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You can't tickle yourself…or can you? The effect of a hypnotic suggestion on sensory attenuation phenomenon

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Abstract

The internal motor simulation mechanism is widely believed to generate anticipatory sensory outcomes on the basis of the efferent copy of the motor commands. What is currently unknown is whether the motor prediction mechanism can integrate non-motor inputs such as a hypnotic suggestion in generating sensory predictions. Seventy-two undergraduate students (M=12, F=60) were recruited via Plymouth University participation pool, to undergo a randomised hypnotic suggestion (IV) of either an alien-hand or an alien-foot. The participants were asked to apply tactile stimulation to their left palm (DV) before and after the suggestion and report the tickling sensations. The results revealed an unexpected trend, which just fell short of statistical significance, not only did the control participants get more ticklish over time, but also some participants in the test group felt more in control as a result of alien-hand suggestion. This study found no evidence to support the idea of higher-level functioning forward model. The discussion explores possible explanations for the unexpected findings and highlights a couple of limitations. Finally, implications of the findings are noted with scope of direction for future studies exploring action control theories.

Introduction

An individual's ability to estimate the state of his body and external environment arises from two different streams of information: the motor stream that predicts what would happen and the sensory stream that reports what actually happened (Shadmehr, Smith, & Krakauer, 2010). These streams form what is commonly known as the Internal models of action control (Wolpert, 1997). One such model is called the forward model (FM) and functions by transforming the (efferent copy of) motor commands of the intended actions, into their sensory outcomes such that every action becomes associated with a specific predicted consequence (Wolpert, 1997; Shadmehr, et al., 2010). For example, as you reach out to catch a ball, your brain has already calculated the impact (force, velocity etc.) of the action. Thus any discrepancy between the predicted (feedforward) and the actual outcome (feedback) of an action generates an error signal, which prompts an update of the present FM (Shadmehr, et al., 2010). For example, if the anticipated sensations (both visual and tactile) of picking up a teacup do not match the actual sensations, the FM sends out corrective actions rapidly in order to avoid the tea spillage. The rapid error prediction and response forms the basis for motor adaptation and learning (Saeb, Weber, & Triesch, 2009). The FM enables people to function in the world by affording useful abilities such as mental modelling of actions (Wolpert, 1997), intentional binding (Poonian & Cunnington, 2013), sensory attenuation (Blakemore, Wolpert, & Frith, 2000) and agency in movement (Desantis, Roussel & Waszak, 2011).

The original FM (Wopert, 1997) asserts that only efferent copy of the motor commands is required to generate sensory predictions. Indeed, there are two strong lines of empirical evidence that support this simplistic model. One line of evidence comes from the observed temporal relationship between the hand kinematics and grip-force related to object movement (Miall & Wolpert, 1996); whereas the other, from a series of studies by Vercher and Gauthier (1992) looking at the ocular tracking of a concealed hand. However, increasingly, recent research suggests that causal inferences strongly shape people's perceptions and actions (Buehner & Humphreys, 2009) such that predictions made about the world, assimilate from an internal principle of causality (Buehner, 2012). This emerging evidence suggests that the assumption of a simple and direct connection between the efferent copy and the FM maybe more complex than originally anticipated. Thus, there are two opposing accounts of the FM: the original low-level FM (Wolpert, 1997) that requires only the efferent copy to function and the higher-level FM, which is influenced by top-down control (prefrontal cortex).

Intentional binding phenomenon is one area in which both accounts of the FM were investigated. Intentional binding (IB) is the subjective compression of the interval between self-generated actions and their ensuing consequences (Hughes, Desantis & Waszak, 2013). In an experiment, Haggard and Clark (2003) used interval estimation paradigm in which the participants were asked to estimate the perceived time interval in the two following conditions: intentional action and an auditory tone, involuntary movement and an auditory tone. The authors reported that a perceived shortening of time (between self-generated action and the tone) only happened when participants had an intention to produce the tone. However, when an imposed involuntary action interrupted that 'intention' in anticipation of the tone, no IB effect was observed. The

