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Comments

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Title

Difficult Turned Easy: Suggestion Renders a Challenging Visual Task Simple

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Keyword

Suggestion, Hypnosis, Perception, Visual Imagery, Perceptual Integration

Abstract

Suggestion, via attention and motivation, can cause some individuals to miss or disregard existing visual stimuli; but can it infuse sensory input with non-existing information? While several prominent theories of hypnotic suggestion propose that mental imagery can change our perceptual experience, data to support this stance remain sparse. The present study addresses this lacuna, showcasing how suggesting the presence of physically-absent, yet critical, visual information recasts an otherwise difficult task into an easy one. Here we show how adult participants, highly susceptible to hypnotic suggestion, successfully hallucinated visual occluders atop an established visual paradigm requiring perceptual integration of object motion. Our findings support the idea that, at least in some people, suggestions can add perceptual information to sensory input. This observation carries meaningful weight to theoretical, clinical, and applied aspects of the brain and psychological sciences.

Statement of Relevance

Mounting evidence shows that hypnotic suggestion can regulate various kinds of perceptual experiences, such as pain. Yet, most of these findings involve reducing or supressing an experience. In the present research, we asked a complementary question – can a hypnotic suggestion enhance or increase perceptual experience? To test this question, we identified young adults who scored especially high or low on a scale of hypnotic suggestibility. We then provided these individuals with the suggestion that they would be able to perceive phantom (i.e., non-existent) geometric shapes on a computer screen while completing a visuo-spatial task. Our experimental approach rested on the idea that being able to imagine these geometric shapes on the screen would benefit participants' performance on this otherwise difficult task. Our results are consistent with this prediction and show that the suggestion improved performance of individuals who scored high on the suggestibility scale, while having little effect on those who scored low. These findings imply that individuals susceptible to hypnotic suggestions are capable of creating novel perceptual experiences.

Introduction

Suggestions can dramatically alter how individuals processing perceptual information (e.g., Lifshitz, Aubert Bonn, Fischer, Kashem, & Raz, 2013), including the suppression of visual inputs on visual processing (Schmidt, Hecht, Naumann, & Miltner, 2017). Conversely, evidence remains ambiguous as to whether they can reliably infuse novel information into the perceptual stream, which contrasts with prominent theories that emphasize the ability of hypnosis to generate perceptual experiences and hallucinations (e.g., Kirsch & Braffman, 2001; Martin & Pacherie, 2019; Spiegel, 2003). In particular, glaring caveats often weaken findings that support such viewpoints like reliance on self-reports prone to bias and demand characteristics (e.g., Kirsch et al., 2008), reverse inferences from brain imaging (e.g., McGeown et al., 2012), as well as small samples and anecdotal case studies (e.g., S. Kallio & Koivisto, 2013). Further highlighting these limitations, recent findings intimate that suggestions induce a response bias for hallucination-prone individuals in noisy perceptual contexts (Alganami, Varese, Wagstaff, & Bentall, 2017). Accordingly, positive hallucinations may correspond to a re-interpretation of the sensory experience rather than genuine changes to the perceptual content. Research into consciousness deals with a similar conundrum where reports of awareness may sometimes follow from a response bias (Peters, Lau, & Ro, 2016). Some researchers have attempted to address this particular issue in the context of hypnotic hallucinations by inducing synesthesia-like experiences through posthypnotic suggestions and then validating the effect with a challenging perceptual task (Anderson, Seth, Dienes, & Ward, 2014; Cohen Kadosh, Henik, Catena, Walsh, & Fuentes, 2009; Sakari Kallio, Koivisto, & Kaakinen, 2017)--heretofore, however, with mixed results (Schwartzman, Bor, Rothen, & Seth, 2019).

Following these shortcomings, the current research examines whether a suggestion to append novel information to perception can transform a difficult perceptual task into an easy one. Our goal was to provide support for the idea that suggestion can instigate perceptual information endogenously while avoiding the aforementioned limitations. To this end, we relied on occlusion-related perceptual integration of object motion, where the presence of shape stimuli at the apex of moving lines produces the percept of an occluded figure performing a circular revolution around a central axis (Figure 1; Lorenceau & Shiffrar, 1992). Critically, this particular percept vanishes whenever the occluding shape stimuli are removed from the display, making it nearly impossible to see the geometric figure and the direction of the revolution without the occluders. We accordingly examined whether a suggestion to imagine the occluders would allow individuals who exhibit greater sensitivity to suggestions, namely highly hypnotizable individuals (HHIs), to experience perceptual integration of the line stimuli and thereby perceive the geometric figure. We compared their performance against that of low hypnotizable individuals (LHIs), as well as against several cohorts of control participants who completed the task both online and within our laboratory.

