Physiological Measures of Changes in Self-Agency During Hypnosis

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Abstract

Alterations in the sense of agency are a defining feature of hypnosis. These alterations in sense of agency can be experienced as a reduced sense of voluntariness while undergoing perceptual, cognitive and motor tasks. Different theoretical accounts of hypnosis assert that these unique responses to tasks are due to disassociations in either the monitoring or control of sub-personal processes involved in the performance of those tasks. This thesis investigated whether a hypnotic ‘alien control’ suggestion administered during a lifting task could alter sub-personal processes involved in the postural control of actions. Two experiments were carried out. In the first experiment I identified a specific physiological/kinematic marker of postural control that could differentiate between intentionally controlled actions and unintentional actions performed outside of hypnosis. In the second experiment, I explored the impact of hypnotic suggestion on this implicit, physiological marker of postural control and on explicit judgements of agency. Results showed that while the hypnotic suggestion significantly altered judged sense of voluntary movement and control, this was not reflected in the kinematic marker of intentional action. Results were more consistent with the theoretical accounts that claim that hypnosis alters the monitoring, rather than the actual control of sub-personal process during motor task performance.

Acknowledgements

Foremost, I would like to express my sincere gratitude and thanks to my Supervisor, Dr Vince Polito for providing the valuable guidance, support and advise that enabled me to complete this thesis.

I would also like to express my sincere gratitude and thanks to Dr Paul Sowman and Dr Regine Zopf who also provided valuable guidance, support and advise in assisting me to complete this thesis.

A special thanks goes to my Master of Research peer, Tatiana Izmaylova who was a tremendous support and source for sharing ideas with. I would also like to thank those people, both fellow students and staff, at Macquarie University who helped me along the way and helped make my experience at the university so rewarding.

Finally, I would like to thank Ms Emma Thembani, whose helpful advice enabled me to take the first steps along this rewarding path. As always, a sincere thank you goes to my family and friends who I know will always be there for me. Their presence in my life is always valuable to me.

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That we are agents that intentionally act upon the world seems like such an intuitively obvious aspect of what it means to be human, we barely ever stop and wonder where this sense of self agency comes from. Descartes (1637/1993) took it as an *a priori* certainty that if he could be sure of nothing else about the world, he could at least be sure that he was an intentionally thinking agent. For Descartes, the self-reflection that he was thinking was enough to assert his own existence. Yet, how do we know that “a thought” belongs to me and not someone else? Similarly, at a more fundamental level, how do we know that it is “I” who is the cause of my actions in the world, such as moving my arm and not someone else? Many cases in clinical psychiatry and neuropsychology show that the fundamental determination that it is “me” who moves my arm or entertains a thought can break-down in such a way that the first-person determination of self-agency can be uncertain (Renes, Vermeulen, Kahn, Aarts, & van Haren, 2013; Schaefer, Heinze, & Galazky, 2010; Spaniel et al., 2016). For example, although rare, some stroke patients with specific brain lesions may experience “Alien Hand Syndrome,” where a limb, such as an arm, can display involuntary and yet complex, goal directed activity not under conscious control of the patient (Panikkath et al., 2014). Studies have shown that even non-clinical populations may also exhibit breakdowns in their experienced sense of self-agency in terms of the initiation of their action and thought, which would suggest that a sense of agency may not be as stable as people may initially think (Wegner, 2002). The malleability of our sense of self-agency has important ramifications, not only for how we understand those clinical disorders where sense of self-agency breaks down, but also for how we understand a normal or “healthy” sense of self-agency. In this study, I explore the degree to which changes in sense of agency can cause alterations at the fundamental level of motor action and control. I do this by looking for, and identifying, kinematic and physiological markers of postural control. I then investigate whether hypnosis, a phenomenon commonly known to alter people's sense of agency, can, alter postural control as identified by these markers. Findings from this study are discussed in terms of three major theoretical approaches to hypnosis: Dissociated Control Theory, Dissociated Experience Theory, and Social Cognitive theories..

Before addressing the predictions of these different hypnotic theories, the following section outlines different approaches to understanding the relationship between the experience of agency and notions of control mechanisms and neural biology more generally. The experience of agency can be understood at three levels of explanation: phenomenological, computational, and physiological.