initial research attributed IB to be a function of the FM such that the prediction of the intended action effect (sensory consequences) resulted in alteration of the phenomenological experience of the sensory event in question (Blakemore, et al., 2000). However, IB has been shown to happen even in an absence of intentions to act (Buehner, 2012). To find out if the intentional actions (generated by FM) are the cause of IB, Buehner (2012) used an event-anticipation paradigm (predicting the LED flash on a response box) to test participants across three conditions: baseline, self-causal and machine causal (mechanical). He found evidence that intentional action was not the only factor that caused IB effect to occur. In fact, intentional action is one of the particular types of causes (among others like mechanical) that can result in the binding effects. Moreover, Poonian and Cunnington (2013) showed that IB occurs even when we observe other peoples actions. In their experiment, participants were asked to estimate the perceived interval in either a self-made or observed action conditions versus an auditory tone. It was found that the participants experienced a significant perceived shortening of time not only in self-generated action condition but also in observed actions and a tone, compared to estimating the interval between just two tones. Overall the finding that IB can result from causal inferences, in the absence of intentions (Buehner, 2012) and from observing other peoples actions (Poonian & Cunnington, 2013) strongly suggested top-down influences feeding into the FM and altering the perceptual experience of these sensory events.

The most important function of the FM is that it attenuates the sensory outcome of self-generated actions (Wopert, 1997). This sensory attenuation effect creates a clear distinction between self and environmentally generated actions (Shadmehr, et al., 2010). For instance, a person can discriminate between a touch of another person versus an accidental tap from himself, because the touch of another person is surprising, whereas the tap from yourself is not. A more profound example of this is the tickling phenomenon. Blackmore et al., (2000) asked their participants to rate the sensation of tactile stimulation (tickling), which was either immediate or delayed systematically in various conditions. The authors found that when anticipated sensory predictions were identical and followed the actual sensory feedback, people did not become ticklish. However, when there was a delay between the tickling and the ensuing sensory feedback, the sensation of tickling was intensified, since the anticipated sensation did not match the reported feedback during the delay period. Thus, the FM explains the reason people find it impossible to tickle themselves. Only surprising sensations are perceived to be ticklish, because they are unpredictable. Any motion predicted by the FM is not surprising and consequently not ticklish (Blackmore, et al., 2000). Because sensory attenuation and IB are functions of the FM mechanism, Hughes et al. (2013) systematically assessed whether the existing evidence supported the assertion that FM were responsible for generating IB and sensory attenuation effect. The evidence supported the claim that the FM generated sensory attenuation effect but IB could not be isolated specifically to the FM. Instead, IB also appears to be affected but not individually determined by casual beliefs (Obhi & Hall, 2011) and temporal control (Desantis, et al., 2011). In fact, Desantis et al. (2011) showed that IB disappeared when the participants believed that the action originated from another subject, supporting the view that the FM was influenced by prior authorship beliefs.

Thus, this is a clear example of top-down (causal beliefs) feeding into the FM and influencing the sensory prediction.

Wolpert, Doya and Kawato (2003) did originally propose that special properties of the FM, such as rapid response prediction and error corrections (*teacup example*), could be used for social functions. This idea was not supported by existing evidence. To investigate whether observing other people's actions activated either motor simulation of their efferent commands (producing sensory attenuation) or sensory simulation of the consequences of the commands (resulting in perceptual enhancement), Thomas, Sink and Haggard (2013) asked participants to estimate the size of the vibrotactile stimulation of their upper lip while watching either still or active speech actions. Their study revealed that perceptual enhancement dominated observations of another's actions. This perceptual enhancement was explained as resulting from somatosensory involvement in action observation (Avikainen, Forss & Hari, 2002). The absence of sensory attenuation effect in observing other's actions would suggest that FM is not involved in interpersonal predictions, which is a higher-level cognitive task. However, It can be argued here that the authors did not control for special properties of speech related lip movements, which may already be predisposed to perceptual enhancement. Recently, Press, Berlot, Bird, Ivry and Cook (2014) did find valid empirical evidence to support Wolpert et al. (2003)'s idea of social functioning FM. Thus for FM to be implicated in social cognition the generated predictions cannot solely rely on the efferent copy of the motor commands (Wolpert, 1997).