Methods

Participants. Our samples were of convenience. We pre-screened individuals for hypnotic susceptibility using the Harvard Group Scale of Hypnotic Susceptibility, Form A (HGSHS: A; Shor & Orne, 1962) from a pool of approximately 500 students in psychology classes at McGill University. Our final sample comprised 16 HHIs (i.e., HGSHS: A > 8) and 16 LHIs (i.e., HGSHS: A score < 4). We recruited additional participants, not screened for hypnotizability, who completed the task in the absence of occluders and without receiving the suggestion--14 completed the task in our laboratory and 186 online. To ascertain possible learning effects, we invited 49 random participants, who completed the task online, to a second session in our research laboratory. Two additional samples performed the task with occluders present–-i.e., 46 participants completed the task online and 17 completed it in the laboratory. All participants (N = 295, 215 women; mean age = 20.81 years; S.D. = 2.27) had normal or corrected-to-normal vision and received course credit in exchange for participation. See supplementary Figure 1 for a diagram describing groups and corresponding experimental conditions.

Short of information regarding the effect size of the experimental suggestion on HHIs for this visual task, we based our sample size for the suggestion conditions on a collection of studies from our own group that similarly investigated the influence of hypnotic suggestion on perception and cognition (for review, see Lifshitz et al., 2013). We reasoned that a meaningful effect size should be at least comparable and easily detectable with a sample of the same size. Following this rationale, we pooled data from our previous studies and performed simulations to estimate the minimal sample size required to achieve a power level of .8 for the detection of the effect of suggestion in HHIs at α = .05 (see supplementary material for details). This procedure revealed a modest effect size of hypnotic suggestion in HHIs (i.e., $R^2_{GLMM(m)}$ = .14), while 13 HHIs were required to attain a power level of .8 for α = .05. Our current sample size aligns with these observations.

When participants performed the task without occluders during controlled conditions, we aimed to recruit as many online participants as possible from psychology classes at McGill University. In contrast, the subset of individuals asked to complete the control task in our laboratory was comparable in size to both our HHIs and LHIs groups. The sample size for participants who completed the task twice merely followed from the limited potency of the learning effects, which we observed in preceding pilot experiments. Here, we aimed to have a large enough sample to assess any potential effect, yet the effect size was quite modest (*d* = .28). Lastly, given that the performance was at ceiling in the presence of occluders, we aimed for a sample size comparable to the suggestion group to ensure a proper comparison. Both our online and laboratory samples met this criterion. All procedures were approved by the local institutional review board.

Task and Procedure. We constructed a web-based Adobe Flash® task that we distributed to participants via a Uniform Resource Locator (URL) in email invitations. We designed the task--hereafter, MoTraK--based on the occlusion-related perceptual integration of object motion (Figure 1; Lorenceau & Shiffrar, 1992). The task comprises trials with moving occluded diamond, square, and triangle, and inverted triangle. The task accordingly involved 72 outlines of each geometric shape in motion--i.e., 18 trials for diamonds, 18 for squares, 18 for triangles, and 18 for inverted triangles--with vertices occluded by shapes that matched the color of the background. Subsequently, only segments of the geometric outlines (i.e., four straight line segments on diamond/square trials and three straight segments for triangle/inverted triangle trials) were visible. We relied on homogenous web colors: uniform grey for the lines (#666666, RGB: R=102, G=102, B=102; CMYK: C=60, M=51, Y=51, K=20) and black for the background (#000000 RGB: R=0, G=0, B=0; CMYK: C=75, M=68, Y=67, K=90) resulting in medium contrast which creates a low coherence of motion. We rotated the diamond by 45º to create a square stimulus and flipped the triangle to create an inverted triangle stimulus. We randomly varied the order of these stimuli on the screen across trials to discourage participants from replacing the occluders with physical objects affixed to the screen (e.g., stickers). A second version of the task contained fully visible occluders inked in white (#ffffff, RGB: R=255, G=255, B=255; CMYK: C=0, M=0, Y=0, K=0). When sitting approximately 45cm away from the screen, the width and height of the lines for the diamond/square stimuli approximated 5.7 d.v.a and 1.3 d.v.a, respectively, while the square occluders roughly measured 6.3 d.v.a. For the diamond/square stimuli the length of lines approximated 7.6 d.v.a, while the pentagon occluders were estimated at 8.8 d.v.a. All target stimuli were centered and would perform small circular revolutions around the fixation point (see Figure 1).

