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Can Hypnosis Make You Ticklish? Using Suggestion to Modulate Agency

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Sense of agency is the subjective sense of control we have over our actions. According to comparator model accounts, this arises when the predicted sensory effects of movements match actual sensory feedback. A consequence of this matching is sensory attenuation of self-generated actions. This explains why, typically, we cannot tickle ourselves. Mechanically manipulating the sensory consequences of actions, however, can create a mismatch and the illusion that they are externally produced; that is, self-tickling becomes ticklish. Across three experiments, we aimed to create similar alterations in agency using hypnosis. We compared different suggestions—based on real-world examples of agency disruptions—for participants of different levels of hypnotizability, with and without a hypnotic induction. We found that suggestions designed to model self-monitoring deficits increased perceived ticklishness. These effects were stronger in high-hypnotizable participants and after an induction. Demand characteristics may explain behavioral but not subjective responses to tickling.

Keywords: agency, hypnosis, involuntariness, self-monitoring, suggestion

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Modulating Responses to Self-Produced Tactile Sensations With Hypnosis

Sense of agency is the subjective experience of causing our intended actions. This is normally a very straightforward phenomenon: If you intend to raise your arm, it typically rises as you expect and you have the felt experience of causing this. This sense of agency is an integral aspect of our sense of self and experience of the world (Haggard, 2019). It highlights elements of our conscious experience that we have caused and allows us to differentiate self-produced effects from those caused by external sources (David, 2012). Alterations in the agency can occur, however, in certain contexts—such as artistic performance and sport (Csikzentmihaly, 1991) and some religious rituals (Cardeña et al., 2009; Hutch, 1980; Port, 2005)—and specific clinical conditions, such as passivity phenomena in schizophrenia (Frith et al., 2000b; Mellor, 1970; Spence et al., 1997). Laboratory-based paradigms can also alter sensory feedback and manipulate the sense of agency more directly (e.g., Daprati et al., 1997; Moore et al., 2009; Wegner et al., 2004). In this article, we aimed to integrate these two methodological approaches—naturalistic study of agency disruption and behavioral illusion paradigms—by creating a hypnotic version of an experimental task previously reported to influence the sense of agency. We modeled suggestions on different clinical conditions of disrupted agency and varied aspects of the hypnotic procedure to examine elements contributing to an altered sense of agency.

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Hypnosis and Agency Change

Hypnosis is a particularly powerful methodology for investigating the sense of agency for two reasons. First, participants in hypnosis reliably experience marked alterations in feelings of control. This is such a ubiquitous quality of hypnosis that Weitzenhoffer (1974) called the experience of diminished agency the "classical suggestion effect" (p. 264). A number of competing accounts have been proposed to explain this (see Lynn et al., 2010; Nash & Barnier, 2008). These theories generally posit that hypnosis either functions by impairing self-monitoring, such that individuals are unaware of the cause of their own actions, or by impairing control of self-generated actions, such that the hypnotists' suggestions are performed impulsively (Bowers, 1990; Bowers & Davidson, 1991; Dienes & Perner, 2007; Lynn et al., 2008). In either case, these impairments result in a feeling of involuntariness for hypnotic responses. As such, hypnosis presents an opportunity to investigate this otherwise difficult-to-isolate phenomenon.

Second, hypnosis is adaptable, meaning that there are multiple ways in which it could potentially influence the sense of agency (Woody & McConkey, 2003). There is evidence that individuals high in hypnotizability have general distortions in their sense of agency (Lush et al., 2016; Terhune & Hedman, 2017). Responding to standard hypnotic suggestions seems to be further associated with a reduction in sense of agency. In addition, it may be possible to use specific hypnotic suggestions to influence participants' perceptions and cognition in specific ways. This means that hypnosis may be able to create nuanced, targeted, and selective changes in participants' agentive experiences (e.g., Haggard et al., 2004). One application of this "instrumental" approach is using hypnosis to model and investigate other phenomena. Passivity phenomena in schizophrenia, for example, are characterized by the experience that body movements, emotions, and thoughts occur without their conscious intention (Mellor, 1970). Hypnotic suggestions based on these and other features of clinical disorders can be used to alter the sense of agency in healthy controls (e.g., Connors, 2015; Polito et al., 2018; Walsh et al., 2015). This can produce "virtual patients" with experiences and behavior functionally similar to the clinical condition but in a way that is time limited (Oakley & Halligan, 2009, p. 266).

A key finding in hypnosis research, however, is that not all participants respond to hypnosis in the same way. Individuals vary in their *hypnotizability*—their capacity to experience hypnotic suggestions (Hilgard, 1965). This trait is normally distributed (Laurence et al., 2008), with approximately 10% considered to be high hypnotizable ("highs") and 10% considered to be low hypnotizable ("lows"). In a research context, this is usually assessed by two consecutive standardized measures, each taking an hour. This means that large samples and significant resources are required to be able to identify sufficient numbers of participants for experiments.

Aspects of a hypnotic procedure may also influence hypnotic response. The hypnotic induction—a process of initiating hypnosis, often with a series of instructions to guide relaxation and focusing of attention—may be particularly relevant. Whilst some theorists question its impact (e.g., Kirsch & Braffman, 2001), some previous research has found that a hypnotic induction increases the likelihood of participants responding to suggestions, including those related to agency (Polito et al., 2014) and more challenging cognitive experiences (see Connors et al., 2013, 2015). However, findings on the importance of a hypnotic induction are mixed with some studies showing no impact (e.g., McGeown et al., 2012).

Experimental Studies of Agency Using Self-Tickling

An influential theory of the mechanisms that underlie alterations to sense of agency is the comparator model (Blakemore et al., 2002; Wolpert, 1997). According to this account, sensory signals are recognized as either self-produced or externally produced based on a comparison of the predicted sensory consequences of an action and actual sensory feedback in the motor system. Sense of agency arises when these two signals correspond; perceived involuntariness arises when the two diverge (for a related account, see Dogge, Aarts, et al., 2019; Pfister, 2019; Wirth et al., 2016). This model provides an explanation for the well-known observation that we usually cannot tickle ourselves (Kilteni et al., 2019; Weiskrantz et al., 1971; for attenuation of self-touch in general, see Kilteni et al., 2018, 2020). Given the correspondence between predicted action and sensory response, sensory response is attenuated, thereby resulting in a lack of ticklishness (Blakemore et al., 1999, 2000).

Blakemore et al. (1999) examined this phenomenon by creating a task in which there was a discrepancy between participants' predicted tickle sensations and their actual tickle sensations. They altered the temporal or spatial relationship between participants' self-produced actions and the sensory feedback from those actions. Participants made tickling actions with their left hand while holding a sensor on a mechanical device. A robotic "arm" then made corresponding movements to tickle the participant's right hand after a variable delay or at an altered spatial angle. The authors found that when the movement occurred simultaneously and identically to participants' movements, the stimulus was not experienced as tickly (just as when an individual tickles herself). However, as the delay or spatial displacement increased, participants rated the stimulus as increasingly tickly. This supports predictions of the comparator model by showing that, as the discrepancy between participants' predicted feedback and their actual sensory feedback increased, participants' actions felt less self-produced.

The Present Studies

We sought to recreate this self-tickling paradigm with hypnosis to examine both hypnotic disruptions to sense of agency and the comparator model more generally. Whereas Blakemore et al. (1999) used "bottom-up," low-level manipulations of sensory–motor perception to alter the sense of agency, we used hypnosis to produce "top-down," high-level cognitive alterations of the subjective experience of motor control (Polito et al., 2013, 2014, 2018; see also Kilteni et al., 2018). We developed two distinct hypnotic suggestions based on clinical conditions involving altered agency. One was based on the alien control delusion in which patients report that their movements are controlled by an external entity (Frith et al., 2000b). The other was based on anesthesia, in which patients report that they cannot feel the affected body part, but do not typically claim that it is externally controlled (Spence, 2008). These two suggestions are associated with quite distinct cognitive changes that have each been shown to alter the sense of agency. Specifically, Frith et al. (2000b) showed that alien control is associated with impaired motor predictions that result in a lack of felt volition, whereas Spence (2008) explained psychogenic experiences of analgesia as resulting from directing attention toward executive processes without monitoring that activity. Comparing suggestions based on these two conditions allowed us to examine the unique contribution of experiencing one's actions as externally initiated versus self-initiated.

Across three studies, we compared responses to self-produced and externally produced tactile stimuli both before and after hypnotic suggestions. Tickling movements were alternatively self-produced (i.e., produced by participants tickling their own hands) and externally produced (i.e., produced by the hypnotist tickling the participants' hands). We investigated the influence of hypnotizability (Experiment 1), hypnotic induction (Experiment 2), and demand characteristics (Experiment 3) on participants' experience of tactile stimuli in our hypnotic version of Blakemore et al.'s (1999) task. Based on previous research, we expected suggestions to produce alterations in the sense of agency in high-hypnotizable participants (Polito et al., 2013), that these effects would be larger after a hypnotic induction (Woody & Sadler, 2016), and that hypnotic changes in the sense of agency would not be explained by demand characteristics (Connors et al., 2013).

