 (1.00-1.85)	1.42 (1.02-1.82)	2.42 (2.09-2.75)
Experiment 2	1.42 (1.04-1.8)	1.47 (0.96-1.98)	-	2.63 (2.26-3.00)
Experiment 3	1.84 (1.46-2.22)	1.42 (0.94-1.9)	-	2.16 (1.61-2.71)

Note. 95% confidence intervals are in parentheses; Item 0 = induction by eye closure; Item 3 = mosquito hallucination; Item 8 = arm immobilization; Loop Item 8 = arm immobilization with increased activation of imaginative processes. Scores range from 0 to 3.

Table 2. Percentages of participants who successfully performed Item 8 in SHSS-C across different samples.

Experiment	USA	Spain	Italy	Exp. 1.
Item 3 (mosquito)	48%	60%	53%	52%
Item 8 (arm im.)	36%	59%	63%	48%

Note. mosquito = mosquito hallucination; arm im. = arm immobilization. USA = data reported in Hilgard (1965). Spain = data reported in Lamas et al. (1996). Italy = data are reported in De Pascalis et al. (2000).

Appendix 1: Instructions (French version)

Instructions were translated from the *Stanford Hypnotic Susceptibility Scale - SHSS: C* (Wietzenhoffer & Hilgard, 1962). They correspond essentially to a translation of the SHSS except for the term "hypnosis" that has been systematically deleted. This choice comes from the extremely variable beliefs that individuals can have about hypnosis, beliefs that can both facilitate or inhibit the individuals to whom this test is proposed. Also, even if the instructions remain substantially the same, there are no mention of hypnosis but of imagination, introspection and cognitive activities.

A) General organization

1- When participants arrived in the testing room, they are installed in a semi-circle facing the experimenter. They are asked to turn-off their mobile phone and a short discussion starts about their studies. We finally thank them for their participation.

2- They receive information about the experiment which is about the role of imagination in our perception of the world. They also receive a consent form.

3- The experimenter explains that, as part of the experiment, we need to make a video capture and that a camera is installed in order to see all the participants. We reassure them that this video will only be used for research purposes. They are then asked to sign the consent form.

4- At the end of the session, we make sure that all participants are doing well and that they have come out of the experience. We finally thank them again for their participation.

B) Instruction for the induction – Item 0 (in French)

Je vais vous demander de choisir un point sur le mur et de le fixer attentivement. J'appellerai ce point la « cible ». Je vais vous demander de vous détendre en vous asseyant confortablement sur votre chaise, en posant simplement vos mains sur vos jambes, et de fixer la cible sur le mur tout en écoutant simplement ma voix. Je vais ainsi vous donner quelques instructions qui vont vous aider à vous détendre et à vous concentrer encore plus sur la cible.

(1) Tout en continuant à écouter mes paroles, je vous demande de bien fixer la cible et de vous concentrer à la fois sur la cible et sur mes paroles. Je vous demande de faire de votre mieux pour fixer la cible tout en laissant venir toutes les sensations qui peuvent se présenter à vous. Autorisez-vous à porter pleinement votre attention sur la cible, sur ces sensations et sur ce que je suis en train de vous dire. Si votre esprit commence à partir sur d'autres pensées, je vous demande de ramener simplement vos pensées sur la cible ainsi que sur mes paroles.

(2) Je vous demande maintenant de vous relaxer et de vous détendre, de plus en plus et de mieux en mieux. Continuez de regarder la cible aussi fixement que vous le pouvez, et ne pensez qu'à elle et à mes paroles. Si vos yeux commencent à dériver, ne les laissez pas partir. Re-concentrez-vous simplement à nouveau sur la cible. Portez attention à la façon dont la cible change, à la manière dont les ombres jouent autour d'elle, comment elle devient parfois floue, ou au contraire très claire et nette. Quel que soit ce que vous percevez, tout est bon et agréable à prendre. Laissez venir à votre esprit tout ce qui peut apparaître, mais continuez de rester concentré sur la cible encore un peu. Maintenant que vous avez regardé la cible suffisamment longtemps, je vous propose

de simplement constater que vos yeux se sentent un peu fatigués, et que tout naturellement, ils se mettent à cligner. Vous pouvez même avoir envie de les fermer. Vous pouvez alors éventuellement les laisser se fermer par eux-mêmes et noter les sensations agréables que cela vous procure.

(3) Vous êtes maintenant bien concentré, très détendus et vous pouvez même ressentir un certain bien être. Vos yeux sont fermés ou se ferment progressivement et vous pouvez adopter une respiration calme et sereine tout en restant concentré sur la cible sur le mur. Vous êtes de plus en plus détendu et vous vous sentez de mieux en mieux.