Throughout the task, the diamond/square shapes would solely move in a clockwise or counterclockwise fashion, whereas the triangle/inverted triangle could move in a clockwise, counterclockwise, but also directionless motion--i.e., neither clockwise nor counterclockwise. Note that the directionless motion could therefore only occur for the triangle shape. For directionless motion trials, the shape would move around the fixation point without following a specific trajectory while repeatedly expanding and then shrinking in size. We included the directionless motion for triangles/inverted triangles as catch trials. Participants were aware of these contingencies.

Our Adobe Flash® interface recorded, and immediately sent the measures to a php–MyAdmin password protected MySQL^{TM} online database. The program recorded responses when participants depressed keys on a keyboard: the “F”, “J”, and spacebar keys for counterclockwise, clockwise and directionless motion for triangles and inverted triangles, respectively. Participants completed the task in two separate blocks: The first block comprised only diamond/square trials, while the second one included only the triangle/inverted triangle trials. We opted for this design because we wanted to avoid confusion and ensure that participants only considered the response option of directionless motion during triangle/inverted triangle trials.

To ensure that participants understood the task well, we included two short training periods in the pre-assessment of MoTraK. During the first training session, participants went through consecutive 15-second interactive demonstrations, in which they could make the occluders visible or invisible on a moving--first clockwise, then counterclockwise--pentagon shape. Using a pentagon for training prevented exposure to the actual stimuli prior to data collection. Next, participants practiced on a few trials with feedback stating whether they were "correct" or "incorrect.” These practice trials consisted of six pentagon pseudo-randomized trials, three clockwise and three counterclockwise. After the practice trials, we informed participants that they would no longer receive feedback. The second training block occurred between the diamond/square and the triangle/inverted triangle blocks, during which participants viewed a single interactive demonstration of directionless motion on a pentagon. To ascertain comprehension, the post-assessment of MoTraK included no demonstrations, only three practice trials with feedback. Instructions emphasized both speed and accuracy. The overall task lasted about 15 minutes.

Procedure for HHIs and LHIs. First, for testing performance without suggestion, we sent an email to all potential participants providing them with a URL of the web page hosting MoTraK and inviting them to complete the task online in a calm environment of their choice. The online consent forms informed participants of their right to withdraw from the study at any time and that information and data gathered, including response time and accuracy, would be used only for scientific research. We gathered demographic information, as well as IP addresses, which allowed us to identify and exclude participants, who completed the task more than once. In addition, MoTraK automatically assigned a random number (i.e., a unique completion code) to each participant. This number was required to complete the post-assessment. During the first session without suggestion, participants were unaware that this research involved suggestion. This strategy minimizes the potential influence of holdback effects. Approximately a week after their online participation, we approached participants by email and invited them to participate in a second session at our laboratory. Upon arriving at the laboratory, an experimenter greeted and obtained informed consent, disclosing that they would receive a hypnotic suggestion. The experimenter then escorted participants to a separate room to meet with one of the authors (A.R), a researcher with more than 30 years of experience working with hypnosis and a diplomat of the American Board of Psychological Hypnosis. A.R. administered a hypnotic induction adapted from the Carleton University Responsiveness to Suggestion Scale (Spanos, Radtke, Hodgins, Stam, & Bertrand, 1983). He then suggested to all participants that they would be able to view the occluders at the vertices of the moving lines while playing MoTraK, and that this hallucination would allow them to perform the task quickly and easily. A script of the suggestion is available in the supplementary materials. Induction and suggestion took about ten minutes. Thereafter, participants completed the task. Upon completion, A.R. administered a standard hypnotic termination. The experimenter then escorted participants out of the room for debriefing. Accordingly, we tested participants under two conditions: first at baseline without suggestion, and then with a specific suggestion to perceive phantom occluders covering the otherwise uncovered corners. Note that A.R. was blind as to whether participants were LHIs and HHIs.