Experiment 1

In experiment 1, we were interested in whether hypnotic suggestions influenced participants' sense of agency in our hypnotic adaptation of Blakemore et al.'s (1999) tickling task. To test this, we compared the performance of highs with lows (Woody & Barnier, 2008). We also compared a suggestion to experience alien control (Polito et al., 2018) and a suggestion to experience anesthesia (McConkey et al., 1999; Wilton et al., 1997). Participants who received the alien control suggestion were told that they would experience the movements of their right arm and hand as being controlled by someone else. Participants who received the anesthesia suggestion were told that they would not feel anything from the movements of their right arm and hand. Participants in this study (a) rated the perceived ticklishness of self-produced and externally produced tactile stimuli at baseline (in counterbalanced order); (b) rated the same stimuli following a hypnotic suggestion; (c) identified the source of tactile stimuli; (d) completed the Sense of Agency Rating Scale (SOARS; Polito et al., 2013); and (e) made ratings of their subjective experiences while generating self-produced stimuli.

We predicted that participants would generally rate externally produced tactile stimuli as more ticklish than self-produced tactile stimuli. However, we expected that highs would report an increase in ratings of ticklishness for self-produced stimuli following the administration of the hypnotic suggestions relative to their baseline ratings. We also expected that highs would be less accurate in identifying the source of self-produced stimuli compared to lows. Finally, we expected that scores on the SOARS and posthypnotic ratings of subjective experiences would reflect reduced agency for self-produced actions for highs during hypnosis, compared to lows. We did not have specific predictions about whether alien control on anesthesia suggestions would have a greater impact on participants' experiences.

Method

Prescreening

Participants for all three experiments reported in this article were recruited from a database of student volunteers who had been prescreened to determine their level of hypnotizability. Specifically, these individuals previously completed a modified version of the Harvard Group Scale of Hypnotic Susceptibility, Form A (HGSHS:A; Shor & Orne, 1962), and a modified version of the Stanford Scale of Hypnotic Susceptibility, Form C (SHSS:C; Weitzenhoffer & Hilgard, 1959). The 10-item modified HGSHS:A included head falling, eye closure, hand lowering, finger lock, moving hands together, communication inhibition, experiencing of fly, eye catalepsy, posthypnotic suggestion, and posthypnotic amnesia. The arm rigidity and arm immobilization items were removed. The 11-item modified SHSS:C included hand lowering, moving hands apart, mosquito hallucination, taste hallucination, arm rigidity, dream, age regression, arm immobilization, anosmia, negative visual hallucination, and posthypnotic amnesia. The auditory hallucination item was removed. These modifications were made to ensure that the modified HGSHS:A could be completed within 1 hour in a class and to ensure that the modified SHSS:C could be completed in a 1-hr individual session. We have previously used modified versions of these scales as screening tools for identifying low- and high-hypnotizable participants across multiple studies (Connors, Barnier, et al., 2014; Connors, Halligan, et al., 2014; Polito et al., 2018; see also Hilgard et al., 1979). Confirming hypnotic ability through both the HGSHS:A and SHSS:C is considered the gold standard in hypnotic research (Kihlstrom, 2008). Highs scored 7 or more on the modified HGSHS:A and 7 or more on the modified SHSS:C. Lows scored between 0 and 3 on the modified HGSHS:A and between 0 and 3 on the modified SHSS:C.

Participants

We tested 40 undergraduate participants at Macquarie University; however, three participants were excluded (two for not making any self-produced movements when instructed and one due to a data collection error). The final sample consisted of 37 participants (nine males, 28 females) with mean age of 21.2 ($SD = 4.1$) years. After exclusions, there were 22 highs and 15 lows.

Materials

Tactile Stimuli Task. In the tactile stimulus task, participants rated the subjective experience of self or externally generated tactile stimuli. The tactile stimulus consisted of gently pressing a "tickling stick" in a repeated circular motion against participants' left palms for a period of 5 s. The tickling stick was a standard craft brush consisting of a plastic handle 10 cm long and a rectangular foam head 5 cm wide. Following the procedure of Blakemore et al. (1999), participants made verbal ratings of the ticklishness, intensity, pleasantness, and irritation of each tactile stimulus on a scale from 1 to 10. For example, participants were asked, "On a scale of 1–10, how tickly was the sensation if 1 means *not at all tickly* and 10 means *very tickly*." As only ticklishness ratings have been theoretically linked with the sense of agency (Blakemore et al., 2000), only these results are reported. Analysis of variance (ANOVA) results for ratings of intensity, pleasantness, and irritation are included in Supplemental Tables S6–S12. Participants experienced both self-produced tactile stimuli, caused by their own self-tickling movements, and externally produced tactile stimuli, caused by the actions of the hypnotist (see the Procedure section). In all cases, tactile stimuli lasted for 5 s. The order in which self-produced and externally produced movements occurred was counterbalanced between participants.

Source Identification Task. Following both self-generated and externally generated tactile stimuli, participants were asked, "Tell me, who tickled you?" We coded responses to the source attribution question as either correct ("me" for self-produced movement trials and "someone else" or "you" for externally produced movement trials) or incorrect (any other response).

Sense of Agency Rating Scale. Following the tactile stimulus tasks, participants completed the SOARS (Polito et al., 2013). This 10-item scale indexes subjective alterations of the sense of agency. Participants rate their level of agreement with statements such as "My experiences and actions felt self-produced" on a 7-point Likert scale from *strongly disagree* to *strongly agree*. This scale has two factors: Involuntariness, representing a subjectively experienced reduction in control over one's own actions, and Effortlessness, representing a subjective increase in the ease and automaticity with which actions occur. A total score for each factor is obtained by taking the mean of the relevant items (range 5–35 for each subscale). Good internal consistency has been reported for both subscales (Cronbach's α for Involuntariness = .907 and for Effortlessness = .734; Polito et al., 2013).

Posthypnotic Subjective Experience Scale. This was a custom, six-item scale that captured participants' subjective experiences during hypnosis. Participants were instructed to think back to their self-produced movements following the hypnotic suggestion. They then made ratings on a 10-point scale to describe their subjective experiences in response to the following six questions: (1) How much control did you feel over your right hand and arm? (2) How much control did you feel over the tickling sensation? (3) How much did you believe that your right hand and arm belonged to someone else? (4) To what extent did it feel like someone else was tickling you? (5) How numb or anesthetized did your right hand and arm feel? and (6) To what extent could you tell the difference between you tickling your own palm and me tickling your palm? A response of 1 meant *not at all* and 10 meant *completely*.

Design

Participants took part in a 2 (hypnotizability [between-subjects]: low vs. high) × 2 (suggestion [between-subjects]: alien control vs. anesthesia) × 2 (source [within-subjects]: self vs. other) × 2 (time [within-subjects]: baseline vs. after suggestion) mixed design. Participants were randomly assigned to receive one of two hypnotic suggestions designed to alter their experience of tactile sensations, either a suggestion for alien control or anesthesia. Nineteen participants received the alien control suggestion (eight lows, 11 highs) and 18 received the anesthesia suggestion (seven lows, 11 highs). The order in which participants experienced tactile sensations at each time point was randomly counterbalanced: 19 participants first tickled themselves and then were tickled by the hypnotist; 18 participants did this in the reverse order.

Procedure

Participants first experienced a standard hypnotic induction, taken from the SHSS:C, of approximately 12-min duration and completed three simple hypnotic filler tasks to establish and reinforce the hypnotic context: moving hands apart (taken from the SHSS:C), finger lock (taken from the HGSHS:A), and verbal inhibition (taken from the HGSHS:A). In the first phase of the experiment, participants completed the tactile stimulus task at baseline, making ratings of self-produced and externally produced tactile stimuli. Participants were asked to open their eyes and the hypnotist showed them the tickling stick. Participants were then asked to hold the tickling stick in their right hand and to practice making circular movements on the hypnotist's hand. The experimenter used these trials to approximate similar pressure for their externally produced movements. After this practice, participants were asked to close their eyes once more.

In the second phase of the experiment, participants again completed the tactile stimulus task, this time following the administration of a hypnotic suggestion. The hypnotist first gave a hypnotic deepening instruction and then administered a hypnotic suggestion aimed at altering participants' experience of their own self-produced actions. Participants were randomly allocated to one of two experimental groups, receiving either a suggestion to experience alien control over their right hand or a suggestion to experience anesthesia of their right hand. Both suggestions were triggered by the phrase "tickle palm." Verbatim suggestions are provided in Supplemental Table S1 (https://osf.io/ef973/).

Following the appropriate suggestion, participants self-tickled and were tickled by the hypnotist in the same counterbalanced order as at baseline. Participants again made verbal ratings of ticklishness immediately after each tactile stimulus. After the initial round of the tactile stimulus task, the hypnotist reminded participants of the suggestion and the cue ("tickle palm"). The task was then repeated so that participants experienced self-produced and externally produced tactile stimuli a second time. We used the average of these two ratings in all analyses.

Following the final rating of each tactile stimulus, participants completed the source identification task. To prompt participants, the hypnotist first read back their rating from the previous task. For example, after the second round of tactile stimulus task, the hypnotist might say, "You rated the ticklishness of that sensation as 6 out of 10 just now. Tell me, who tickled you?" After the source identification task, the hypnotist canceled the hypnotic suggestion.