(4) Tout votre corps est maintenant gagné par cette détente. Si vos yeux ne sont pas encore fermés, vous pouvez constater que vos paupières clignent de plus en plus et que vous vous sentez de mieux en mieux. Continuez à focaliser votre attention sur ce que je dis; écoutez ma voix et n'oubliez pas de vous concentrer aussi sur la cible sur le mur. Si vos yeux sont fermés, vous pouvez maintenant vous concentrer aussi sur votre respiration qui devient de plus en plus calme, ce qui vous procure des sensations de plus en plus agréables. Si vos yeux sont encore ouverts, vous pouvez maintenant les fermer doucement tout en respirant de plus en plus calmement. Voilà. Tout en n'oubliant pas la cible sur le mur, vous constatez que vous vous sentez de mieux en mieux et de plus en plus détendus.

(5) Pour les quelques personnes qui auraient éventuellement les yeux encore ouverts, je vous demande maintenant, de fermer vos yeux volontairement.

Score +3 if the eyes are closed after Paragraph 2

Score +2 if the eyes are closed after Paragraph 3

Score +1 if the eyes are closed after Paragraph 4

Score 0 if the eyes are closed after Paragraph 5

C. Deepening instructions (in French)

Maintenant, vous êtes profondément détendus, et vous allez vous détendre encore plus, beaucoup plus. Vos yeux sont maintenant fermés. Vous allez les garder fermés jusqu'à ce que je vous demande de les ouvrir.

Relaxez-vous de plus en plus. Plus vous pensez à vous détendre, plus vos muscles se détendent. Vous allez commencer par relâchez les muscles de la jambe droite... Maintenant, faites la même chose avec les muscles de la jambe gauche... Laissez la détente s'installer partout en vous... Relaxez la main droite maintenant, puis l'avant-bras, le bras, l'épaule... Voilà... Maintenant, la main gauche... l'avant-bras et le bras... puis l'épaule. Détendez le cou et la poitrine... Encore plus détendu que cela... complètement détendu.

D. Count up (in French)

Plus vous continuez à écouter ma voix, plus vous plongez dans cette sensation de détente... Dans un instant je vais compter de 1 à 10. Plus le compte avancera plus vous vous sentirez plonger, toujours plus loin, dans une détente profonde et réparatrice, où vous serez en mesure de faire ce que je vous demande de faire sans vous réveiller, jusqu'à UN ... Vous allez vous détendre plus profondément... DEUX... Plongez vers le bas, vers le bas dans une détente toujours plus profonde... TROIS, QUATRE... de plus en plus détendu... CINQ, SIX... Vous vous laissez envahir par une détente très profonde. Rien ne peut vous déranger... Restez toujours concentré sur ma voix et sur les choses

auxquelles je vous demande de penser, vous vous détendez toujours de plus en plus... SEPT, HUIT, NEUF... Profonde détente... Proche du sommeil... DIX Vous êtes maintenant extrêmement détendu. Vous sortirez de cette détente que lorsque je vous le demanderai. Vous allez maintenant profiter de ces sensations de détente confortablement et vivre les expériences que je vais vous décrire. Vous serez en mesure de parler, de bouger, et même d'ouvrir les yeux si je vous demande de le faire, et tout en restant détendu comme vous l'êtes maintenant. Peu importe ce que vous ferez, vous resterez profondément détendu jusqu'à ce que je vous invite à sortir de cette détente profonde...

E. Item 3 : mosquito hallucination (in French)

Jusqu'à maintenant vous m'avez écouté avec concentration, en m'accordant toute votre attention. Ainsi, vous n'avez pas pu remarquer le moustique qui était en train de voler dans la pièce... le bourdonnement de ce moustique... Écoutez le maintenant... Percevez son bourdonnement aigu comme s'il volait autour de votre main droite... Il atterrit sur votre main... peut-être cela vous chatouille-t-il un peu... Puis, il s'envole à nouveau... Vous entendez plus fort son bourdonnement... Maintenant, il est de retour sur votre main, cela chatouille... Il pourrait vous piquer... Vous ne l'aimez pas ce moustique... Vous souhaitez vous en débarrasser... Allez-y, chassez le... Débarrassez-vous de lui s'il vous dérange...

Wait for 10 seconds and look at the responses

Ca y est, il est parti... Tout redevient calme... Voilà un soulagement... Vous n'êtes plus dérangé... Le moustique a disparu... maintenant vous vous relaxez, vous vous détendez complètement.