Procedure for online participants. We provided all participants with a URL to MoTraK and asked them to complete the task online. A written notice in the task asked them to complete the computer task in a calm environment, free from distractions. Participants provided consent by clicking on the “Accept” button following the consent information. We gathered demographic information, student identification numbers and IP addresses to avoid repeated participation.

Procedure for participants in the laboratory. In the laboratory, the experimenter greeted participants and led them into a quiet room with a computer. The experimenter sat beside participants to monitor their engagement and ensure that they refrain from utilizing alternative strategies while performing the task (i.e., participants would remain seated in a stable and appropriate position: looking forward with their eyes normally open, looking at the target without averting their gaze, at an approximate distance of 45cm from the screen).

For those who completed the task twice, participants received an automatically generated email inviting them to participate once again in our study, either online or at our laboratory. The purpose here was to control for learning effects. Moreover, an additional group of participants completed the task with white occluders present. We expected this experiment to yield ceiling effects across participants because the percept effortlessly emerges as soon as the occluders become visible.

Analysis. We removed anticipation (< 150ms) and timeout (> 3 s.d from mean) trials based on response times. Overall, anticipation trials corresponded to less than 1% of total trials, whereas timeout trials represented approximately 1% of total trials. No additional observations were removed from analysis. We gauged overall performance using hierarchical single-trial logistic regression predicting accuracy for each trial (i.e., correct versus incorrect discrimination) and including hypnotizability (i.e., low versus high), suggestion (with versus without), shape (i.e., square/diamond versus triangle/inverted triangle) and their interactions as fixed factors; as well as the participants as random factors. MATLAB© (Mathworks, MA; version R2017B) and the *fitglme* function fitted all regression models. We opted for the Laplace fitting method and selected the best fitting model via goodness-of-fit Chi-square test over deviance ($\alpha = .05$), and by evaluating the Bayesian Information Criterion (BIC). Post-hoc evaluations were performed using permutations pairwise t-tests (i.e., 10000 permutations).

We similarly compared task improvements for HHIs against several control conditions (Figure 2). We first compared the performance of HHIs without and with the suggestion against individuals who performed the same task online and in the laboratory. We relied on non-parametric two-tailed permutation tests (i.e., 10000 permutations) to compare mean accuracy rates.

Our goal was twofold: first, to validate that performance was no different between

HHIs and a matched-controlled group prior to receiving the suggestion; second, to demonstrate that the improvement in HHIs marked a significant departure from baseline performance following suggestions. One group of participants also performed the task twice, once online and another time in the laboratory, which allowed us to assess learning effects and underline how the improvement seen for HHIs related to that of learning. Here, we accordingly contrasted the difference in performance between the first and second session for this control group and the performance with-suggestion minus the performance without-suggestion for HHIs. Lastly, we compared the performance of HHIs with that of individuals who performed the task with occluders present. Again, one sample performed the task online and another in our laboratory. The purpose of this control condition was to accurately gauge the effects of endogenously hallucinating the occluders compared to performance when the occluders are physically present. In this way, we contrasted how visual imagery measured up against the actual perception of the occluders. Lastly, note that we further computed the Jeffrey-Zellner-Siow Bayes factor to evaluate evidence in favor of the null hypothesis using the default Cauchy r scaling value of .707 (Rouder, Speckman, Sun, Morey, & Iverson, 2009). Bootstrapped confidence intervals were computed using Matlab's *Bootfun* algorithm.

