RUNNING HEAD: Can hypnosis make you ticklish?

Can hypnosis make you ticklish? Using suggestion to modulate agency

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All data and analysis scripts for this project can be found at <https://osf.io/4g8s2/>

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Abstract

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 is why, typically, we cannot tickle ourselves. However, previous research has found that mechanically manipulating the sensory consequences of actions can create the illusion that they are externally-produced; i.e., 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, while varying the hypnotisability of subjects, and the presence of a hypnotic induction. We found that suggestions designed to model self-monitoring deficits did increase perceived tickliness. These effects were stronger in high hypnotisable participants and after an induction; and could not be explained by demand characteristics alone. These results highlight the capacity of hypnosis to alter sense of agency and model deficits associated with clinical conditions using hypnosis.

Keywords: Agency, Hypnosis, Passivity Phenomena, Involuntariness, Self-Monitoring, Sense of Agency, Suggestion

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. However, sense of agency is an integral aspect of our sense of self and experience of the world. It represents aspects elements of our conscious experience that we have caused and allows us to differentiate self-produced effects from those caused by external sources. Previous research has studied alterations in agency that occur in contexts such as artistic performance and sport (Csikzentmihaly, 1991); rituals that involve trance (Cardeña, van Duijl, Weiner, & Terhune, 2009; Hutch, 1980; Port, 2005), and in clinical conditions such as passivity phenomena in schizophrenia (Frith, Blakemore, & Wolpert, 2000a; Mellor, 1970; Spence et al., 1997). Another line of research has used lab-based paradigms to alter sensory feedback and manipulate sense of agency more directly (e.g., Daprati et al., 1997; Moore, Wegner, & Haggard, 2009; Wegner, Sparrow, & Winerman, 2004). In this paper, we aimed to integrate these two methodological approaches (direct investigation of situations involving agency disruption and behavioural illusion paradigms) by creating a hypnotic version of an experimental task previously reported to influence sense of agency. We modelled suggestions on clinical conditions of disrupted agency and varied different aspects of the hypnotic procedure to examine elements contributing to altered sense of agency.

Hypnosis and Agency Change

Hypnosis is a particularly powerful methodology for investigating 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 called the experience of diminished agency the “classical suggestion effect” (1974, p. 264). A number of competing accounts have been proposed to explain this (see Lynn, Rhue, & Kirsch, 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 (Polito, Barnier, & Connors, 2018). 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 sense of agency (Woody & McConkey, 2003). Responding to standard hypnotic suggestions seems to be associated with a general 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' agentic experiences. One application of this 'instrumental' approach is using hypnosis to model and investigate other phenomena. Passivity phenomena in schizophrenia, for example, are characterised by the experience that body movements, emotions and thoughts occur without their conscious intention (Mellor, 1970). Hypnotic suggestions based on these features can be used to alter sense of agency in healthy controls (e.g., Connors, 2015; Polito et al., 2018; Walsh, Oakley, Halligan, Mehta, & Deeley, 2015) and create "virtual patients" with experiences and behaviour functionally similar to the clinical condition (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 *hypnotisability* – their capacity to experience hypnotic suggestions (Hilgard, 1965). This trait is normally-distributed (Laurence, Beaulieu-Prévost, & du Chênè, 2008), with approximately 10% considered to be high hypnotisable ("highs") and 10% considered to be low hypnotisable ("lows"). Aspects of the

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), previous research has found that a hypnotic induction increases the likelihood of participants responding to suggestions, including those related to agency (Polito, Barnier, Woody, & Connors, 2014) and more challenging cognitive experiences (see Connors et al., 2013; Connors, Barnier, Langdon, & Coltheart, 2015; Connors et al., 2015).