IB and sensory attenuation phenomena are related to the sense of agency in movement (Paees et al. 2014). A sense of agency is the subjective awareness of being the causal agent of one's actions in the world (Desantis et al., 2011). This sense of ownership is generated by the sensory attenuation effect and any disruption to it results in an altered experience of self-generated movement (Sato & Yosuda, 2005; Gentch, Schute, Endras & Kathmann, 2012). This is apparent in alien control disorders, such as schizophrenia (Blackmore, Frith & Wolpert, 2001; Colheart, 2007). If the FM is responsible for generating a sense of agency in movement, then low level motor commands are at the very least involved in the generation of initial causal agent experience. Hypnotic suggestion has been shown to modulate low-level automatic processes such as the Stroop effect. The Stroop effect suggests that participants tend to be slower at naming ink colour of incongruent stimuli (e.g., naming the red colour of the printed word 'blue') than congruent stimuli because word identification is automatic, even if participants are asked to attend exclusively to the ink colour (Stroop, 1935; Lifshitz, Bonn, Fischer, Kashem & Raz, 2013). However, when highly hypnotisable participants were given a hypnotic suggestion to experience the word-stimulus as meaningless, the Stroop effect was partially reduced (Raz & Cambell, 2011) or even completely lifted (Lifshitz et al. 2013). Although the exact mechanism of this effect is unclear, it has been suggested to result from the top down suppression of the visual information (Lifshitz et al. 2013).

Hypnosis is an important tool used to study clinical conditions in laboratories (Oakley & Halligan, 2013). In fact, hypnotic models have been used to study functional amnesia, obsessive-compulsive disorder, delusional beliefs, hallucinations and voluntary motor control (Oakley & Halligan, 2013). In an experiment, Deeley et al. (2014) investigated 3

types of hypnotically induced loss of control, in which the participants were told that their hand movements were controlled either by a malfunctioning machine, remotely or by an engineer within themselves. The controls were not given any suggestions. After each suggestion, participants had to move a joystick from side to side and rate their perceived sense of control. As expected, participants reported reduced sense of control in all three conditions compared to the control. In contrast to the previous findings, in another study (Haggard, Cartledge, Dafydd & Oakley, 2004) the participants were given a hypnotic suggestion of anomalous finger control in order to investigate the role of subjective freewill in time estimation of finger movement. There were 3 conditions: voluntary, passive and hypnotically induced involuntary finger movements. Even though the hypnotic suggestion did not affect the voluntariness of willed or passive movements, the time estimations of hypnotically suggested movements resembled that of the passive finger movement condition. Yet in another study, Blakemore, Oakley and Frith (2003) evaluated the effect of a hypnotic suggestion on participant's arm motion when it was caused by the action of a mechanical pulley system. Participants not only performed the appropriate motor movements on their own, but also experienced a sense of passivity while performing the action. Indeed, the experience of passivity was reflected in the activation of cerebellum and parietal cortex, which under normal circumstances are not active during the performance of voluntary motor movements. Although it is not clear why these brain areas where activated during passive action performance, the motor hypnotic suggestion seems to interact with FM, reflected in the activation of cerebellum, which is believed to be the physiological basis of FM (Hughes, et al. 2013).

So in summery, reviewed evidence on IB supports the higher-level FM (Buehner, 2012) whereas the literature exploring the sensory attenuation effect supports the original FM (Blakemore, et al., 2000). If the same FM generates both sensory attenuation and IB effect then, sensory attenuation should also be subject to the top-down influences much like the IB effect. Thus this study investigated if a hypnotic suggestion modulated the sensory attenuation effect that normally happens when people try to tickle themselves. Specifically, this study looked at whether alien-hand hypnotic suggestion reduced the sensory attenuation effect in tickling. If the FM is only dependent on the efferent copy of the motor commands, then a higher-level hypnotic suggestion should not have any influence on ticklishness, since the original FM (Wolpert, 1997) cannot assimilate from non-motor inputs. Conversely, if hypnotic suggestion is found to modulate the experience of sensory attenuation within the tickling phenomenon, it would suggest that the FM prediction mechanism is not based solely on the individual's motor commands. The participants were given a waking hypnotic suggestion of an alien-hand to temporarily reduce their sense of agentic movement (Colheart, 2007) of their hand, which has been shown to result in anomalous motor control in highly suggestible individuals (Cox, Barnier & Scott, 2014). Following the suggestion treatments, the participants had to tickle their left palm.