In the third phase of the experiment, participants were asked to think back to their experience of tickling themselves after hearing the suggestion (i.e., the final instance of self-tickling) and then to open their eyes and make ratings of that experience using the SOARS. After completing the scale, participants were given a hypnotic deinduction instructing them to return to their normal state of wakefulness.

In the final phase of the experiment, participants completed the Posthypnotic Subjective Experience Scale.

All studies were approved by the Macquarie University's Human Research Ethics Committee (Protocol No. HE31JUL2009D00051).

Results

Ratings of Tactile Stimuli

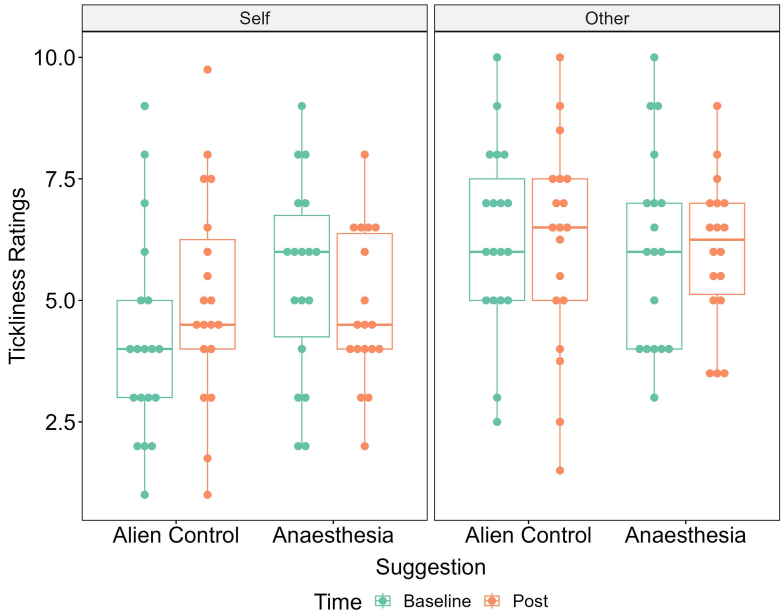
Table 1 shows participants' ratings of self-produced and externally produced tickle stimuli at baseline and following a hypnotic suggestion. A 2 (hypnotizability) × 2 (suggestion) × 2 (source) × 2 (time) ANOVA revealed a main effect of source, $F(1, 33) = 40.75$, $p < .001$, $\eta_p^2 = .553$. As predicted, participants experienced externally produced tactile stimuli as more tickly ($M = 6.16$, $SE = .22$) than self-produced stimuli ($M = 4.85$, $SE = .23$), 95% CI_{diff} [0.89, 1.73]. There also was a main effect of hypnotizability, $F(1, 33) = 5.21$, $p = .029$, $\eta_p^2 = .136$, indicating that highs ($M = 5.97$, $SE = .19$) experienced tactile stimuli as more tickly overall than lows ($M = 4.82$, $SE = .29$), 95% CI_{diff} [0.13, 2.18]. Finally, there was a significant interaction of Suggestion × Source × Time, $F(1, 33) = 4.54$, $p = .041$, $\eta_p^2 = .121$. As shown in Figure 1, this three-way interaction was driven by a significant two-way interaction of Suggestion × Time for self-produced tactile stimuli, $F(1, 35) = 5.17$, $p = .029$, $\eta_p^2 = .129$, but no significant interaction of Suggestion × Time for other-produced tactile stimuli, $F(1, 35) = 0.04$, $p = .845$, $\eta_p^2 = .001$. Specifically, for self-produced stimuli, ticklishness ratings tended to increase following the alien control suggestion ($M_{\text{diff}} = .87$, CI_{diff} [−0.10, 1.84]) but tended to decrease following the anesthesia suggestion ($M_{\text{diff}} = -.64$, CI_{diff} [−1.64, 0.37]). Contrary to expectations, we found no evidence of an interaction between

Table 1
Ticklishness Ratings in Experiment 1

	Self-produced stimuli		Other-produced stimuli	
Hypnotizability	Alien control	Anesthesia	Alien control	Anesthesia
Baseline				
Low	3.50 (0.78)	4.71 (0.92)	6.19 (0.88)	5.36 (0.82)
High	4.64 (0.61)	5.91 (0.51)	6.46 (0.43)	6.54 (0.58)
After suggestion				
Low	4.16 (0.78)	4.07 (0.62)	5.28 (0.91)	5.29 (0.67)
High	5.66 (0.61)	5.27 (0.41)	6.80 (0.50)	6.50 (0.37)

Note. Values in parentheses are standard errors.

Figure 1
Ticklishness Ratings as a Function of Suggestion, Source, and Time



Note. See the online article for the color version of this figure.

hypnotizability, source, and time, $F(1, 33) = 0.32$, $p = .577$, $\eta_p^2 = .010$.

Identifying the Source of Tactile Stimuli Following Hypnotic Suggestion

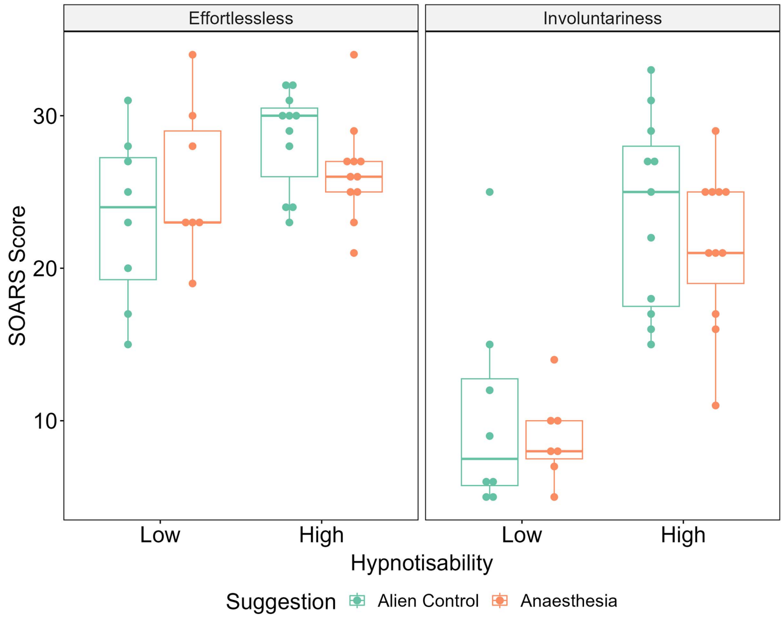
Following the final rating of each tactile stimulus, participants were asked to identify the source of the sensation. Participants misidentified a greater proportion of self-produced stimuli ($M = .30$, $SE = .08$), compared to externally produced stimuli ($M = .12$, $SE = .06$), although this difference was not significant, $t(32) = 1.98$, $p = .056$, $d = 0.345$. For self-produced stimuli, a 2 (hypnotizability) × 2 (suggestion) between-subjects ANOVA of source identification errors revealed a main effect of hypnotizability, indicating that as predicted, highs ($M = .47$, $SE = .12$) made more errors than lows ($M = .07$, $SE = .07$), 95% CI_{diff} [0.09, 0.72], $F(1, 29) = 7.04$, $p = .013$, $\eta_p^2 = .195$. The main effect of suggestion, $F(1, 29) = 0.95$, $p = .338$, $\eta_p^2 = .003$, and the interaction between hypnotizability and suggestion, $F(1, 29) < 0.01$, $p = .967$, $\eta_p^2 < .001$, were both nonsignificant.

SOARS Scores

After the tactile stimulus tasks, participants completed the SOARS, indicating the degree to which they experienced disruptions to their sense of agency for self-produced actions following the hypnotic suggestion. Figure 2 shows SOARS scores for highs and lows administered each suggestion. For Involuntariness, a 2 (hypnotizability) × 2 (suggestion) factorial ANOVA revealed a main effect of hypnotizability, $F(1, 33) = 46.38$, $p < .001$, $\eta_p^2 = .584$, indicating that highs experienced significantly greater levels of involuntariness ($M = 22.50$, $SE = 1.23$) than lows ($M = 9.67$, $SE = 1.37$), 95% CI_{diff} [9.07, 16.79]. The main effect of suggestion, $F(1, 33) = 0.95$, $p = .337$, $\eta_p^2 = .028$, and the interaction between hypnotizability and suggestion, $F(1, 33) = 0.31$, $p = .862$, $\eta_p^2 < .001$, were both nonsignificant.

For Effortlessness, again we found a significant main effect of hypnotizability, $F(1, 33) = 4.22$, $p = .048$, $\eta_p^2 = .113$, with highs having higher scores ($M = 27.40$, $SE = .73$) than lows ($M = 24.40$, $SE = 1.38$), 95% CI_{diff} [0.03, 5.83]. The main effect of suggestion, $F(1, 33) = 0.17$, $p = .897$, $\eta_p^2 < .001$, and the interaction between

Figure 2
SOARS Scores as a Function of Hypnotizability, Suggestion, and SOARS Subscale



Note. SOARS = Sense of Agency Rating Scale. See the online article for the color version of this figure.

hypnotizability and suggestion, $F(1, 33) = 2.56$, $p = .120$, $\eta_p^2 < .072$, were both nonsignificant.