Experimental Studies of Agency Using Self Tickling

An influential theory of the mechanisms that underlie alterations to sense of agency in both clinical and nonclinical contexts is the comparator model (Blakemore, Wolpert, & Frith, 2002; Wolpert, 1997). According to this account, sensory signals are recognised 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. This model provides an explanation for the well-known observation that we usually cannot tickle ourselves (Weiskrantz, Elliott, & Darlington, 1971). Given the correspondence between predicted action and sensory response, sensory response is attenuated, thereby resulting in a lack of tickliness (Blakemore, Frith, & Wolpert, 1999; Blakemore, Wolpert, & Frith, 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 Current Studies

We sought to recreate this self-tickling paradigm but 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 sense of agency, we used hypnosis to produce “top down”, high-level cognitive alterations of subjective experience of motor control (Polito et al., 2018; Polito, Barnier, & Woody, 2013; Polito et al., 2014). 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., 2000a). The other was based on anaesthesia, in which patients report that they cannot feel the affected body part, but do not typically claim that it is externally controlled (Spence, 2008). Comparing these suggestions allowed us to examine the unique contribution of experiencing one's actions as self- versus externally-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 hypnotisability (study one), hypnotic induction (study two), and

demand characteristics (study three) 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 sense of agency in high hypnotisable participants and that these effects would be larger after a hypnotic induction.

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 anaesthesia (McConkey, Gladstone, & Barnier, 1999; Wilton, Barnier, & McConkey, 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 anaesthesia suggestion were told that they would not feel anything from the movements of their right arm and hand. Participants in this study: (1) rated the perceived tickliness of self-produced and externally-produced tactile stimuli at baseline (in counterbalanced order); 2) rated the same stimuli following a hypnotic suggestion; (3) identified the source of tactile stimuli; (4) completed the Sense of Agency Ratings Scale (SOARS: Polito et al., 2013); and (5) 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 tickliness for self-produced stimuli following 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.

Method

Participants and design

We tested 40 undergraduate participants at Macquarie University, however three participants were excluded (2 for not making any self-produced movements when instructed and 1 due to a data collection error). The final sample consisted of 37 participants (nine males, 28 females) of mean age 21.2 (SD = 4.1) years. Participants took part in a 2 (hypnotisability: low vs. high) x 2 (suggestion: alien control vs. anaesthesia) x (2) (source: self vs. other) x (2) (time: baseline vs. after suggestion) mixed design. Prior to the study, all participants completed the Harvard Group Scale of Hypnotic Susceptibility, Form A (HGSHS:A; Shor & Orne, 1962), and the Stanford Scale of Hypnotic Susceptibility, Form C (SHSS:C; Weitzenhoffer & Hilgard, 1959). Confirming hypnotic ability through these two measures is considered the gold standard in hypnotic research (Kihlstrom, 2008). Highs scored 7 or more on the HGSHS:A and 7 or more on the SHSS:C.¹ Lows scored between 0 and 3 on a modified, 10-item, version of the HGSHS:A, and between 0 and 3 on an 11-item version of the SHSS:C. After exclusions there were 22 highs and 15 lows.

¹ 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; arm rigidity and arm immobilization items were removed. The 11-item tailored SHSS:C included: hand lowering, moving hands apart, mosquito hallucination, taste hallucination, arm rigidity, dream, age regression, arm immobilization, negative visual hallucination, and posthypnotic amnesia; the auditory hallucination item was removed. These modifications were made to ensure that the procedure could be conducted within the time available.

Participants received one of two hypnotic suggestions designed to alter their experience of tactile sensations; either a suggestion for alien control or anaesthesia. Nineteen participants received the alien control suggestion (8 lows, 11 highs) and 18 received the anaesthesia suggestion (7 lows, 11 highs). The order in which participants experienced tactile sensations was counterbalanced both at baseline and after suggestion: 19 participants first tickled themselves, and then were tickled by the hypnotist; 18 participants did this in the reverse order.

Materials and measures

The tactile stimulus consisted of gently pressing a ‘tickling stick’ in a repeated circular motion against participants’ left palms for a period of 5 seconds. The tickling stick was a standard craft brush consisting of a plastic handle 10cm long and a rectangular foam head 5cm wide. 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 seven-point Likert scale from ‘strongly disagree’ to ‘strongly agree’. This scale has two factors: *Involuntariness*, representing a subjectively experienced reduction in control over ones’ 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.