Methodology

Participants

Seventy-two undergraduate psychology students (36 in the test and the control groups, 12 males and 60 females) were recruited to participate in this study. Participants volunteered via the Plymouth University SONA system and were allocated credits for participating.

Out of the 72 participants, 5 were left-handed and 67 were right-handed. General demographics (age) data was not collected, as it was not required for this experiment. All 72 participants were included in the preliminary analysis. Forty-two participants who did not respond to the alien-hand hypnotic suggestion were excluded from further analysis, resulting in the population sample of 30 participants used in this study.

Materials

The materials required for this study included a pre-recorded hypnotic audio script, audio speakers (Philips SPA7220 2.0), an audio player (Apple), a relaxation room with 5 soft chairs (for 5 people at a time) and a response sheet for each participant.

A male and a female experimenter recorded a total of 2 audio scripts (experimental and control) each that were used interchangeably during the experiment (a total of 4 audio scripts). This was done to reduce any voice response bias.

Within the chosen room, the chairs were arranged in a pentagonal shape, facing outwards. The soft chairs were high backed and obstructed the peripheral vision of the other participants, giving privacy to each participant taking part. The speakers were placed into the middle of the pentagonal shape (position of the speakers has no effect on hypnotic suggestion (Lynn, Laurence & Kirsch, (2015)) so as to be completely out of the participants' sight.

The study involved initially a recording of a hypnotic script. The script was recorded and edited with the software Audacity. The same software was used to transform the recorded sound into MWA format so it can be put onto an external audio player. The first section of the script contained an introduction to hypnosis, a deepening staircase relaxation exercise and arm levitation suggestion. The second section had either experimental alien-hand suggestion or control alien-foot suggestion. The introduction of the audio script explained what hypnosis was and asked the participant to participate in the process. A hypnotic induction was included because it was shown to be significant for inducing alien control delusions in participants (Cox, Barnier & Scot, 2014). This induction included a descending relaxation countdown exercise in which the participants had to imagine walking down a staircase, progressively getting more relaxed as they reached the bottom. This countdown exercise used such phrases as 'eight, sinking into a more comfortable, calm, peaceful position'. The arm levitation test included a suggestion of the right arm getting lighter, such as 'your arm is beginning to feel lighter and lighter, and as it feels lighter, it begins to rise into the air'. Participants were given 15 seconds of response time after the suggestion to respond.

The alien-hand suggestion contained a progressive relaxation of the entire right arm components such as bones, forearms, hands and fingers. For instance the script included statements such as 'feel the gentle pulsation of blood nourishing the bones and each muscle fibre*'.* Then participants were given a progressive hypnotic suggestion of inhibitive nature: loss of ownership over their entire right arm. The suggestions took the following form 'your right arm, elbow, palm, fingers feel like they do not belong to your body'.

In the Alien-foot condition, the right leg of the participant was progressively relaxed in stages. The stages included shifting attention to specific constituents of the leg such as muscles (thighs, hamstrings), bones, calves and feet. Examples of suggestions included 'as you experience your right leg, notice that your right thigh is starting to feel numb'. Then participants were given a progressive hypnotic suggestion of inhibitive nature: loss of ownership over their entire right leg, such as 'making your entire leg feel like it does not belong to your body'.

The response sheet had 3 sections. All sections contained a number of responses that each participant had to rate, based on their own experience of the experiment until that point in time. These responses were assessed on a Likert scale of 1-7, with 1 being in the category of negative valence (completely disagree, not at all, etc.), and 7 in the positive valence (agree, in control, etc.). The values on each extreme were adapted for specific responses in each section. The first section in the response sheet contained susceptibility response to Arm Levitation suggestion. The response assessed how light did the participants arm feel. The second and the third section focused on the arm/hand conditions prior to and post suggestion. The post suggestion scores included rated questions such as 'I felt in control of my actions' and 'after suggestion, my right hand felt'. The answers to such questions were aimed to capture the experience of the participants.