To investigate whether these agency scores related to participants' ratings of ticklishness, bivariate correlations were calculated between the SOARS subscales and ratings of self-produced tactile stimuli following the suggestion. ticklishness ratings correlated significantly with Involuntariness, $r = .56$, $p < .001$, but not with Effortlessness, $r = .29$, $p = .087$. These results indicate that the less control participants felt, the more they experienced their self-produced actions as tickly.

Posthypnotic Ratings of Subjective Experience

Following hypnosis, participants rated their experience of generating self-produced actions. Supplemental Table S2 shows the mean ratings of subjective experiences made by participants in each condition. As these questions displayed excellent internal consistency ($\alpha = .897$), we computed a mean score of subjective alteration to self-control. A 2 (hypnotizability) × 2 (suggestion) between-subjects ANOVA showed that self-control varied significantly with hypnotizability, $F(1, 33) = 51.42$, $p < .001$, $\eta_p^2 = .609$, indicating that highs ($M = 5.19$, $SE = 0.32$) experienced significantly greater disruption to feelings of control than lows ($M = 1.89$, $SE = 0.27$), 95% CI_{diff} [2.37, 4.25], but there was no evidence of differences in responses between participants who experienced alien control and those who experienced anesthesia, $F(1, 33) = 0.06$, $p = .816$, $\eta_p^2 = .002$, and no interaction, $F(1, 33) = 0.03$, $p = .854$, $\eta_p^2 = .001$. This is surprising, as the two hypnotic suggestions had different effects on ticklishness, yet here participants reported equivalent alterations in their subjective feelings of control. This demonstrates the multidimensional nature of the sense of agency (Polito et al., 2014). It also indicates that the change in ticklishness ratings evident following the alien control suggestion was not simply due to a general change in feelings of control (as the anesthesia suggestion similarly led to changes in subjective control but not to changes in the experience of ticklishness). Rather, this indicates the specific content of the alien control suggestion led to an alteration of self-monitoring that influenced participants' experience of ticklishness.

Discussion

Overall, in Experiment 1, we found that hypnotic suggestions (particularly the alien control suggestion) influenced participants' experiences of their own self-produced actions. Usually, self-produced tactile stimuli are less tickly than externally produced stimuli (due to the normal attenuation of self-generated actions). Following the hypnotic suggestions, there was a trend toward the ticklishness of self-generated stimuli increasing following the alien control suggestion and decreasing following the anesthesia suggestion. This may be because the alien control suggestion more directly described a change in the agency, whereas the anesthesia suggestion described a change in internal sensory experience. In other words, the alien control suggestion led participants to experience their self-produced actions as more like externally produced actions. This increase in ticklishness was associated with increased Involuntariness scores, suggesting that this hypnotic paradigm led to changes in self-monitoring. This interpretation is supported by the finding that highs were particularly impaired at identifying the source of self-produced sensations, frequently confusing their own actions for external ones.

The hypnotic suggestions in this experiment were designed to reduce participants' sense of agency for self-produced actions. This led to altered perceptions of ticklishness. Surprisingly, although highs found tactile stimuli more tickly than lows overall, the specific increase in ticklishness following the alien control suggestion occurred regardless of hypnotizability. This suggests that hypnotic ability may not be necessary for participants to use specific cognitive strategies to alter their sense of agency. We investigated the importance of formal hypnosis for altering the sense of agency in Experiment 2.

Experiment 2

In Experiment 2, we were interested in whether a formal hypnotic induction was necessary for agency alterations in our hypnotic adaptation of Blakemore et al.'s (1999) tickling task. This experiment utilized a hypnosis-wake design whereby we compared the performance of highs with an induction (hypnosis group) and highs without a hypnotic induction (wake group; Cox & Bryant, 2008). We used the same two suggestions as Experiment 1 (alien control and anesthesia).

We predicted that participants would rate externally produced tactile stimuli as more tickly than self-produced tactile stimuli. Based on work that has shown the facilitatory effect of a hypnotic induction (Connors et al., 2012; McConkey et al., 2001; Polito et al., 2014), we expected that participants administered an induction would report an increase in ratings of ticklishness for self-produced tactile stimuli following the hypnotic suggestions, relative to their baseline ratings. We also expected that participants administered an induction would be less accurate at identifying the source of self-produced stimuli compared to externally produced stimuli. Finally, we expected that scores on the SOARS and posthypnotic ratings of subjective experiences would reflect reduced agency for self-produced actions for highs during hypnosis, compared to the wake condition.

Method

Participants and Design

We tested 52 undergraduate participants at the University of New South Wales; however, two participants were excluded due to not making self-produced movements when instructed to. The final sample consisted of 17 males and 34 females, with a mean age of 19.20 years ($SD = 1.58$). Participants took part in a 2 (induction [between-subjects]: hypnosis vs. wake) × 2 (suggestion [between-subjects]: alien control vs. anesthesia) × 2 (source [within-subjects: self vs. other) × 2 (time [within-subjects]: baseline vs. after suggestion) mixed design. As in Experiment 1, all participants were previously screened on both the HGSHS:A and SHSS:C. All participants were confirmed as highs, scoring between 7 and 10 on a modified, 10-item, version of the HGSHS:A and between 7 and 11 on an 11-item version of the SHSS:C. None had participated in Experiment 1.

Participants were randomly allocated to either the hypnosis or wake group. These random groups did not differ on HGSHS:A, $F(1, 42) = 3.714$, $p = .061$, or SHSS:C scores, $F(1, 42) = 0.149$, $p = .702$. The final sample consisted of 25 hypnosis and 25 wake participants. Twenty-five participants received the alien control suggestion (12 hypnosis, 13 wake) and 25 received the anesthesia suggestion (13 hypnosis, 12 wake). The order of self-produced and externally produced movements was similarly counterbalanced.

Procedure

The procedure was identical to Experiment 1, except that participants in the wake group did not receive a hypnotic induction. Instead, these participants completed two distracter tasks, selected to actively engage attention. These were the Symbol Search task from the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997) and a geometric puzzle requiring them to bisect an L-shaped figure using a pencil, paper, and ruler (Nogrady et al., 1985) for 12 min.

Results

Ratings of Tactile Stimuli

Table 2 shows participants' ratings of self-produced and externally produced tactile stimuli at baseline and following a hypnotic suggestion. A 2 (induction) × 2 (suggestion) × 2 (source) × 2 (time) ANOVA revealed a main effect of source, $F(1, 46) = 28.01$, $p < .001$, $\eta_p^2 = .378$, indicating that, overall, participants experienced externally produced stimuli as more tickly ($M = 6.33$, $SE = .24$) than self-produced stimuli ($M = 5.19$, $SE = .24$), 95% CI_{diff} [0.70, 1.57]. There was also a significant main effect of induction, $F(1, 46) = 4.09$, $p = .049$, $\eta_p^2 = .082$, indicating that the hypnosis group experienced stimuli as more tickly ($M = 6.32$, $SE = 0.22$) than the wake group ($M = 5.20$, $SE = 0.24$), 95% CI_{diff} [0.01, 2.18].

As shown in Figure 3, the predicted interaction of Induction × Source × Time approached significance, $F(1, 46) = 3.98$, $p = .052$, $\eta_p^2 = .080$. This three-way interaction was driven by a significant interaction of Induction × Time for self-produced tactile stimuli, $F(1, 48) = 4.95$, $p = .031$, $\eta_p^2 = .093$, but no significant interaction of Induction × Time for other-produced tactile stimuli, $F(1, 48) < 0.01$, $p > .999$, $\eta_p^2 < .001$. For other-produced tactile stimuli, there was also a significant main effect of induction, $F(1, 48) = 6.38$, $p = .015$, $\eta_p^2 = .117$, with higher ratings of ticklishness in the hypnosis group ($M = 7.09$, $SE = 0.27$) compared to the wake group ($M = 5.57$, $SE = 0.35$).

Identifying the Source of Tactile Stimuli Following Hypnotic Suggestion

Following the final rating of each tactile stimulus, participants were asked to identify the source of the sensation. Participants misidentified a greater proportion of self-produced stimuli ($M = .53$, $SE = .08$), compared to externally produced stimuli ($M = .38$, $SE = .07$), 95% CI_{diff} [−.001, .31], and this difference approached statistical significance, $t = 2.00$, $p = .051$, $d = 0.300$. For self-produced stimuli, a 2 (induction) × 2 (suggestion) between-subjects ANOVA of source identification errors revealed a main effect of suggestion, indicating that participants administered the alien control suggestion was more impaired at identifying the source of self-produced actions ($M = .70$, $SE = .10$) compared to participants administered the anesthesia suggestion ($M = .36$, $SE = .11$), 95% CI_{diff} [.07, .64], $F(1, 41) = 6.27$, $p = .016$, $\eta_p^2 = .133$. There was no main effect of induction, $F(1, 41) = 1.62$, $p = .210$, $\eta_p^2 = .038$, and no interaction between induction and suggestion, $F(1, 41) = 1.62$, $p = .210$, $\eta_p^2 = .038$.