Procedure

Participants experienced a standard hypnotic induction, taken from the SHSS:C, of approximately 12 minutes duration and completed several simple hypnotic filler tasks to establish and reinforce the hypnotic context. In the first phase of the experiment, participants made baseline 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. Participants then 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 using another identical tickling stick. In all cases tactile stimuli lasted for 5 seconds. The order in which self-produced and externally-produced movements occurred was counterbalanced between participants. Following the procedure of Blakemore et al. (1999), participants made verbal ratings of the tickliness of each tactile stimulus on a scale from 1 to 10.²

In the second phase of the experiment, participants again made ratings of self-produced and externally-produced movements, 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 anaesthesia of their right hand. Both suggestions were triggered by the phrase "tickle palm". Verbatim suggestions are provided in Table S1 (<https://osf.io/ef973/>).

² We also obtained ratings of the intensity, pleasantness, and irritation of each stimulus. Tickliness ratings proved to be the only scores that varied systematically in response to the hypnotic suggestions and so, for simplicity, only these results have been reported. Data for these alternate measures is available at <https://osf.io/4g8s2>

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 tickliness immediately after each tactile stimulus. After the initial round of tactile stimuli, the hypnotist reminded participants of the suggestion and the cue (“tickle palm”). The sequence was then repeated so that participants experienced self-produced and externally-produced tactile stimuli a second time. Following the final rating of each tactile stimulus, the hypnotist read back participants ratings, and participants were asked to identify the source of the sensation. For example, after the second round of tactile stimuli and ratings, the hypnotist might say, “you rated the tickliness of that sensation as 6 out of 10 just now. 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). The hypnotist then cancelled the hypnotic suggestion.

In the third phase of the experiment, participants were asked to think back to their experience of tickling themselves 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 a brief posthypnotic interview. Participants were instructed to think back to their self-produced movements following the hypnotic suggestion. Participants 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 anaesthetised 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?

All studies were approved by the Macquarie University Human Research Ethics Committee (protocol number HE31JUL2009D00051).

Results

Table 1 - Tickliness Ratings in Experiment 1

Hypnotisability	Self-produced stimuli		Other-produced stimuli	
	Alien control	Anaesthesia	Alien control	Anaesthesia
<i>Baseline</i>				
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)
<i>After suggestion</i>				
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.

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 (hypnotisability) x 2 (suggestion) x (2) (source) x (2) (time) analysis of variance (ANOVA) revealed a main effect of source, $F(1, 33) = 40.75, p < .001, \eta^2 = .553$. As predicted, participants experienced externally-produced tactile stimuli as more tickly ($M = 6.16, SE = .22$) than self-produced stimuli ($M = 4.85, SE = .23$), $95CI_{diff} [0.89, 1.73]$. There also was a main effect of hypnotisability, $F(1, 33) = 5.21, p = .029, \eta^2 = .136$, indicating that highs ($M = 5.97, SE = .19$) experienced tactile stimuli as more tickly overall than lows ($M = 4.82, SE = .29$), $95CI_{diff} [0.13, 2.18]$. Finally, there was a significant interaction of suggestion x source x time, $F(1,$

33) = 4.54, $p = .041$, $\eta p^2 = .121$. As shown in Figure 1, this three-way interaction driven by a significant two way interaction of suggestion x time for self-produced tactile stimuli, $F(1, 35) = 5.17$, $p = .029$, $\eta p^2 = .129$, but no significant interaction of suggestion x time for other-produced tactile stimuli, $F(1, 35) = 0.04$, $p = .845$, $\eta p^2 = .001$. Specifically, for self-produced stimuli, tickliness ratings tended to increase following the alien control suggestion ($M_{\text{diff}} = .87$, $CI_{\text{diff}} [-0.10, 1.84]$) but tended to decrease following the anaesthesia suggestion ($M_{\text{diff}} = -.64$, $CI_{\text{diff}} [-1.64, 0.37]$). Contrary to expectations, we found no evidence of an interaction between hypnotisability, source, and time, $F(1, 33) = 0.32$, $p = .577$, $\eta p^2 = .010$.