The Phenomenological Level

The phenomenological level of explanation entails describing or explaining our sense of agency in terms of first-person experience. Reflection and report on the nature of self-agency as known through such first-person accounts provides us with third-person knowledge about the variety of experiences we normally associate with self-agency (Markič, 2012). These may include: awareness that we may be trying to obtain a goal, awareness of an intention to act and of the initiation of an action, awareness of movement and mental effort, a sense of control, and a sense of ownership of our actions (Balconi, 2010). These phenomenologically different aspects of our sense of agency, may not necessarily all exist together at any one time however. For example, an increased sense of self-reflective awareness of one's self as an agent may not necessarily be accompanied by a greater sense of personal control while performing an action (Vuorre & Metcalfe, 2016) and our sense of self-agency in performing an action may not be accompanied by a greater sense of body-ownership over an arm performing that action (Tsakiris, Schütz-Bosbach & Gallagher, 2007). That a self-reflective sense of self may be differentiated from a sense of self that is controlling specific actions has led some researchers to draw a distinction between a primal "Feeling of Agency" coming from bodily interactions that help differentiate us from the world, and "higher-order," self-reflective "Judgements of Agency" (Synofzik, Vosgerau, & Voss, 2013). Similarly, researchers have also drawn a distinction between having a sense of self-ownership and a sense of self-agency, as when one is aware that they are moving a part of their body, such as their arm, but fail to identify that they are the initiator of that same arm movement (Sato & Yasuda, 2005). The phenomenological level of explanation shows us that we experience our sense of agency in a multi-faceted way and that we can sometime have ambiguous feelings about our own sense of agency. This can lead to potential inconsistencies between our feelings of agency and our judgements or beliefs about our own agency. The vagaries of introspective self-reports about how our sense of agency may be shaped or formed has led researchers to explore the degree to which our sense of agency can be determined by processes outside of explicit awareness.

The Computational Level

As agents in the world there are many goals states that we seek to achieve. A computational level of explanation looks at information systems, such as biological organisms, in terms of what problem is being solved by the system, while an "algorithmic level" looks at how mechanistic solutions to the problem may be implemented in a physical system such as the human brain (Marr, 1982). In theory, a computational/algorithmic model of self-agency may enable a mapping to be made between self-agency at the phenomenological level of our experienced representations of goals and intended actions to the physiological level of our brain and body as a goal-directed information processing system. A representation of the self as an agent in the world is necessary for an information system to predict, monitor and identify not only its own actions and intentions, but the actions and intentions of others (Kahl & Kopp, 2017). For example, our intentions and actions can be seen as potential outputs or actual outputs to the environment and sensory feedback from the environment can be seen as a form of informational input used to help guide our intentions and actions (Merker, 2013). In order for an organism to interact successfully with its environment, its intentional states can be modelled as a computational system that monitors and controls sensory inputs and motor outputs in order to achieve its goals.

One prominent computational/algorithmic model suggests that our sense of agency comes from a sub-personal cognitive mechanism that compares an intended action and its sensory outcome to the sensory outcomes of actually executed actions (Wolpert & Miall, 1996). The notion of sub-personal mechanisms is derived from the idea that human capacities to interact and reason about the world are determined by multiple, simultaneous processes operating as distinct systems in the brain's cognitive architecture. At one level of the human cognitive architecture are so-called "sub-personal" processes that are thought to process information in an automatic, fast, parallel and non-conscious manner (Dennett, 1969). In contrast, personal processing occurs at the level of conscious awareness and involve the slow, serial, effortful processing of information. While a sense of self-agency is an experience operating at the level of personal conscious awareness, a computational theory of agency contends that this sense of agency may depend on a sub-personal process that matches intended actions with sensory outcomes. The descriptive model of how these sub-personal processes function in action, perception and agency is commonly referred to as the "Comparator Model" (Wolpert, 1997). The Comparator Mechanism is hypothesised to correlate with a felt sense of self agency when expected or predicted actions and sensory outcomes, determined by a predictive signal, sometimes referred as an "efferent signal," matches the actual "reafferent" signals of executed actions and sensory feedback. According to this theory, if there is a mismatch between the efferent signal leading to a predicted action or sensory outcome, an agent may experience this mismatch as a reduced sense of agency (Wolpert, 1997). The accurate matching of predicted sensory feedback with actual sensory feedback is theorised to lead to attenuation of the actual sensory feedback, which in turn, acts as an indicator of self-initiated action. This attenuation of sensory feedback has therefore been hypothesised to represent a sub-personal marker of sense of agency. For example, initial studies suggested that one cannot tickle themselves due to attenuation of the felt sensation of tickling one-self created by the matching between the predicted and actual sensory outcome (Blakemore, Wolpert & Frith, 2000).