SOARS Scores

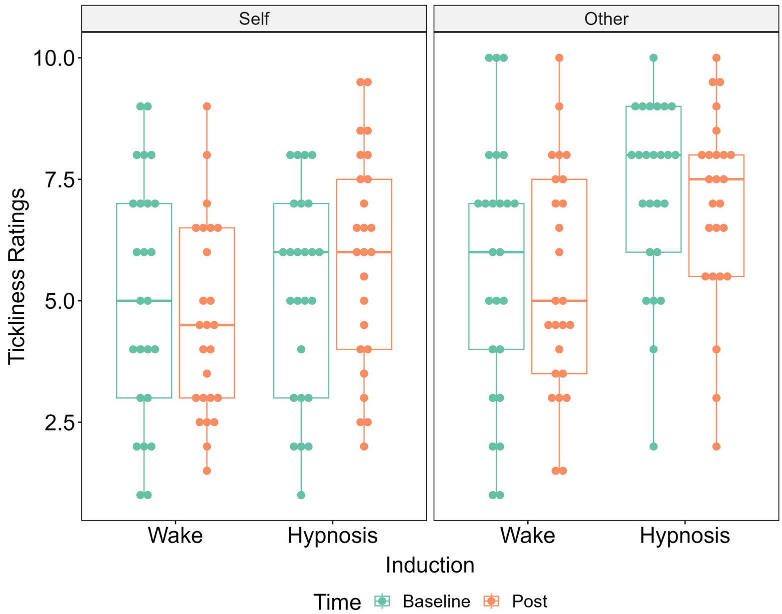
Figure 4 shows SOARS scores for hypnosis and wake participants administered each suggestion. For Involuntariness, a 2 (induction) × 2 (suggestion) between-subjects ANOVA revealed a significant main effect of suggestion, $F(1, 46) = 4.13$,

Table 2
Ticklishness Ratings in Experiment 2

Condition	Self-produced stimuli: Alien control	Self-produced stimuli: Anesthesia	Other-produced stimuli: Alien control	Other-produced stimuli: Anesthesia
Baseline				
Wake	4.54 (0.64)	5.75 (0.76)	5.31 (0.65)	6.17 (0.89)
Hypnosis	5.00 (0.59)	5.31 (0.63)	7.08 (0.61)	7.38 (0.49)
After suggestion				
Wake	4.15 (0.47)	5.00 (0.66)	5.00 (0.62)	5.88 (0.70)
Hypnosis	6.38 (0.80)	5.50 (0.44)	7.04 (0.77)	6.85 (0.31)

Note. Values in parentheses are standard errors.

Figure 3
Ticklishness Ratings as a Function of Induction, Source, and Time



Note. See the online article for the color version of this figure.

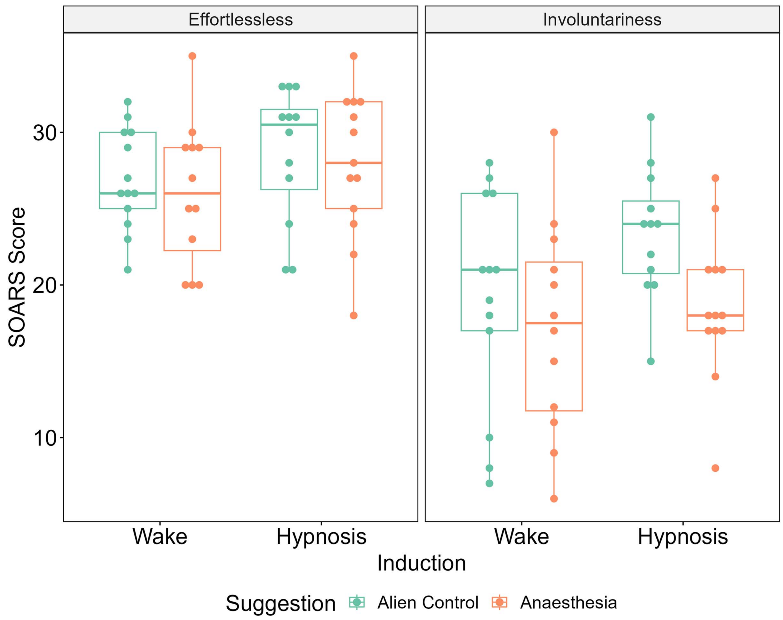
p = .048, η_p^2 = .082, indicating that participants administered the alien control suggestion experienced greater levels of involuntariness (M = 21.20, SE = 1.24) than those administered the anesthesia suggestion (M = 17.90, SE = 1.16), 95% CI_{diff} [0.03, 6.76]. Contrary to expectations, there was no significant main effect of induction, $F(1, 46) = 2.92$, $p = .094$, $\eta_p^2 = .060$, and there was no interaction, $F(1, 46) = 0.71$, p = .404, η_p^2 = .015. For Effortlessness, there was no main effect of suggestion, $F(1, 46) = 0.42$, p = .522, η_p^2 = .009, no main effect of induction, $F(1, 46)$ = 2.13, p = .151, η_p^2 = .044, and no interaction, $F(1, 46) = 0.01$, $p = .915$, $\eta_p^2 < .001$.

To investigate whether these agency scores related to participants' ratings of self-produced movements, bivariate correlations were calculated between the SOARS subscales and ratings of self-produced tactile stimuli following the suggestion. Ticklishness ratings correlated significantly with Involuntariness, r = .32, p = .023, but not with Effortlessness, r = .18, p = .222. Consistent with the results of Experiment 1, this indicates that a subjective reduction in control was associated with increased ticklishness following the hypnotic suggestions.

Posthypnotic Ratings of Subjective Experience

Subjective ratings of self-produced actions (Supplemental Table S3) again showed excellent internal consistency (α = .848), so we analyzed the mean score. A 2 (induction) × 2 (suggestion) between-subjects ANOVA showed a significant main effect of induction, $F(1, 45)$ = 4.29, p = .044, η_p^2 = .087, with higher ratings for the hypnosis condition ($M = 4.65$, $SE = 0.37$) than the wake condition ($M = 3.62$, $SE = 0.40$), 95% CI_{diff} [0.03, 2.10]. There was also a significant main effect of suggestion, $F(1, 45)$ = 6.90, p = .012, η_p^2 = .133, with higher ratings for participants administered the alien control suggestion (M = 4.83, SE = .41) compared to those administered the anesthesia suggestion ($M = 3.49$, $SE = 0.35$), 95% CI_{diff} [0.31, 2.38]. The interaction between induction and suggestion was not significant, $F(1, 45) = 1.62$, $p = .210$, $\eta_p^2 = .035$. Taken together, these results indicate that whereas participants administered an induction felt less in control of their self-produced actions than participants who did not receive an induction overall, those who received the alien control suggestion were most likely to experience self-generated stimuli as if they were externally caused.

Figure 4
SOARS Scores as a Function of Induction, Suggestion, and SOARS Subscale



Note. SOARS = Sense of Agency Rating Scale. See the online article for the color version of this figure.

Discussion

Overall, in Experiment 2, participants administered the alien control suggestion exhibited a reduced sense of agency as demonstrated by increased ticklishness ratings, poorer source discrimination, and higher SOARS scores than participants administered the anesthesia suggestion. In other words, the alien control suggestion had a specific influence on participants' experiences of self-produced actions, indicating that this was a genuine hypnotic effect. Surprisingly, in this sample of high-hypnotizable participants, a hypnotic induction influenced ticklishness ratings but had little effect on other measures. To clarify the degree to which the agency alterations identified are hypnotic effects, the influence of demand characteristics was investigated in Experiment 3.

Experiment 3

Experiments 1 and 2 indicated that participants who received the alien control suggestion were particularly likely to experience alterations to their sense of agency for self-produced movements and that effects were stronger in high hypnotizables and, for ticklishness, after induction. The potential influence of demand characteristics on participants' reported sense of agency, however, was unclear. In addition, results from Experiments 1 and 2 may have been influenced by experimenter effects, as no attempt was made to blind the hypnotist to participants' level of hypnotizability or experimental condition. Experiment 3 utilized the real-simulating design of Orne (1959, 1962) to address these issues. In this procedure, a hypnotist blinded to participants' hypnotizability gives suggestions to highs and lows, with the latter group specifically instructed to act as if they are hypnotized and to deceive the hypnotist. By comparing these conditions, it is possible to isolate the effect of genuine hypnotic responding from the effect of acquiescent responding due to demand characteristics (Orne, 1979).

In this experiment, we also investigated how participants' responses to self-produced and externally produced stimuli varied at different time points within a hypnosis session. In both previous experiments, baseline ratings of tactile stimuli were obtained following a hypnotic induction and then again after participants received a specific hypnotic suggestion. In this experiment, ratings were taken at three time points: before receiving a hypnotic induction, after receiving a hypnotic induction (but before any suggestions were administered), and after a hypnotic suggestion. Given its success in altering the sense of agency in Experiments 1 and 2, participants in this experiment were all administered the alien control suggestion (prior to the third time point).

We predicted that participants would rate externally produced tactile stimuli as more tickly than self-produced tactile stimuli at all time points. We expected that genuinely hypnotized participants (reals) would report an increase in ratings of ticklishness at Time Point 3 (following the alien control suggestion). We also expected that reals would be less accurate than simulators at identifying the source of self-produced stimuli compared to simulators. Finally, we expected that scores on the SOARS and posthypnotic subjective ratings would reflect reduced agency for self-produced actions for reals.