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

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, $t = 1.98$, $p = .056$, $d = 0.345$. For self-produced stimuli, a 2 (hypnotisability) x 2 (suggestion) between-subjects ANOVA of source identification errors revealed a main effect of hypnotisability, indicating that as predicted, highs ($M = .47$, $SE = .12$) made more errors than lows ($M = .07$, $SE = .07$), $95CI_{diff} [0.09, 0.72]$, $F(1, 29) = 7.04$, $p = .013$, $\eta^2 = .195$. The main effect of suggestion, $F(1, 29) = 0.95$, $p = .338$, $\eta^2 = .003$, and the interaction between hypnotisability and suggestion, $F(1, 29) < 0.01$, $p = .967$, $\eta^2 < .001$, were both non-significant.

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 (hypnotisability) x 2 (suggestion) factorial ANOVA revealed a main effect of hypnotisability, $F(1, 33) = 46.38$, $p < .001$, $\eta^2 = .584$, indicating that highs experienced significantly greater levels of involuntariness ($M = 22.50$, $SE = 1.23$) than lows ($M = 9.67$, $SE = 1.37$), $95CI_{diff} [9.07, 16.79]$. For *Effortlessness*, again we found a significant main effect of hypnotisability, $F(1, 33) = 4.22$, $p = .048$, $\eta^2 = .113$, with highs having higher scores ($M = 27.40$, $SE = .73$) than lows ($M = 24.40$, $SE = 1.38$), $95CI_{diff} [0.03, 5.83]$. There were no other significant main effects or interactions for either SOARS factor.

To investigate whether these agency scores related to participants' ratings of tickliness, bivariate correlations were calculated between the SOARS subscales and ratings of self-produced tactile stimuli following the suggestion. Tickliness ratings correlated

significantly with *Involuntariness*, $r = .56$, $p < .001$, but not with *Effortlessness*, $r = .17$, $p = .324$. These results indicate that the less control participants felt, the more they experienced their self-produced actions as tickly.

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

Posthypnotic ratings of subjective experience

Following hypnosis, participants rated their experience of generating self-produced actions. 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 (hypnotisability) x 2 (suggestion) between-subjects ANOVA showed that self control varied significantly with

hypnotisability, $F(1, 33) = 51.42, p < .001, \eta^2 = .609$, indicating that highs ($M = 5.19, SE = 0.32$) experienced significantly greater disruption to feelings of control than lows ($M = 1.89, SE = 0.27$), $95CI_{diff} [2.37, 4.25]$, but there were no differences in responses between participants who experienced alien control and those who experienced anaesthesia, $F(1, 33) = 0.06, p = .816, \eta^2 = .002$, and no interaction, $F(1, 33) = 0.03, p = .854, \eta^2 = .001$. This is surprising, as the two hypnotic suggestions had different effects on tickliness, yet here participants reported equivalent alterations in their subjective feelings of control. This indicates that the change in tickliness ratings evident following the alien control suggestion was not simply due to a general change in feelings of control (as the anaesthesia suggestion also led to changes in subjective control but not to changes in the experience of tickliness). Rather, this indicates the specific content of the alien control suggestion led to an alteration of self-monitoring that influenced participants' experience of tickliness.

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 suggestion for alien control, however, participants reported an increase in the tickliness of self-produced stimuli compared to baseline. In other words, the alien control suggestion led participants to experience their self-produced actions as more like externally-produced actions. This increase in tickliness 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 and participants who self-tickled first 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 tickliness. Surprisingly, although highs found tactile stimuli more tickly than lows overall, the specific increase in tickliness following the alien control suggestion occurred regardless of hypnotisability. This suggests that hypnotic ability may not be necessary for participants to use specific cognitive strategies to alter sense of agency. We investigated the importance of formal hypnosis for altering 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 utilised 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 anaesthesia).