Procedure

This experiment used repeated measures, within subjects design. The independent variable (IV) was hypnotic suggestion (either alien-hand or alien-foot) and the dependent variable (DV) was Ticklishness. The participants reported their subjective rating of the ticklish sensations in the response sheet given to them. The experiment controlled for experimenter bias and demand characteristics by minimising contact with the participant and exiting the room once the experiment started.

The five participants within each group were randomly allocated to either experimental condition: the experimental alien-hand suggestion or the control condition: alien-foot suggestion. In each condition, the participants had to use the index finger of their right hand to tickle the palm of their left hand, in a concentric pattern. The only difference between conditions was that experimental participants received an alien-hand suggestion for their right hand and the controls did not receive such a suggestion for their right hand. Thus the tickling procedure remained the same despite of varying hypnotic suggestion.

All the self-tickling procedures lasted for exactly 10 seconds in both pre and post suggestions. The pre-recorded tape allowed precisely one minute responding to 4 questions in each section.

The study began with the five participants reading the experimental brief and signing the consent form. All the participants were asked to turn off their phones completely and remain as quiet as possible. The participants were also given additional instructions to keep their legs uncrossed and eyes closed unless instructed otherwise. The participants were also given a clipboard and a pen with the response questionnaire to answer in accordance with the audiotape procession. Once all participants were seated and ready, the experimenter started the audiotape and exited the room. After the participants responded to the last section, the experimenter came in and the participants were fully debriefed. Then given contact information if they wanted any further assistance.

Results

Preliminary Analysis

SPSS (version 21) was used for data analysis.

Table 1: In Each Condition, The Number Of Participants (N) General Means (M) And Standard Deviations (SD)

		Pre-tickling		Post-tickling	
Conditions	**N**	**M**	**SD**	**M**	**SD**
Alien-hand	36	3.61	1.63	3.19	1.55
Alien-foot	36	3.19	1.47	3.11	1.77

Table 1 shows that on average, participants in the alien-hand condition reported to be more ticklish compared to the controls in the pre-tickle phase. Both of the means however are reduced in the post suggestion-tickling phase. Specifically the mean for alien-hand scores reduced by 0.42.

To test the hypothesis that hypnotic suggestion could modulate the tactile stimulation intensity, an analysis of covariance (ANCOVA) was used to evaluate the difference between hypnotic suggestions on post-tickling scores when controlling for pre-tickling score. The ANCOVA was not significant ($F(2,30)= .26$, $p= 0.62$).