The Comparator Model has also been suggested as a mechanism involved in another phenomenon that has been identified as a marker of self-agency: "Intentional Binding." Intentional Binding is an empirically observed phenomenon whereby intended actions and their sensory outcomes are felt to subjectively occur closer in time then they really are. That is, the perceived interval in time between an action and its effect are shorter if there if the action is initiated by an agent voluntarily. At the computational level, Haggard and Clark (2003) have suggested that Intentional Binding is due, at least in part, to the production of an efferent copy of motor signals produced by the brain during the formation of an intentional action. However, some researchers have noted that Intentional Binding can occur for external or observed causal interactions, without the observer physically generating any motor actions as part of the causal process (Dewey and Knoblich, 2014). Similarly, this Comparator Model of self-agency and Sensory Attenuation may also not be sufficient to account for a felt sense of agency. Synofzik, Vosgerau & Newen (2007) have argued that the comparison between efferent copy signals and actual sensory signals is not sufficient or necessary to explain sense of self agency. For example, participants who engage in self-ticking while receiving tactile feedback that is spatially or temporally incongruent with them initiating the self-tickling, may experience reduced sensory attenuation but still experience themselves as the causal agent in the self-tickling (Frith, 2005). Another possible disconfirmation of the Comparator Mechanism comes from so-called "Helping Hands" experiments (Wegner, Sparrow & Winerman, 2004). In this paradigm, a participant observes the hands of another person while this other person is totally hidden from view with the exception of their hands. The hidden other person's hands are located in a position congruent with the participant's own hands. In such experiments people may identify the intentional actions of the hand actions initiated by the hidden person as being their own. That such an illusion can be induced clearly excludes the possibility that an efferent copy of motor action must always be involved in creating a felt sense of agency (Wegner, Sparrow & Winerman, 2004). Furthermore, Dewey and Knoblich (2014) have shown that both Sensory Attenuation and Intentional Binding are not significantly correlated with each other, nor with more "explicit" measures of self-agency, such as a person's self-reports on subjective feelings of control. Interestingly, a person's beliefs about their sense of self as an agent in the world, have also been shown to influence or modulate the so-called "sub-personal" or implicit measures of self-agency seen in Intentional Binding and Sensory Attenuation. As a result, Hughes, Desantis and Waszak (2012) have suggested that there may be a "belief mechanism" acting independently of a prediction mechanism that may modulate implicit measures of self-agency. In summary, the Computational level of explanation promises to help researchers to identify the sub-personal level mechanisms that underlie our felt sense of agency, removed from the conscious self-evaluations or beliefs about our sense of agency. It is hoped that such sub-personal mechanisms in some way map or play an explanatory role in determining how our felt and judged sense of agency is generated. Unfortunately, computational explanations of sense of agency in terms of a comparator mechanisms seem to correlate poorly with people's self-reported judgements about their sense of agency and cannot account for all experiences of self-agency. A complementary but supportive approach to finding mechanisms that underlie sense of agency is therefore to look at the neural correlates of sense of agency.