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, Barnier, Coltheart, Cox, & Langdon, 2012; McConkey, Szeps, & Barnier, 2001; Polito et al., 2014), we expected that participants administered an induction would report an increase in ratings of tickliness 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 ($SD = 1.58$). Participants completed a 2 (induction: hypnosis vs. wake) x 2 (suggestion) x (2) (source) x (2) (time) 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. 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 anaesthesia suggestion (13 hypnosis, 12 wake). The order of self- 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 (Wechsler, 1997) and a geometric puzzle requiring them to bisect an L-shaped figure using a pencil, paper and ruler (Nogrady, McConkey, & Perry, 1985) for 12 minutes.

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

Table 2 - Tickliness Ratings in Experiment Two

Condition	Self-produced stimuli		Other-produced stimuli	
	Alien control	Anaesthesia	Alien control	Anaesthesia
<i>Baseline</i>				
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)
<i>After suggestion</i>				
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.

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

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

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 ($M = .38$, $SE = .07$), $95CI_{diff} [-.001, .31]$, and this difference approached statistical significance, $t = 2.00$, $p = .051$, $d = 0.300$. For self-produced stimuli, a 2 (induction) x 2 (suggestion) between-subjects ANOVA of source identification errors revealed a main effect of suggestion, indicating that participants administered the alien control suggestion were more impaired at identifying the source of self-produced actions ($M = .70$, $SE = .10$) compared to participants administered the

anaesthesia suggestion ($M = .36$, $SE = .11$), $95CI_{diff} [.07, .64]$, $F(1, 41) = 6.27$, $p = .016$, $\eta^2 = .133$. There was no main effect of induction, $F(1, 41) = 1.62$, $p = .210$, $\eta^2 = .038$, and no interaction between induction and suggestion, $F(1, 41) = 1.62$, $p = .210$, $\eta^2 = .038$.

SOARS scores

Figure 4 shows SOARS scores for hypnosis and wake participants administered each suggestion. For *Involuntariness*, a 2 (induction) x 2 (suggestion) between-subjects ANOVA revealed a significant main effect of suggestion, $F(1, 46) = 4.13$, $p = .048$, $\eta^2 = .082$, indicating that participants administered the alien control suggestion experienced greater levels of involuntariness ($M = 21.20$, $SE = 1.24$) than those administered the anaesthesia suggestion ($M = 17.90$, $SE = 1.16$), $95CI_{diff} [0.03, 6.76]$. Contrary to expectations, there was no main effect of induction, $F(1, 46) = 2.92$, $p = .094$, $\eta^2 = .060$, and there was no interaction, $F(1, 46) = 0.71$, $p = .404$, $\eta^2 = .015$. For *Effortlessness*, there was no main effect of suggestion, $F(1, 46) = 0.42$, $p = .522$, $\eta^2 = .009$, no main effect of induction, $F(1, 46) = 2.13$, $p = .151$, $\eta^2 = .044$, and no interaction, $F(1, 46) = 0.01$, $p = .915$, $\eta^2 < .001$.

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. Tickliness 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 tickliness following the hypnotic suggestions.

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

Posthypnotic ratings of subjective experience

Subjective ratings of self-produced actions (Table S3) again showed excellent internal consistency ($\alpha = .848$), so we analysed the mean score. A 2 (induction) x 2 (suggestion) between-subjects ANOVA showed a significant main effect of induction, $F(1, 45) = 4.29$, $p = .044$, $\eta^2 = .087$, with higher ratings for the hypnosis condition ($M = 4.65$, $SE = 0.37$) than the wake condition ($M = 3.62$, $SE = 0.40$), $95CI_{diff} [0.03, 2.10]$. There was also a significant main effect of suggestion, $F(1, 45) = 6.90$, $p = .012$, $\eta^2 = .133$, with higher ratings for participants administered the alien control suggestion ($M = 4.83$, $SE = .41$) compared to those administered the anaesthesia suggestion ($M = 3.49$, $SE = 0.35$), $95CI_{diff} [0.31, 2.38]$. 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.