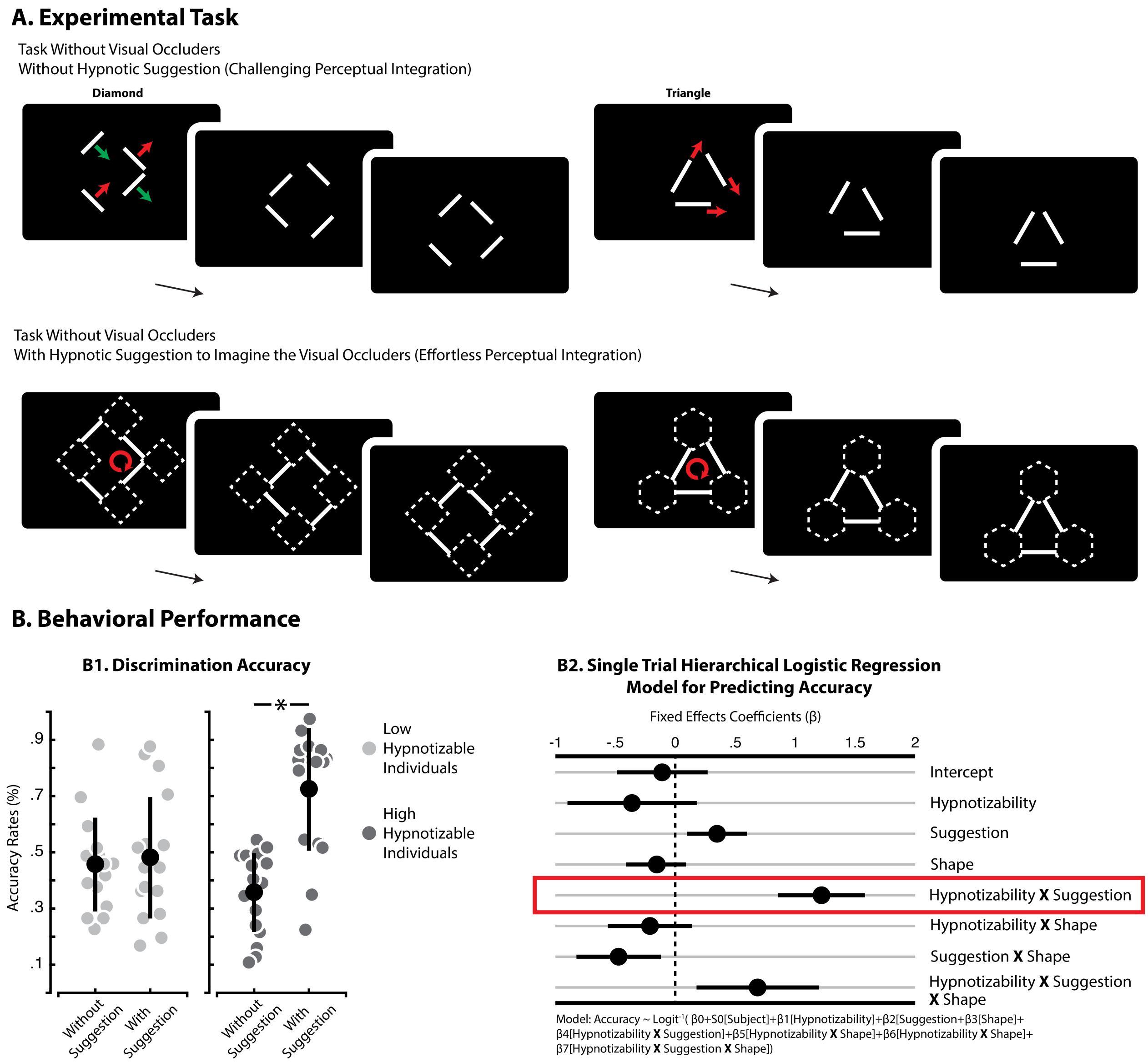

Figure 1. A) Schematic of the experimental task where we presented four or three moving lines in the diamond/square and triangle/inverted triangle trials, respectively (see Methods section). In line with the training trials and visual demos, we suggested to both HHIs and LHIs that they imagine the occluders at the vertices of the moving lines. Participants indicated the direction (i.e., clockwise, counterclockwise or directionless motion) of the moving shape. Without the occluders, this task is difficult because perceptual integration of the moving shape is nearly impossible to achieve, while the lines appear to be moving disjointly. Conversely, imagining the occluders allowed HHIs to experience perceptual integration and see the moving shape. Movies of diamond trials with and without occluders are available in the supplementary material. B) B1. Discrimination accuracy for LHIs and HHIs across conditions: with and without suggestion. Black dots represent average accuracy rates per condition while error bars correspond to bootstrapped 95% C.I. Grey dots represent individual performance. B2. Coefficients from single trial hierarchical logistic regression model for predicting accuracy. Here we plot the regression coefficients from the best fitting model following Chi-square goodness-of-fit statistics over the deviance and following the BIC. The red frame highlights the statistically reliable hypnotizability by suggestion interaction, which captures the perceptual gain in HHIs following the suggestion to imagine the occluders.