The Physiological Level

One possibility for accounting for the schism between sub-personal and first-personal accounts of sense of agency, is that the automatic processes that are connected with sub-personal markers of agency are functionally and anatomically distinct from processes involved in higher level personal beliefs and judgements of agency. While functionally distinct cognitive processes should not prima facie be seen as being associated with distinct anatomical regions of the brain (Coltheart, 1999), evidence points toward distinct neural regions and pathways of the brain that seem to be strongly correlated with a sense of agency. Functional Magnetic Resonance Imaging (fMRI) has identified a number of brain areas as significant to the felt sense of agency, including the ventral premotor cortex, the supplementary motor area, the cerebellum, the dorsolateral prefrontal cortex, the posterior parietal cortex, posterior segments of the superior temporal sulcus and the insula (David, Newen & Vogeley, 2008). David, Newen and Vodeley (2008) contend that no consistent or clear idea currently explains how these brain areas functionally relate to sense of agency, but they note that research does indicate that areas such as the premotor cortex, supplementary motor area and the cerebellum are all related to sensory-motor transformations and motor control, while other brain areas relevant to agency appear to be multi-modal association areas connected with cognitive functions. One general view is that the motor region areas of the brain involved in sense of agency subserve "executive functions," such as cognitive control of behaviour while association areas may subserve more "supervisory functions," such as the attentional monitoring of actions involved in the sense of agency. Synofzik et al. (2007) suggests that "Feeling of Agency" may be associated with low level sensory-motor process associated with the Comparator Model of agency, while higher order, reflexive "Judgements of Agency" may be associated with the dorsolateral pre-frontal cortex. With regards to supervisory functions involved in sense of agency, it is hypothesised that the Posterior

Parietal cortex is involved in the online central monitoring of the comparator mechanism before being then involved in the intentional motor actions and their visually perceived consequences. At the level of motor routines, the cerebellum has been connected with the signalling of discrepancies been predicted and actual sensory consequences of actions. Intentional Binding has been associated with increased activity in the supplementary and pre-supplementary motor areas of the brain, which seems to be related to people's experience of intentions in action (Della Sala, Marchetti & Spinnler, 1991). Hence, the physiological level of explanation appears to shed some light on how feelings of agency versus judgements of agency distinguished at the phenomenological level, could in turn be represented as distinct processing systems located in definable anatomical regions of the brain. Sub-personal comparator processes may operate within areas such as the parietal cortex and the cerebellum and personal processing at the level of conscious awareness, generating judgements or beliefs about agency, may operate within the dorsolateral pre-frontal cortex. However, the endeavour of finding how the neural correlates of sense of agency are functionally related to both neural function and the experience of sense of agency still need to be worked out in greater detail.

Top-Down Manipulation of Self-Agency Using Hypnosis

Paradigms involving Intentional Binding or Sensory Attenuation have been used to argue that sense of agency is derived from mechanisms that operate at the sub-personal level, below that of conscious awareness and judgement. However, as noted above, our beliefs and judgements about our agency appear to also alter these sub-personal comparator mechanisms, suggesting that a bi-directional relationship exists between sub-personal processing of sense-of-agency operating from the bottom-up and personal level processing of sense of agency operating from top-down. The "top-down" processes are said to be constituted by personal beliefs and expectations an individual may have about their causal agency in the world. One method that has been used to explore how top-down changes in beliefs about agency may alter people's sense of agency has been the use of hypnosis (Cojan et al., 2009; Schlegel et al. 2015). Hypnosis is a process in which one person, the hypnotist, offers suggestions to another person, the subject, for imaginative experiences that may alter perceptions, actions and memories (Khilstrom, 2008). Responsiveness to hypnosis can be measured using standardised normative hypnotisability scales. Hypnotic susceptibility, as measured on scales such as the Stanford Hypnotic Susceptibility Scale (SHSS; Weitzenhoffer & Hilgard, 1959), have shown to have a broad distribution and a clear "central tendency" (Heap, 2011). Those who score highly on such scales are routinely referred to as "Highs." These individuals who score highly on hypnotic susceptibility scales have also been shown to report a stronger sense of involuntariness then others, even without hypnotic induction (Meyer & Lynn, 2011), although this sense of involuntariness is increased by use of hypnotic induction (Derbyshire et al., 2009).