Discussion

Overall, in experiment 2, participants administered the alien control suggestion exhibited reduced sense of agency as demonstrated by increased tickliness ratings, poorer source discrimination, and higher SOARS scores than participants administered the anaesthesia 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 hypnotisable participants, a hypnotic induction influenced tickliness 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 hypnotisables and, for tickliness, after induction. The potential influence of demand characteristics on participants' reported sense of agency, however, was unclear. Experiment 3 utilised the real-simulating design of Orne (1959, 1962). In this procedure, a hypnotist blinded to participants' hypnotisability gives suggestions to highs and lows, with the latter group specifically instructed to act as if they are hypnotised 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 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 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 hypnotised participants (reals) would report an increase in ratings of tickliness 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 ($SD = 1.88$). Participants completed a 2 (condition: hypnosis vs. simulating) x 2 (source) x 3 (time: before induction vs. after induction vs. after suggestion) mixed-model 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 always blind as to 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.

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 this experiment, 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 hypnotisable. The researcher then repeated the subjective experience rating questions asked earlier by the hypnotist.

Results

Ratings of tactile stimuli

Table 3 shows participants' ratings of self-produced and externally-produced tactile stimuli at each time point. A 2 (condition) x (2) (source) x (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 ($M = 4.88, SE = .25$), $95CI_{diff} [0.18, 1.10]$. There was also a significant main effect of time, $F(2, 54) = 4.45, p = .016, \eta p^2 = .141$. Contrasts showed that tickliness rose significantly from time point 1 (before the induction; $M = 4.72, SE = .27$) to time point 2 (after the induction; $M = 5.36, SE = .32$), $95CI_{diff} [0.12, 1.17], F(1, 27) = 6.45, p = .017, \eta p^2 = .193$. However, there was no significant difference from time point 2 to time point 3 (after the suggestion; $M = 5.53, SE = 0.29$), $95CI_{diff} [-0.50, 0.86], F(1, 27) = 0.31, p = .584, \eta p^2 = .011$. Finally, as illustrated in Figure 5, we found a significant interaction of condition x source x time, $F(2, 54) = 4.13, p = .021, \eta p^2 = .133$.

To explore this interaction, we performed (2) (source) x 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, $F(1, 27) = 3.11, p = .089, \eta p^2 = .103$.

Table 3- Tickliness Ratings in Experiment Three

Condition	Self Generated			Externally Generated		
	Before	After	After	Before	After	After
	Induction	Induction	Suggestion	Induction	Induction	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. Means shown with standard errors in parentheses.

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

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 ($M = .41$, $SD = .50$), compared to externally-produced stimuli ($M = .04$, $SD = .19$), $95CI_{diff} [0.19, 0.57]$, $t = 4.14$, $p < .001$, $d = 0.768$. 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 administered at each time point. For *Involuntariness*, a 2 (condition) x (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 ($M = 19.7, SE = .1.20$), $95CI_{diff} [2.77, 7.85], t(26) = 4.43, p < .001, d = .85$. The change from time point 2 to time point 3 ($M = 21.9, SE = 1.26$), $95CI_{diff} [-0.38, 4.21]$, was non-significant, $t(26) = 1.85, p = .075, d = .36$. 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 ($M = 18.2, SE = 1.61$), $95CI_{diff} [3.09, 10.65], t(14) = 3.90, p = .002, d = 1.01$, and again from time point 2 to time point 3, following the suggestion ($M = 22.2, SE = 1.86$), $95CI_{diff} [0.23, 7.77], t(14) = 2.28, p = .039, d = 0.59$. For simulators, *Involuntariness* rose from time point 1, before the induction ($M = 17.8, SE = 1.92$) to time point 2, after the induction ($M = 21.6, SE = 1.74$), $95CI_{diff} [0.11, 7.39], t(11) = 2.27, p = .044, d = 0.66$, but did not change from time point 2 to time point 3, after the suggestion ($M = 21.4, SE = 1.72$), $95CI_{diff} [-2.75, 2.42], t(11) = 0.14, p = .890, d = 0.04$. 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 ($M = 11.3, SE = 1.49$), $95CI_{diff} [1.58, 11.42], t(25) = 2.72, p = .014, d = 1.05$. There was no difference between reals and simulators after the induction ($95CI_{diff} [-1.52, 8.28], t(25) = 1.42, p = .167, d = 0.55$), or after the suggestion ($95CI_{diff} [-6.11, 4.54], t(25) = 0.30, p = .765, d = 0.12$).