Results

Comparison of HHIs and LHIs. The performance of HHIs improved significantly, compared to LHIs, for whom the suggestion made little difference. We tested the efficiency of the suggestion to add new perceptual information (i.e., visualizing the occluders) by evaluating accuracy rates across all trials--i.e., trials involving diamond, square, triangle, and inverted triangle shapes--through hypnotizability and suggestion conditions (Figure 1). Here we relied on single-trial logistic regression where we predicted accuracy and included hypnotizability (i.e., LHIs versus HHIs), suggestion (i.e., with versus without), shape (diamond/square versus triangle/inverted triangle) and their interactions as fixed factors, as well as participants as random factors. Fixed factors were included in a stepwise approach. Our results show that the best fitting model included suggestion (β = .35, SE = .127, 95% CI [.1, .597]), the hypnotizability by suggestion interaction (β = 1.22, SE = .184, 95% CI [.857, 1.58]), the suggestion by shape interaction (β = -.471, SE = .18, 95% CI [-.824, -.118]), and the hypnotizability by suggestion by shape interaction (β = .69, SE = .26, 95% CI [.18, 1.2]) as reliable predictors. See Figure 1, as well as Tables 1 and 2 in supplementary material for details. Following the hypnotizability by suggestion interaction, post-hoc pairwise permutation tests confirmed limited benefits between conditions with suggestion and without suggestion for LHIs (M = .46, SD = .17 without suggestion; M = .48, SD = .23 with suggestion; t(15) = .65, p = .53; JZS BF = 3.25), whereas we reject the null hypothesis for HSIs when comparing performance with and without suggestion (M = .36, SD = .15 with suggestion; M = .72, SD = .22 without suggestion; t(15) = 5.14, p < .001, JZS BF = 239.88). These results are therefore consistent with our primary research objective and provide evidence for the hypothesis that the experimental suggestion would change how HHIs process perceptual information and subsequently improve their performance. Note that our analyses further confirmed that the hypnotizability by suggestion two-way interactions was reliable for both square/diamond and triangle/inverted triangle trials separately (see Tables 3 and 4 in supplementary material). Moreover, we further controlled for conservative strategies and the tendency to indicate motionless direction between LHIs and HHIs for diamond trials. This analysis shows no difference between both groups.

LHIs serve as a control group for HHIs, in the sense that they perform the exact same experiment. However, we wanted to gauge the benefits of suggestions on HHIs against additional control conditions. In particular, we looked at baseline performance when participants completed the task online (N=186) and in our research laboratory (N=14). This way, we could further certify suggestion-related improvements for HHIs against a larger sample. We similarly investigated learning effects in a group of individuals (N=49) who completed the task twice because HHIs also completed the task on two occasions. Lastly, we also compared the benefits of HHIs, who imagined the presence of the occluders, against participants who played MoTraK the occluders physically present (N=46 online and N=17 in our research laboratory), thereby comparing veridical perception with suggestion-induced visual imagery.