Method

Participants and Design

We tested 29 undergraduate participants at the University of New South Wales (18 males, 11 females) with a mean age of 19.66 years (SD = 1.88). Participants took part in a 2 (condition [between-subjects]: hypnosis vs. simulating) × 2 (source [within-subjects]: self vs. other) × 3 (time [within-subjects]: before induction vs. after induction vs. after suggestion) mixed design. As in Experiments 2 and 3, all participants were previously screened on both the HGSHS:A and SHSS:C. Participants in the hypnosis group were highs (n = 15), scoring between 7 and 10 on the HGSHS:A and between 7 and 11 on the SHSS:C. Participants in the simulating group were lows (n = 14), scoring between 0 and 3 on both the HGSHS:A and the SHSS:C. Five participants in the hypnosis group had also participated in Experiment 2 (approximately 16 months earlier). The hypnotist in this experiment was blind as to the participants' experimental group (hypnosis or simulating).

Procedure

Participants in the hypnosis condition were given a brief overview of the study but were not told that some participants would be faking hypnosis. Participants in the simulator condition were given detailed instructions to simulate hypnosis (Orne, 1979). Following the briefing, the hypnotist—who was blind to the condition of each individual—was called into the room and the experiment proceeded identically for all participants.

The hypnotist first recorded whether he thought that the participant was in the hypnosis or simulation condition. Participants then made ratings of self-produced and externally produced tactile stimuli (in counterbalanced order) following the same procedure as Experiments 1 and 2. Participants received a hypnotic induction, after which they again made ratings of self-produced and externally produced tactile stimuli. Participants then completed a series of unrelated hypnotic tasks not associated with this study. Next, all participants received the alien control suggestion and then once more made ratings of self-produced and externally produced tactile stimuli. In Experiments 1 and 2, participants made two separate ratings of tactile sensations following the hypnotic suggestion. In Experiment 3, participants made only a single rating of each stimulus at every time point.

Following this final block, participants were asked to identify the source of the preceding tactile stimuli following the same procedure as Experiments 1 and 2. In Experiment 3, immediately after each block of tactile stimuli (i.e., before the induction, after the induction, and after the alien control suggestion), participants rated their sense of control during the immediately preceding self-produced movements on the SOARS. Upon completion of the experimental tasks, the hypnotist once again recorded which group they believed the participant to be in, and participants were administered a hypnotic deinduction.

After the deinduction, participants were asked to give ratings of their subjective experience (in response to the same questions as Experiments 1 and 2). After this, the hypnotist left the room and the original researcher returned. At this point, simulators were told they could stop responding as if they were high hypnotizable. The researcher then repeated the subjective experience rating questions asked earlier by the hypnotist.

Results

Hypnotist's Perception of Experimental Condition

At the end of each hypnosis session, the hypnotist recorded their guess as to the participant's experimental condition. Overall, the hypnotist correctly identified the experimental condition for 15 out of 29 participants (51.7%). However, accuracy was greater for identifying simulators (11 out of 14; 78.6% correctly identified) compared to genuine hypnotic responders (four out of 15; 26.7% correctly identified), $F(1, 27) = 9.96$, $p = .004$.

Ratings of Tactile Stimuli

Table 3 shows participants' ratings of self-produced and externally produced tactile stimuli at each time point. A 2 (condition) × 2 (source) × 3 (time) ANOVA revealed a main effect of source, $F(1, 27) = 8.07$, $p = .008$, $\eta_p^2 = .230$, indicating that, overall, participants experienced externally produced stimuli as more tickly ($M = 5.53$, $SE = .23$) than self-produced stimuli ($M = 4.88$, $SE = .25$), 95% CI_{diff} [0.18, 1.10]. There was also a significant main effect of time, $F(2, 54) = 4.45$, $p = .016$, $\eta_p^2 = .141$. Contrasts showed that ticklishness rose significantly from Time Point 1 (before the induction; $M = 4.72$, $SE = .27$) to Time Point 2 (after the induction; $M = 5.36$, $SE = .32$), 95% CI_{diff} [0.12, 1.17], $F(1, 27) = 6.45$, $p = .017$, $\eta_p^2 = .193$. However, there was no significant difference from Time Point 2 to Time Point 3 (after the suggestion; $M = 5.53$, $SE = 0.29$), 95% CI_{diff} [−0.50, 0.86], $F(1, 27) = 0.31$, $p = .584$, $\eta_p^2 = .011$. Finally, as shown in Figure 5, we found a significant interaction of Condition × Source × Time, $F(2, 54) = 4.13$, $p = .021$, $\eta_p^2 = .133$.

To explore this interaction, we performed 2 (source) × 2 (condition) ANOVAs separately for each time point. Before the induction, there was a significant main effect of condition, with reals ($M = 5.4$, $SE = 0.34$) rating stimuli as more tickly than simulators ($M = 4.0$, $SE = 0.40$), $F(1, 27) = 4.45$, $p = .044$, $\eta_p^2 = .142$. There was also a significant main effect of source, with externally produced stimuli ($M = 5.21$, $SE = 0.37$) rated as more tickly than self-produced stimuli ($M = 4.24$, $SE = 0.39$), $F(1, 27) = 11.88$, $p = .002$, $\eta_p^2 = .306$. The interaction between condition and source was not significant, $F(1, 27) = 0.37$, $p = .548$, $\eta_p^2 = .014$. After the induction, there was a significant main effect of source, with externally produced stimuli ($M = 5.62$, $SE = 0.46$) rated as more tickly than self-produced stimuli ($M = 5.10$, $SE = 0.45$), $F(1, 27) = 4.58$, $p = .042$, $\eta_p^2 = .145$. There was no significant main effect of condition, $F(1, 27) = 1.07$, $p = .310$, $\eta_p^2 = .038$, or interaction between condition and source, $F(1, 27) = 1.11$, $p = .301$, $\eta_p^2 = .040$. Finally, after the suggestion, there was no significant main effect of condition, $F(1, 27) = 0.13$, $p = .721$, $\eta_p^2 = .005$; no significant main effect of source, $F(1, 27) = 1.38$, $p = .251$, $\eta_p^2 = .048$; and no significant interaction between condition and source, $F(1, 27) = 3.11$, $p = .089$, $\eta_p^2 = .103$.

Identifying the Source of Tactile Stimuli Following Hypnotic Suggestion

Following the final rating of each tactile stimulus, participants were asked to identify the source of the sensation. Participants misidentified a greater proportion of self-produced stimuli ($M = .41$, $SD = 0.50$), compared to externally produced stimuli ($M = .04$, $SD = 0.19$), 95% CI_{diff} [0.19, 0.57], $t = 4.14$, $p < .001$, $d = 0.768$. For self-produced stimuli, a one-way between-subjects ANOVA with condition (real, simulator) revealed no main effect of condition, $F(1, 27) = 0.80$, $p = .381$, $\eta_p^2 = .029$.

SOARS Scores

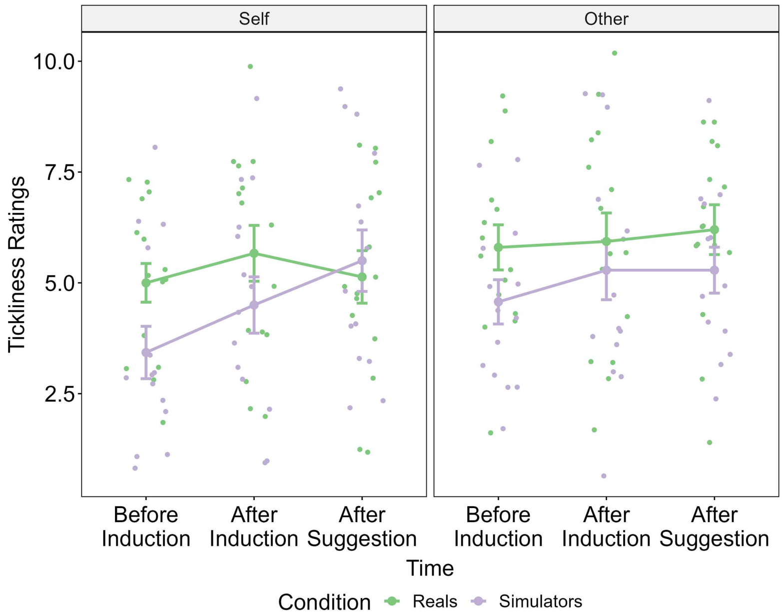
After each block of tactile stimuli, participants completed the SOARS indicating the degree to which they experienced disruption to their sense of agency for self-produced actions. Figure 6 shows SOARS scores for reals and simulators

Table 3
Ticklishness Ratings in Experiment 3

	Self-generated			Externally generated		
Condition	Before induction	After induction	After suggestion	Before induction	After induction	After suggestion
Real	5.00 (0.44)	5.67 (0.63)	5.13 (0.59)	5.80 (0.51)	5.93 (0.64)	6.20 (0.56)
Simulator	3.43 (0.59)	4.50 (0.64)	5.50 (0.69)	4.57 (0.50)	5.29 (0.67)	5.29 (0.52)

Note. Mean values in parentheses are standard errors.