For *Effortlessness*, a 2 (condition) x (3) (time) ANOVA showed no main effects or interaction.

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

Posthypnotic ratings of subjective experience

Following hypnosis, participants rated their subjective experiences. These questions were 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 hypnotisable when the original investigator first re-entered 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. S4 shows the mean ratings made by participants at both time points.

Subjective ratings of self-produced actions (Table S4) showed excellent internal consistency at time 1 ($\alpha = .777$) and at time 2 ($\alpha = .890$), so we analysed the mean score at

each time point. A 2 (condition) x (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 ($M = 3.60, SE = 0.53$), $95CI_{diff} [0.89, 3.08]$. 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 ($M = 3.56, SE = 0.36$), $95CI_{diff} [1.44, 2.92]$. As expected, these were qualified by a significant condition x 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 ($M = 5.67, SE = 0.64$), $95CI_{diff} [-1.47, 1.51], t(27) = 0.03, p = .976, d = 0.01$, but at time point 2, reals ($M = 5.47, SE = 0.44$) rated significantly higher than simulators ($M = 1.52, SE = 0.32$), $95CI_{diff} [2.81, 5.08], t(27) = 7.14, p < .001, d = 2.65$. These results indicate that there was a difference in the subjective reports of simulators compared to genuinely hypnotised participants.

Figure 7. Subjective Experience as a Function of Condition and Time

Discussion

Unlike experiments 1 and 2, the genuinely hypnotised highs in this experiment did not report increased tickliness for self-generated actions following during hypnosis. In addition, simulators were able to produce tickle responses that were broadly similar to reals. This indicates that changes in tickliness 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 some changes in subjective awareness that were not due to demand characteristics.

General Discussion

Our results demonstrate that hypnosis can influence the way that participants perceive the sensory consequences of their self-produced actions. Hypnotic suggestion, in particular 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. These changes in the perception of tickliness occurred despite there being no reference to tickling or tickliness in either of the hypnotic suggestions. The hypnotic alteration of sense of agency appears to have had a similar effect on participants' experience of self-produced tactile stimuli as Blakemore et al.'s (1999) behavioural illusion paradigm.

Highs showed a marked reduction in 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 tickliness 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.

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 those who received the alien control suggestion and those who received the anaesthesia suggestion. In experiment 2, subjective ratings showed more of a difference between participants who received the alien control suggestion and those who received the anaesthesia 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 anaesthesia suggestion did not show changes in tickliness 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 (Gallagher, 2000, 2012). Indirect measures, such as tickliness ratings, may be of greater utility in assessing such implicit aspects of sense of agency.

Finally, experiment 3 demonstrated that hypnotised participants had distinct experiences from participants simulating hypnosis. 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 hypnotised 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 agentic 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 suggests that the hypnotic context may have had some effect on participants' experience of tactile stimuli, even in the absence of specific hypnotic suggestions.

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 hypnotised 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, Hohwy, & Symmons, 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, Oakley, and Frith (2003) investigated the perception of self-produced movements by hypnotised 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. (2000b) who claimed that, with regards 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 frameworks (Martin & Pacherie, 2019; Woody & McConkey, 2003). Woody and McConkey 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 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, Wolpert, & Frith, 1998; Blakemore et al., 2000; Imamizu et al., 2000; Walsh, Oakley, Halligan, Mehta, & Deeley, 2017). 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) behavioural illusion task.

Limitations

There are a number of limitations to these experiments. First, although the hypnotic suggestions did not specifically mention tickliness, 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, 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 hypnotisable 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.

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 to understanding both our subjective sense of agency and the clinical conditions that disrupt it.

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