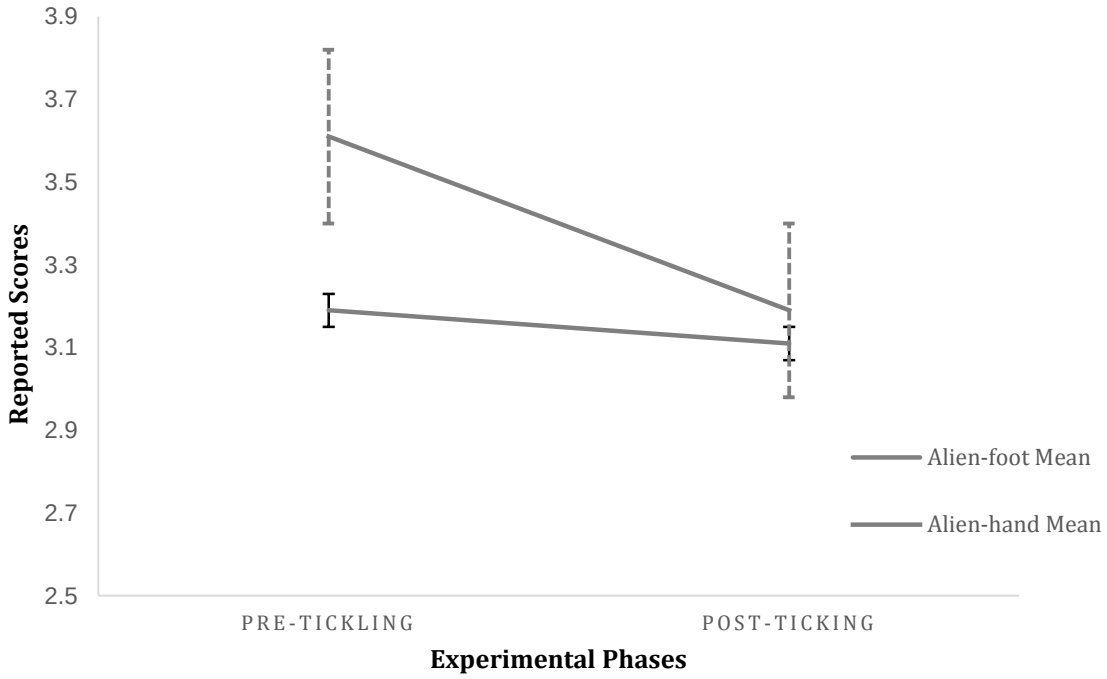

Figure 1: Reported mean tickling scores for pre and post tickling in the experimental and control groups.

Figure 1 shows that when taking the entire sample of 72 participants, those in the alien-hand condition reported being less ticklish (3.19) after the hypnotic suggestion whereas the controls reported only a slight decrease (of 0.08) in ticklishness after suggestion.
Due to the fact that the result did not show the expected statistical significance, the further tests were performed looking specifically at the variables that were manipulated in this experiment. Due the original premise that participants need to accept alien-hand as a suggestion for the experiment to work, the data was stratified into groups. The participants were separated into groups based on subjective reports of perceived control in the pre and post suggestion phases. The participants, whose reported control level remained the same or increased, were eliminated from this secondary analysis, leaving those who perceived to have lost control. This criterion of exclusion is justified by the previous empirical studies (Cox, et al. 2014; Deeley, et al. 2014) that found highly suggestible individuals experience loss of control during anomalous motor control suggestions.

Further Analysis

Table 2: The Means (M) And Standard Deviations (SD) For Participants Who Lost their Sense Of Control

		Pre-tickling		Post-tickling	
Conditions	**N**	**M**	**SD**	**M**	**SD**
Alien-hand	18	3.89	1.41	3.44	1.29
Alien-foot	12	3.92	1.16	4.42	1.31

Table 2 shows that when the reported self-control was taken into account, participants in the alien-hand condition showed reduction in the means across the two phases (of 0.45), with the scores clustered closely around the mean, specifically in the post-tickling phase (1.29). The alien-foot means actually increased from pre-tickling to post tickling phases (by 0.5).

To test the hypothesis that hypnotic suggestion could modulate the tactile stimulation intensity, an ANCOVA was used to determine the significance of the difference between hypnotic suggestions on post-tickling scores when controlling for pre-tickling scores for the participants who lost control. The ANCOVA showed that when perceived control was taken into account, the manipulation approached a marginal difference ($F(2, 27)=3.891$, $p=.056$). This unexpected trend suggests that hypnotic suggestion had a partial effect on the participants when they perceived a loss control.

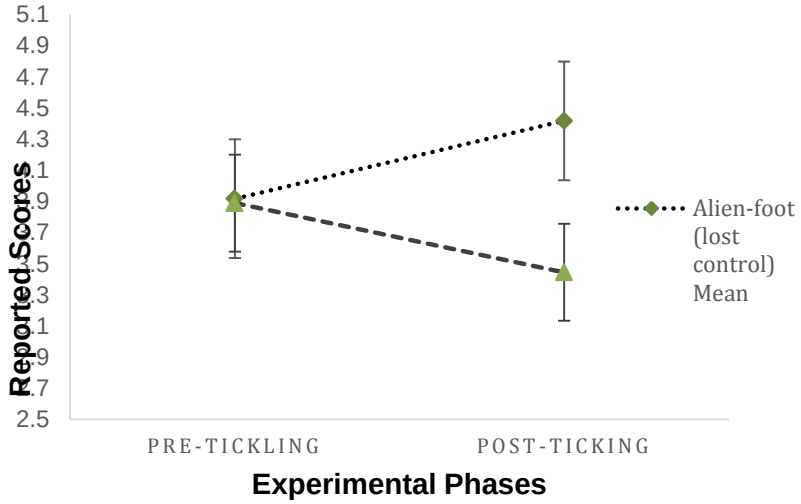

Figure 2: Reported mean tickling scores for pre and post tickling in the experimental and control groups, after controlling for loss of control.