Score +3 for a large movement

Score +2 for a moderate movement

Score +1 for a small movement

Score 0 if no movement

F. Item 8 : arm immobilization (in French)

Vous êtes toujours très détendu et confortablement installé avec une sensation de lourdeur et de bien être dans tout votre corps. Vos mains sont bien posées sur vos jambes et vous vous sentez bien, de mieux en mieux. Je voudrais maintenant que vous pensiez à votre bras et à votre main gauche. Portez-y toute votre attention... Vous allez les sentir s'engourdir et devenir lourds, très lourds... Ressentez combien votre main est lourde... Plus vous pensez qu'elle est lourde, plus la lourdeur se développe...

Votre bras gauche aussi devient plus lourd... lourd... de plus en plus lourd... Votre main devient plus lourde, très lourde, comme si elle s'enfonçait sur la surface sur laquelle elle repose. Vous pouvez maintenant percevoir à quel point votre main est lourde... Elle vous semble beaucoup trop lourde pour pouvoir bouger... Cependant, malgré sa lourdeur, peut-être pouvez-vous la déplacer un peu, ou peut-être est-elle trop lourde même pour cela... Pourquoi ne tenteriez-vous pas de percevoir à quel point elle est lourde... Essayez simplement de lever votre main... Juste essayez

Wait for 10 seconds and look at the responses

Très bien... Arrêtez d'essayer... Détendez-vous Votre main comme votre bras retrouvent leurs sensations normales, maintenant. Ils ne sont plus lourd. Détendez-vous Détendez-vous de partout.

Score +3 if no movement

Score +2 if the arm moves less than 3 cm during the period of 10s.

Score +1 if the arm moves from 3 to 10 cm during the period of 10s.

Score 0 if the arm moves higher than 10 cm during the period of 10s.

G. Wake-up (in French)

Très bien. Continuez à rester calme et détendu comme vous l'étiez. Vous allez commencer à revenir ici dans le présent dans un instant. Pour vous y aider je vais compter de DIX à UN. Quand je dirais UN vous ouvrirez les yeux, vous serez éveillé, réveillé dans un parfait état de forme, totalement dans votre corps et dans le présent, en pleine possession de vos moyens.

DIX, NEUF, HUIT... vous revenez dans cette pièce, sur votre chaise et vous reprenez le contrôle de toutes les parties de votre corps... SEPT, SIX, CINQ... Vous entendez ma voix plus forte et reprenez conscience de votre environnement extérieur... QUATRE, TROIS, DEUX... Vous vous réveillez complètement et sereinement... UN vous ouvrez les yeux, vous êtes éveillé, réveillé dans un parfait état de forme, totalement dans votre corps et dans le présent, en pleine possession de vos moyens.

H. Loop Item 8 (in French)

(1) Je vous propose de rester confortablement installé sur votre chaise... Je vais vous demander maintenant d'utiliser volontairement toutes vos capacités d'imagination. Imaginer ne veut pas dire juste penser, mais véritablement vivre « comme si » l'expérience était réelle. Vous pouvez faire cet exercice en refermant maintenant les yeux et en gardant le silence. Allez-y.

Si vous m'avez compris faites-moi un signe oui de la tête. Bien...

(2) Imaginez maintenant que votre bras gauche est d'une lourdeur extrême... tellement lourd que vous êtes incapable de le bouger, ni de le lever. Quand vous parvenez à l'imaginer faites-moi un signe oui de la tête tout en continuant à rester dans votre imagination, le temps que tout le monde y parvienne. Bien...

(3) Maintenant, tout en continuant à rester dans cette imagination, imaginez que vous êtes bloqués dans cette imagination. Imaginez que quoi que vous fassiez vous ne puissiez pas en sortir... Imaginez que quoi que vous fassiez, votre bras gauche reste tellement lourd que vous êtes incapable de le bouger, ni de le lever.... Quand vous parvenez à l'imaginer faites-moi un signe oui de la tête tout en continuant à rester dans votre imagination, le temps que tout le monde y parvienne. Bien...

(4) Maintenant tout en continuant à imaginer, essayer de lever le bras...

Wait for 10 seconds and look at the responses

Très bien... Arrêtez d'essayer... Et arrêtez d'imaginer... Vous reprenez le contrôle de votre bras qui retrouve instantanément ses sensations normales... Détendez-vous et bougez votre bras...

Score +3 if no movement

Score +2 if the arm moves less than 3 cm during the period of 10s.

Score +1 if the arm moves from 3 to 10 cm during the period of 10s.

Score 0 if the arm moves higher than 10 cm during the period of 10s.