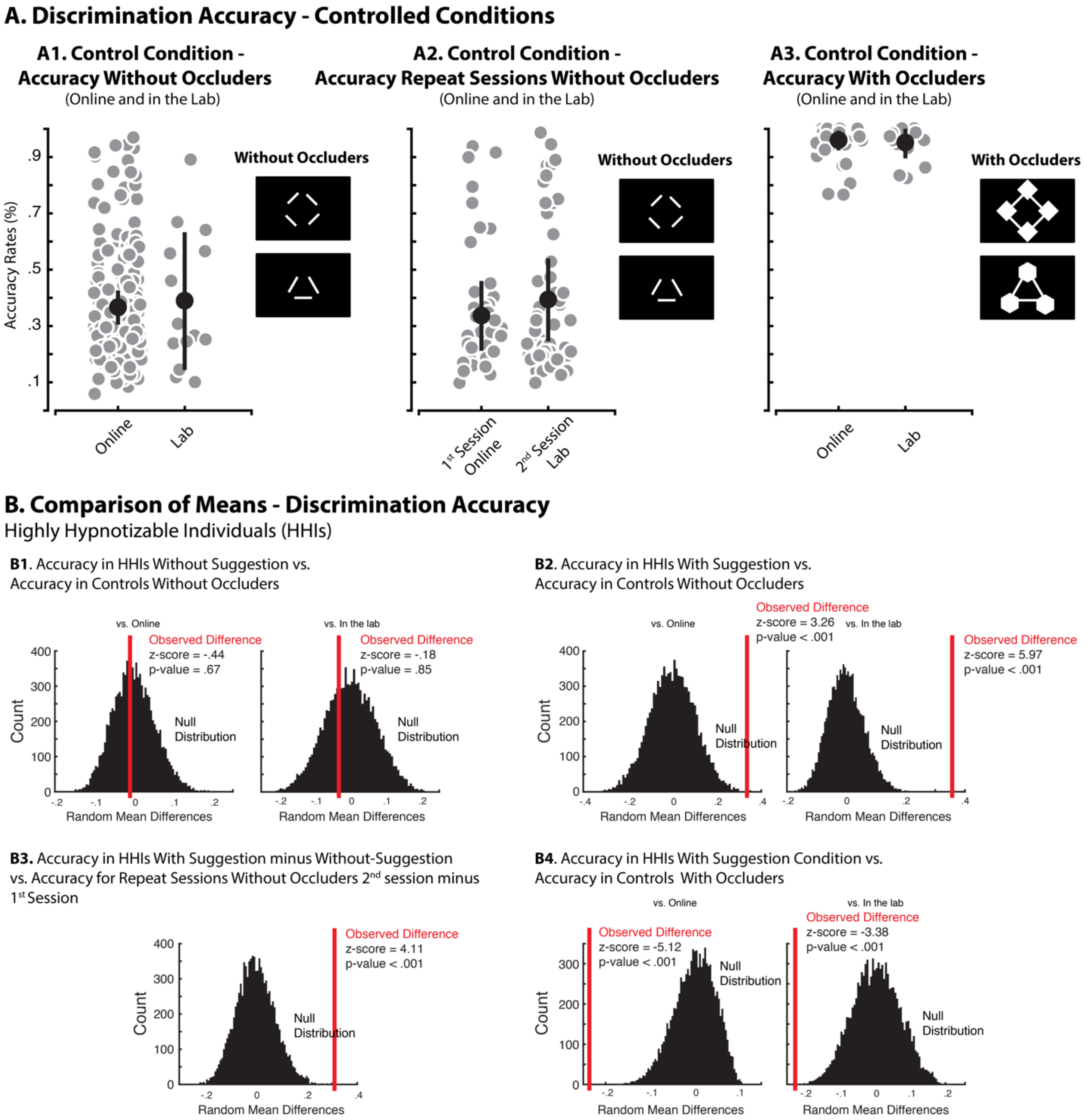

Figure 2. A) Discrimination accuracy rates across controlled experimental conditions for all trials (i.e., diamond, square, triangle, inverted triangle, see Methods section): A1. Performance of individuals who completed the task online and in our research laboratory while the visual occluders were absent; A2. Performance of individuals who completed the task twice, once online and then in our research laboratory, to control for learning effects; A3. Performance of individuals who performed the task with occluders online and then in our research laboratory. Black dots represent group averages and error bars correspond to 95% bootstrapped confidence interval. B) Null distributions of random permutations and observed differences following mean comparison tests for accuracy rates across the following comparisons. B1. We compared the performance of HHIs without suggestion against participants who completed the same task both online and in the laboratory. B2. We compared the performance of HHIs with the suggestion phase against participants who completed the same task both online and in the laboratory. B3. We compared the improvement of HHIs across sessions (i.e., performance with suggestion minus performance without suggestion) against the improvement of controlled participants who completed the same task twice (i.e., once online and then in our laboratory) without receiving suggestion (performance on second session minus first session) a. B4. We compared the performance of HHIs with the suggestion phase against participants who completed the task with visual occluders both online and in the laboratory.

Comparison of HHIs *against Control Condition Without Occluders.* We evaluated the performance of HHIs across sessions with- and without suggestion against the performance of the online and laboratory groups who completed the task without occluders (Figure 2). Here, we relied on permutation tests over the mean accuracy rate of each group. Without the suggestion, evidence indicates that HHIs performed similarly to both the online (Observed mean difference = -.0099; p = .86; *d* = -.06; Figure 2.B1) and laboratory groups (Observed mean difference = -.032; p = .67; *d* = -.16; Figure 2.B1). Conversely, evidence corroborates that, following the suggestion, HHIs performed better than the online group (Observed mean difference = .35; p < .001; *d* = 1.67; Figure 2.B2) and the laboratory group (Observed mean difference = .34; p < .001; *d* = 1.45; Figure 2.B2). Together, both analyses convey that HHIs performed similarly to the baseline groups without the suggestion, and significantly improved their performance with the suggestion, which further highlights how suggesting the presence of occluded improved performance on an otherwise difficult task.