Figure 5
Ticklishness Ratings as a Function of Source, Condition, and Time



Note. See the online article for the color version of this figure.

administered at each time point. For Involuntariness, a 2 (condition) × 3 (time) ANOVA revealed a main effect of time, $F(2, 50) = 16.37, p < .001, \eta_p^2 = .396$. Contrasts showed that Involuntariness increased significantly from Time Point 1, baseline (M = 14.2, SE = 1.33) to Time Point 2, after the induction (M = 19.7, SE = .1.20), 95% CI_{diff} [2.77, 7.85], $t(26) = 4.43, p < .001, d = .85$. The change from Time Point 2 to Time Point 3 (M = 21.9, SE = 1.26), 95% CI_{diff} [−0.38, 4.21], was nonsignificant, $t(26) = 1.85, p = .075, d = .36$.

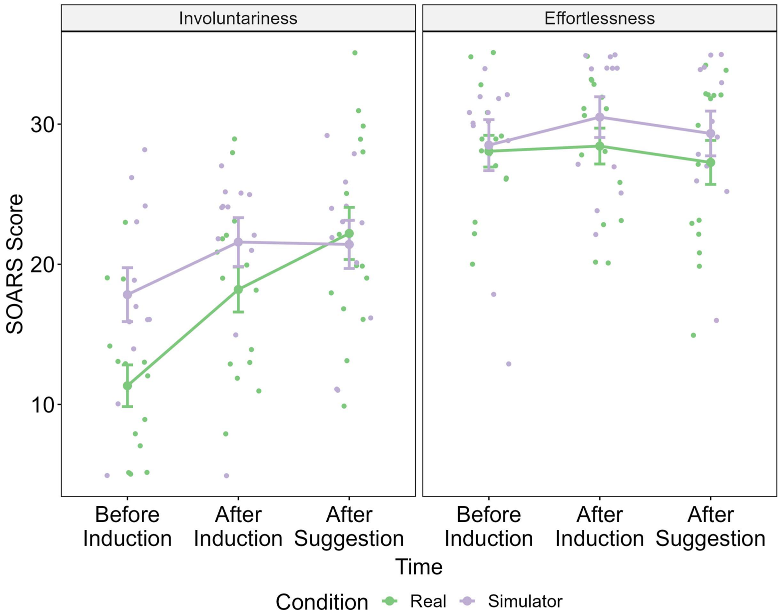
There was also a significant interaction between condition and time, $F(2, 50) = 3.90, p = .027, \eta_p^2 = .135$, indicating that participants' experience of control over time was different for the hypnosis and simulation group. In particular, for the hypnosis group, Involuntariness rose from Time Point 1, before the induction (M = 11.3, SE = .1.49), to Time Point 2, after the induction (M = 18.2, SE = 1.61), 95% CI_{diff} [3.09, 10.65], $t(14) = 3.90, p = .002, d = 1.01$, and again from Time Point 2 to Time Point 3, following the suggestion (M = 22.2, SE = 1.86), 95% CI_{diff} [0.23, 7.77], $t(14) = 2.28, p = .039, d = 0.59$. For simulators, Involuntariness rose from Time Point 1, before the induction (M = 17.8, SE = 1.92), to Time Point 2, after the induction (M = 21.6, SE = 1.74), 95% CI_{diff} [0.11, 7.39], $t(11) = 2.27, p = .044, d = 0.66$, but did not change from Time Point 2 to Time Point 3, after the suggestion (M = 21.4, SE = 1.72), 95% CI_{diff} [−2.75, 2.42], $t(11) = 0.14, p = .890, d = 0.04$. A second set of post hoc analyses showed that before the induction, Involuntariness scores were higher for simulators (M = 17.8, SE = 1.92) compared to reals (M = 11.3, SE = 1.49), 95% CI_{diff} [1.58, 11.42], $t(25) = 2.72, p = .014, d = 1.05$. There was no difference between reals and simulators after the induction, 95% CI_{diff} [−1.52, 8.28], $t(25) = 1.42, p = .167, d = 0.55$, or after the suggestion, 95% CI_{diff} [−6.11, 4.54], $t(25) = 0.30, p = .765, d = 0.12$.

For Effortlessness, a 2 (condition) × 3 (time) ANOVA revealed no main effect of condition, $F(1, 25) = 0.86, p = .362, \eta_p^2 = .033$; no main effect of time, $F(2, 50) = 0.734, p = .485, \eta_p^2 = .029$; and no interaction, $F(2, 50) = 0.35, p = .703, \eta_p^2 < .014$.

Posthypnotic Ratings of Subjective Experience

Following hypnosis, participants rated their subjective experiences. These questions were

Figure 6
SOARS Scores as a Function of Condition, Time, and SOARS Subscale



Note. SOARS = Sense of Agency Rating Scale. See the online article for the color version of this figure.

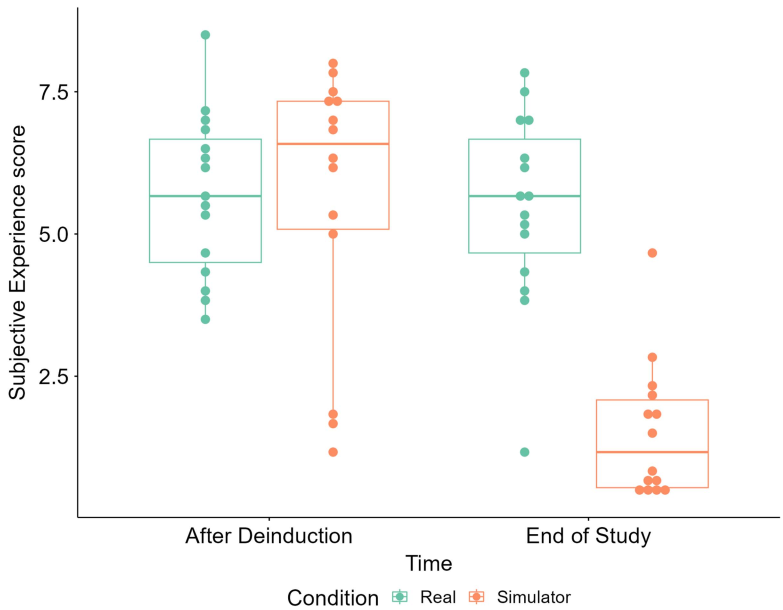
first asked by the hypnotist and then later repeated by the original experimenter in the final phase of the experiment. As simulating participants were told they could stop acting as if they were high hypnotizable when the original investigator first reentered the room, the responses of these participants on the second occasion should be seen as reflecting their actual experience, whereas their answers on the first occasion represent their simulated experience. Supplemental Table S4 shows the mean ratings made by participants at both time points.

Subjective ratings of self-produced actions (Supplemental Table S4) showed excellent internal consistency at Time 1 ($\alpha = .777$) and at Time 2 ($\alpha = .890$), so we analyzed the mean score at each time point. A 2 (condition) × 2 (time) ANOVA revealed a significant main effect of condition, $F(1, 27) = 13.79$, $p = .001$, $\eta_p^2 = .338$, with reals ($M = 5.58$, $SE = 0.28$) having higher ratings than simulators ($M = 3.60$, $SE = 0.53$), 95% CI_{diff} [0.89, 3.08]. There was also a significant main effect of time, $F(1, 27) = 36.43$, $p < .001$, $\eta_p^2 = .574$, with higher ratings at Time 1 ($M = 5.68$, $SE = 0.36$) than at Time 2 ($M = 3.56$, $SE = 0.36$), 95% CI_{diff} [1.44, 2.92]. As expected, these were qualified by a significant Condition × Time interaction, $F(1, 27) = 29.39$, $p < .001$, $\eta_p^2 = .521$. This interaction showed that at Time Point 1, there was no significant difference between reals ($M = 5.69$, $SE = 0.37$) and simulators ($M = 5.67$, $SE = 0.64$), 95% CI_{diff} [−1.47, 1.51], $t(27) = 0.03$, $p = .976$, $d = 0.01$, but at Time Point 2, reals ($M = 5.47$, $SE = 0.44$) rated significantly higher than simulators ($M = 1.52$, $SE = 0.32$), 95% CI_{diff} [2.81, 5.08], $t(27) = 7.14$, $p < .001$, $d = 2.65$. These results indicate that there was a difference in the subjective reports of simulators compared to genuinely hypnotized participants (Figure 7).

Discussion

Unlike Experiments 1 and 2, the genuinely hypnotized highs in this experiment did not report increased ticklishness for self-generated actions during hypnosis. This finding was surprising and may be due to a small change in the procedure. In Experiments 1 and 2, participants repeated ratings of tactile stimuli made after a hypnotic suggestion, and the average of these two ratings were

Figure 7
Subjective Experience as a Function of Condition and Time



Note. See the online article for the color version of this figure.

used in all analyses (see Supplemental Table S5, for more details). In Experiment 3, participants made only a single rating at each time point. This change may have led to relatively less precision in ratings obtained in Experiment 3.

In any case, simulators were able to produce tickle responses that were broadly similar to reals. This indicates that changes in ticklishness in this paradigm may be partially due to demand characteristics. However, differences in SOARS scores and posthypnotic ratings between reals and simulators suggest that reals did experience changes in subjective awareness that cannot be explained by demand characteristics alone.