Figure 2 shows that participants who reported a loss of control, show a marginal effect of group (p=0.056), only in the opposite direction. The control participants reported to be more ticklish (4.4) after the hypnotic suggestion, whereas the experimental condition participants reported to be less ticklish (3.4) post hypnotic suggestion. Both groups reported similar pre-tickling scores (test group = 3.88, control group= 3.91).

Discussion

This study investigated whether a hypnotic suggestion could reduce the sensory attenuation effect that normally happens when people tickle themselves. Preliminary analysis showed no significant differences between the conditions. After eliminating participants who did not experience a hypnotically induced loss of control, an unexpected trend was observed. Even though there was marginal significance, the elicited results failed to support the thesis that a hypnotic suggestion could reduce the sensory attenuation effect in self-tickling. The unexpected finding was that the marginal significance supported reversed predictions, in that the control participants became more ticklish and the test group became less ticklish as a result of the hypnotic suggestion. This is an interesting finding as it suggested that not only did participants get more ticklish over time, but also that some participants felt more in control as a result of an alien-hand suggestion.

This experiment was the first to test directly if sensory attenuation could be modulated by a hypnotic suggestion. The observed trend suggests this is implausible and seems to contradict Blakemore, et al., (2000)'s finding that sensory attenuation results in an altered experience of self-stimulation. If the sensory attenuation affects perceptual experience of sensory stimuli, then hypnotic suggestion should have been able to modulate this perceptual experience, as has been shown in the studies of Stroop effect (Lifshitz et al., 2013). After all, it was found that schizophrenic patients are able to tickle themselves, which has been explained as a faulty FM prediction mechanism (Blakemore, et al., 2000). However, schizophrenic like symptoms can also be hypnotically induced in highly hypnotisable individuals (Rahmanovic, Barnier, Cox, Langdon & Coltheart, 2012). Moreover, Buehner, (2012) research clearly showed that casual inferences were fed into the FM in generation IB effects. However, the observed trend in this experiment supports Hughes, et al., (2013) deduction that the relationship between FM and IB is tenuous, thus leaving the possibility that the FM is only remotely involved with the generation of IB effect and thus would explain why targeting a direct function (sensory attenuation) of FM, did not work in this experiment: the relationship between the two functions maybe tenuous as well.

This unexpected direction of the trend cannot be easily explained; however there are a few possible explanations. Sensory prediction in certain contexts can amplify rather than attenuate sensory signals (Doherty, Rao, Mesulam & Nobre, 2005; Chaumon, Drouet, & Tallon-Baudry, 2008). As such, Bayesian models of perception suggest that attention and prediction work together to optimise the precision of perceptual inference (Kok, Rahnev, Jehee, Lau & Lange, 2011). Specifically the directional attention increases not only precision of predictions but also the weighting of the sensory feedback, thereby reducing the sensory attenuation produced by the prediction

mechanism alone (Kok, et al., 2011). As such, because control participants were primed with tickling prior to the irrelevant hypnotic suggestion and then asked to tickle their right hand again, the enhanced attention on tickling sensations resulted in intensification of the perceived ticklishness and reduction in feedback attenuation. Thus, control participants perceived themselves to be more ticklish over time. On the other hand, the experimental subjects perceived themselves to become less ticklish post hypnotic suggestion because the attentional mechanism is distorted during a hypnotic trance (Kaiser, Barker, Haenschel, Baldeweg & Gruzelier, 1997). This distortion allows the prediction mechanism to attenuate the sensory signals since the inhibiting influence of attention is reduced.