Comparison of HHIs against Control Condition for Repeated Sessions. We also sought to assess learning effects on the task. Here, we aimed to corroborate that the benefits we observed for HHIs follow from the suggestion and not from learning. Note that the LHIs already provide information to that effect since they completed the task under the same experimental conditions than the HHIs, however we aimed for further confirmation with a larger sample. A separate group of participants therefore completed the task twice, once online and later in our laboratory. We first evaluated evidence of improvement for this controlled group with a permutation pairwise t-test over accuracy across the first and second sessions (M = .33, SD = .22 for first session; M = .39, SD = .26 for second session; t(48) = 1.92, p = .06; JZS BF = 1.51). Thus, evidence favored the null hypothesis, promoting that this group showed little improvement from the first to the second session. Comparing the perceptual benefits from both the HHIs (i.e., performance with-suggestion minus without-suggestion) and this control group (i.e., performance on second session minus first) further corroborated that the gain conferred by the suggestion, as we observed greater increase in performance for HHIs (Observed Mean Difference = .31; p < .001; *d* =

1.26; Figure 2.B3). These results, therefore, imply that HHIs improvement on the task does not follow from practice effects.

Comparison of HHIs against Control Condition With Occluders. Lastly, we wanted to evaluate how visual imagery of the occluders induced by the suggestion in HHIs fared against the actual presence of the occluding stimuli. One group of participants completed the task online and another in the laboratory with occluding stimuli located at the vertices of the moving lines. The presence of the occluding stimuli yielded ceiling effects for discrimination accuracy rates (Figure 2). Thus, as one would expect, the comparison between visual imagery and veridical perception of the occluders therefore revealed that, despite the significant performance improvement of HHIs following the suggestion, this benefit remained lower than both groups who completed the task with occluding stimuli in the display (Observed mean difference with online group = -.24; p < .001; *d* = -1.69; Figure 2.B4; Observed mean difference with laboratory group = -.23; p < .001; *d* = -1.64; see Figure 2.B4). Evidence therefore supports the notion that the suggestion conveys reliable perceptual benefits, albeit the subjective experience of visualizing the occluders with suggestion remains substantively different from actually seeing them.

Discussion

Here we show that a hypnotic suggestion to see non-existent occluders improves the performance of HHIs on a challenging visual task. In this fashion, our findings intimate that the suggestion afforded them with the capacity to experience perceptual integration by conjuring the presence of the occluders via endogenous means. These influences, fueled by a suggestion to add visual information to the perceptual stream, therefore yoke together top-down processes driven by expectation and mindset with bottom–up processing mostly driven by sensory inputs. The improvement of HHIs, relative to LHIs, alongside data from multiple control conditions, supports this idea. And yet, suggestion-based performance hardly reached that measured when occluders were present. Imagery therefore appears weaker than actual perception.

Although generalization to other perceptual processes goes beyond the present data, our findings complement other reports that document how expectation and cognition can govern stimulus-driven processes (Szechtman, Woody, Bowers, & Nahmias, 1998). Our results accordingly confirm the reliability of this framework to shed light on mental imagery and perceptual hallucinations. However, it remains uncertain whether the current experimental context applies to other forms of atypical perception, such as those observed in clinical disorders. Still, our work paves the road to a more scientific understanding of suggestion to elucidate mind–body phenomena, including the mechanisms underlying the influence of placebos, symbolic thinking, and expectancy.

Contributions

A.R. designed the experiment. A.R. collected the data and performed an initial exploration of the results with help from two students in the lab (see acknowledgments). M.L. analyzed the data in-depth and wrote a draft of the manuscript. M.L., J.D-C. J.S. and A.R wrote the final version of the manuscript. A.R and M.L. secured funding for this research project.

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Open Practice Statement

The experiment reported in this article was not preregistered. The data and codes for analyses are openly accessible at OSF: https://osf.io/25rpx/

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