General Discussion

Our results demonstrate that hypnosis can influence the way that participants perceive the sensory consequences of their self-produced actions. Hypnotic suggestion—particularly a suggestion based on clinical cases of alien control—disrupted self-monitoring in such a way that self-produced stimuli felt more like externally produced stimuli. This suggests that, consistent with the predictions of the comparator model (Blakemore et al., 2002; Wolpert, 1997), the normal attenuation of the sensory effects of self-produced actions was reduced.[1] These changes in the sensation of ticklishness occurred despite there being no direct instructions for participants to change their perception of tickle sensations in either of the hypnotic suggestions. The hypnotic alteration of the sense of agency appears to have had a similar effect on participants' experience of self-produced tactile stimuli as Blakemore et al.'s (1999) behavioral illusion paradigm.

Highs showed a marked reduction in the sense of agency in this task, as indexed by the SOARS in Experiment 1. Furthermore, increased Involuntariness was specifically associated with greater alterations to the ticklishness of self-produced actions in Experiments 1 and 2. Alterations in participants' self-monitoring were further demonstrated by impaired accuracy in identifying the source of self-produced stimuli. This was particularly notable for highs in Experiment 1 and participants administered the alien control suggestion in Experiment 2.

[1] These findings are also consistent with the ideomotor theorizing account (e.g., Dogge, Aarts, et al., 2019; Horváth, 2015; Kilteni et al., 2018; Wirth et al., 2016).

Ratings of subjective self-control indicated that highs experienced greater levels of alteration to their perception of self-produced actions than lows, regardless of suggestion, in Experiment 1. This was the case even though earlier ratings of tactile stimuli showed clear differences between participants who received the alien control suggestion and those who received the anesthesia suggestion. In Experiment 2, subjective ratings showed more of a difference between participants who received the alien control suggestion and those who received the anesthesia suggestion, with alien control participants rating self-produced stimuli as feeling more external. So, on the one hand, participants showed quite clear distinctions between suggestions, with alien control associated with tactile ratings that indicated markedly changed sensory responses to self-produced actions, while on the other hand, participants' post hoc, subjective ratings of their experiences showed varying degrees of discrimination between suggestions. These findings support the idea that sense of agency is a multifactorial construct (Polito et al., 2013, 2014). Alterations to self-monitoring that led to modified sensory responses to self-produced actions appear to be just one component of agency change, and this component was particularly activated by the alien control suggestion. Although participants who received the anesthesia suggestion did not show changes in ticklishness responses, subjective ratings indicated these participants did experience other aspects of agency change (see McConkey, 2008; Woody & McConkey, 2003, for more on hypnotic suggestions activating particular aspects of conscious experience).

Although the self-monitoring alterations targeted here were associated with changes in feelings of agency (as demonstrated by correlations between Involuntariness and tactile ratings), these two constructs were not equivalent. In other words, participants' subjective ratings of their sense of agency in this task may not have included complete information regarding alterations to self-monitoring, perhaps because these aspects of sense of agency may be less explicitly available to conscious awareness (I. Gallagher, 2000; S. Gallagher, 2012). Indirect measures, such as ticklishness ratings, may be of greater utility in assessing such implicit aspects of sense of agency.

Finally, although genuinely hypnotized participants and simulators did not differ in their behavior in Experiment 3, results from this study did show that hypnotized participants had different subjective experiences from participants simulating hypnosis. In other words, simulators were able to anticipate and mimic behavioral responses that were similar to hypnotized participants but simulating hypnosis did not lead to equivalent feelings of agency and control. Specifically, patterns of SOARS scores and posthypnotic ratings differed between reals and simulators, indicating that hypnosis did lead to shifts in conscious experience for reals. In particular, the SOARS proved a valuable tool for discriminating between genuinely hypnotized participants and those simulating hypnosis. Simulators reported a marked shift in Involuntariness before the induction had occurred, whereas reals reported a gradual increase in Involuntariness at each phase of the experiment. This indicates that, although simulators were able to anticipate that agency changes would occur in hypnosis, they were not aware of how different elements of the hypnotic intervention would change specific aspects of agentive experience. Reals, by contrast, reported marked changes in response to a hypnotic induction and hypnotic suggestions. Experiment 3 also included an extra administration of the tactile stimulation task, occurring before the hypnotic induction. The most notable change in ratings of tactile stimuli in Experiment 3, for both reals and simulators, occurred from Time 1 (before the induction) to Time 2 (after the induction). This may suggest that the hypnotic context has an effect on participants' experience of tactile stimuli, even in the absence of specific hypnotic suggestions. Alternately, these findings may indicate that simulators anticipated that they would be asked to make additional ticklishness ratings during hypnosis and so downplayed their baseline responses.

Theoretical Implications

In the Blakemore et al. (1999) tickling study, a mismatch between predicted sensory feedback and actual sensory feedback occurred due to an experimental manipulation that directly influenced the sensorimotor system. This mismatch resulted in self-produced actions being experienced as if they were externally produced. In the current experiments, a subset of hypnotized participants also experienced their self-produced actions as if they were externally produced. In this case, however, there were no direct external influences on participants' motor control system.

Notably, a study involving the body transfer illusion, which involves dramatic alterations in perceptual cues related to spatiotemporal touch, found no change in tickle responses (Van Doorn et al., 2014). So, the question here is how this hypnotic task (and in particular the alien control suggestion) was able to impact participants' multisensory responses?

In a related study, Blakemore et al. (2003) investigated the perception of self-produced movements by hypnotized participants. Their task was somewhat different in that they focused only on a suggestion for ideomotor arm movements and did not use the self-tickling paradigm; they did not investigate the perception of tactile stimuli or incorporate suggestions specifically targeting self-monitoring. Nevertheless, they found that their hypnotic suggestion led participants to experience particular self-produced movements as if they were involuntary. Blakemore et al. (2003) proposed that their hypnotic task influenced comparator processes by disrupting predictions about the sensory consequences of motor commands. They suggested that either efference copy signals were blocked from reaching the predictor module or the operation of the predictor module was affected such that it could not effectively process efference signals. This proposal is consistent with Frith et al. (2000a) who claimed that, with regard to comparator models, delusions of control and clinical impairments of self-monitoring are associated with errors of prediction, rather than errors related to sensorimotor feedback or reafference.

But how is it that hypnotic suggestion, that is, high-level, top-down, cognitive instructions, can so dramatically alter relatively low-level, bottom-up processes, such as the functioning of comparator processes in the motor system? One way to explain these changes is in terms of predictive coding or ideomotor frameworks (Dogge, Custers, & Aarts, 2019; Jamieson, 2016, 2022; Martin & Pacherie, 2019; Woody & McConkey, 2003). Woody and McConkey (2003) provided an account of how this might occur, based on Friston's (2002) "predictive architecture" model of sensory processing. According to Friston's account, top-down influences on sensory processing establish potent context parameters that constrain and shape individuals' sensory experiences. Woody and McConkey (2003) suggested that hypnosis might influence sensory processing in this way, so that perceptual experiences conform to the content of hypnotic suggestions, even when this is inconsistent with sensory inputs. So in the current experiments, the suggestion for alien control may have created a context for sensory processing in which self-monitoring was altered in such a way that predictions about the sensory consequences of self-produced actions were impaired (as proposed by Blakemore et al., 2003). There is some support for this account from neurophysiological data. Blakemore et al.'s (2003) study of hypnotic ideomotor action found patterns of activation in the hypnotic action condition that were consistent with comparator model processes. More generally, self-produced actions that are associated with a reduced sense of agency in hypnosis have been linked to increased cerebellum activation, a region that has been strongly linked to comparator model activity (Blakemore et al., 1998, 2000; Imamizu et al., 2000; Walsh et al., 2017; see also Kilteni & Ehrsson, 2020). These results suggest that participants' experience of the sensory consequences of their self-produced actions in hypnosis occurred due to altered comparator model functioning in much the same way as occurred in Blakemore et al.'s (1999) behavioral illusion task.

Limitations

There are a number of limitations to these experiments. First, although the hypnotic suggestions did not specifically mention changes in tickle responses, the experimenter did refer to a "tickling stick," providing a cue to participants that this was an important variable in the study. Second, verbal ratings of tactile stimuli are a relatively crude measure. Future research could adopt more sensitive techniques, such as galvanic skin responses, to assess physiological aspects of sensory experience. Third, the experimenter and participant may not have produced tactile movements with consistent pressure across time points. This could potentially be addressed by using an apparatus that standardizes stimuli (e.g., Blakemore et al., 1999). Fourth, although this series of experiments aimed to investigate hypnotic influences on the perception of self-produced actions across a range of experimental designs, it appears that some of the effects of interest are subtle and were only evident for a subset of participants (i.e., high-hypnotizable participants who were administered both a hypnotic induction and the alien control suggestion). Future research could simplify the design, focusing only on these conditions, with a greater number of participants to provide greater statistical power to further explore the phenomena. Fifth, the number of participants in these experiments was relatively low. Future research with larger, better powered studies will be important to confirm this pattern of findings. Larger studies would also allow for the investigation of variation due to demographic factors such as age and gender, which was not practical in the current set of studies.

Conclusions

Overall, converging evidence from a range of experimental designs showed that hypnotic suggestions influenced low-level processes related to self-monitoring and affected participants' perception of the sensory consequences of their own actions. These results demonstrate the capacity of hypnosis to model self-monitoring deficits and create marked cognitive and perceptual alterations. As such, hypnosis remains highly relevant as a tool for understanding both our subjective sense of agency and the clinical conditions that disrupt it.

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