Another possible explanation is that this experiment did not measure the change in ticklishness. The paradigm used in this study is similar to the one used by Cox, Barnier and Scot (2014) in which participants were given a specific alien-hand suggestions and asked to perform everyday motor actions such as signing their name and picking up objects. Instead of looking at the prediction mechanism, the authors observed how many motor mistakes the participants make while doing these actions. Indeed, the participants experienced difficulty not only signing their names but in coordinating their actions. Perhaps by giving the alien-hand suggestion participants in this study had a difficulty coordinating their hand movements. Those participants who reported to have lost a degree of control still perceived themselves to be a partial causal agent of their tickling action, which then resulted in the prediction mechanism generating sensory attenuation effects. This explanation is in line with the empirical finding that patients with psychogenic movement disorders lose the ability to attenuate self-produced actions. Parees et al. (2014) did a force matching task experiment, in which participants (healthy controls and patients) were presented with varying forces applied to their index finger and their task was to match the forces either by pressing on their own finger or operate a robot to press on their finger. They found that the healthy controls overestimated when pressing their own finger but not when using the robot. The patients however, did not exhibit this effect.

It is important to note a few methodological limitations of this study, which could have limited the strength of the results. Although this study screened for general hypnotic suggestibility, that is arm levitation test, it did not thoroughly screen for highly suggestible participants, as other hypnotic studies (Cox, Barnier & Scot, 2014) did. This is because a general consensus within the hypnotic literature holds that hypnosis effect follows a normal distribution curve (Weitzenhoffer, & Hilgard, 1962), thus the majority of people are somewhat responsive to suggestions. The trend found in our results would suggest future studies of similar nature to use exclusively highly suggestible participants who at the very least can respond to *cognitive-inhibitive suggestions.* This study also relied heavily on the subjective score reports and did not take any objective measures. Although issues of veracity (subjectivity) could act as a limiting factor in drawing experimental conclusions, this study controlled for the majority of experimental biases. Furthermore, the use of the Likert scales presented its own set of limitations such as tendency for people to answer in patterns, picking middle ground responses from

previous answers or avoiding extremes. Nonetheless, looking forward objective measures are needed to counterbalance the subjective reports in the future studies.

The study may be limited by its design. When participants use their alien-hand to tickle their left palm, both hands are receiving the sensations resultant from tickling. Even though this experiment focused exclusively on the surprising sensations occurring in the non-suggested hand, the FM (Wolpert, 1997) would also be making predictions about the sensations coming into the alien-hand. Given that the suggestion worked, the sensations going into the alien-hand (finger) would become more surprising due to the lack of an existent sensory prediction and therefore should become more ticklish. The consequences of this surprising sensation coming into the alien-hand (finger) needs to be addressed in any future studies of this nature. Moreover, while it is possible that the design of the study affected the observed findings, issues of power (like the small sample size or too much noise in the data) could have also resulted in the observed trend, although with the trend gearing in the opposite direction, this is quite unlikely. Instead, the observed trend warrants a slight revision to the hypothesis and the theory that has been originally proposed in this study.

Even though an unexpected trend was found, the implications of this research area still remain a potential to be striven for in the future. The internal models of action control, not only adequately explain how people perform highly complex functions with perceptual ease but also what happens when this mechanism breaks down. As a result, the FM has been used as an implicating cause in many clinical conditions, one of which is schizophrenia (Blakemore, et al., 2001). The existence of the higher functioning FM could potentially provide an additional treatment of some schizophrenic symptoms, in that a hypnotic suggestion should be able to reduce the attribution of alien agency to actions. Perhaps the future studies should use patients with schizophrenia to test this hypothesis, in which patients are given suggestions that assert their control over their actions and observed if their self-generated actions (self-tickling perception) then became attenuated.

Investigating the nature of forward models is also important because they are paramount to healthy functioning in the world, as they afford a number of vital abilities including activity performance monitoring and body state estimations (Shadmehr, et al., 2010). Moreover, the prediction mechanism allows people to filter the incoming sensory information, attenuating the unnecessary information while emphasising important information needed for action control (Shadmehr, et al., 2010). As such, the forward models' capacity to predict sensory consequences of our own actions is fundamental not only for movement control but also other higher cognitive functions such as a *sense of agency* which is an essential part of human conscious experience. Thus in the quest to understand the fundamental question of humanity such as the nature of *free will* or *personal agency,* investigating internal forward models serves as the starting point in uncovering answers to the long standing unknowns.

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