Hypnosis has been used to explore changes in self agency for two primary reasons. The first is that hypnotic suggestions can be utilised to specifically target alterations in a sense of self agency by altering sensory, motor and cognitive capacities in specific ways via the nature of the suggestion (Conners, 2015). The usefulness of hypnosis in these situations stems partly from the strength of the first-person conviction of the change that has taken place in the sense of agency while under hypnosis, as this change has been described as being so strong that it "borders on delusion" (Kihlstrom, 2008 p.21). As a result, hypnosis has been used in a number of experimental settings to simulate some of the aspects of pathological conditions which involve an altered sense of agency. For example, Blakemore et al. (2003), used a hypnotic suggestion that participants would not have control of their arm. This suggestion was made in order to model delusions of alien control where people undergo a misattribution of self-initiated actions to an external source. A phenomenon sometimes seen, for example, in patients with schizophrenia. Hypnotic effects on motor actions has also been used as a theoretical model of comparison to the psychogenic disturbances in motor control referred to as Conversion Disorders (Srzich et al., 2016). The second reason to use hypnosis in order to explore alterations in self agency is that the process of hypnotic induction itself, very often entails changes in a felt sense of agency, irrespective of the nature of the suggestion being given to the inductee (Polito, Barnier & Woody, 2013; Polito, Barnier, Woody, & Connors, 2014). This change in sense of agency is connected with a fundamental sense of distorted volution under hypnosis, particularly experienced as a sense of involuntariness and has been defined as the primary experience or the "classic suggestion effect" of hypnosis (Weitzenhoffer, 1974). While it has been long established that the sense of agency is reduced under hypnosis, the mechanisms by which this occurs are not yet well understood, however, various theories of hypnosis touch on why this alteration in agency is such a fundamental part of the phenomenology of hypnosis.

Theories of Hypnosis

Those with high hypnotic ability often experience changes in perceptual, imaginative and affective processes that are accompanied by feelings of involuntariness, particularly in action (Polito et al., 2014). Furthermore, the major theories of hypnosis all either directly or indirectly address the issue of voluntariness in hypnosis, although not necessarily agreeing as to how much hypnosis is or is not a truly a voluntary process. Three of the major theories of hypnosis are: Dissociated Experience Theory; Dissociated Control Theory, and Social Cognitive Theories (Polito, Barnier & Conners, 2018). The Dissociated Experience Theory asserts that hypnotic responses are caused by impaired action monitoring. As a result, effortful and controlled voluntary actions may paradoxically be experienced as effortless, as the cognitive effort is hidden or "disassociated" from conscious awareness (Woody & Sadler, 2008). In contrast, the Dissociated Control Theory asserts that lower processing systems, such as comparator sub-processing systems outlined above, are activated directly by hypnosis, bypassing higher level or personal system processes, so that cognitive effort is both experienced as low and is actually low in terms of real cognitive processing. Social Cognitive Theory contends that normal psychological processes such as individual expectations and felt demands for social compliance may lead to a misinterpretation of felt voluntariness under hypnosis (Lynn, Kirsch & Hallquist, 2008).

All three theories have been subject to some criticism in terms of the capacity to account for the full spectrum of hypnotic phenomena. The Dissociated Experience theory suggests that the lack of awareness of intentions and cognitions seen is hypnosis is due to an "amnesia-like" barrier that divides consciousness into two parts: a hidden part that initiates and inhibits movements while the remaining consciousness part is unaware of these actions (Kirsch & Lynn, 1997). Criticisms of the theory include the contention that the theory relies on the possibility of selective and spontaneous amnesia from the subject about their initiated actions, even though they are unsolicited by the actual hypnotic suggestion and even though these types of amnesic experiences are rarely seen in actual hypnotic responses (Woody & Bowers, 1994).

Dissociated Control Theory posits a weakening of the brain's frontal lobe control which allows for increased suggestibility of externally administered hypnotic suggestion, but Kirsch & Lynn (1997) argue that such reduced frontal lobe control fails to account for people's capacity to engage in self-induced hypnosis, which may require the increased use of frontal lobe structures to self-induce a hypnotic state. Furthermore, it is supposed that since these frontal lobe dissociations occur in hypnosis, then hypnotic suggestibility should be different from nonhypnotic everyday experiences of suggestibility, which presumably, do not involve frontal lobe disassociation. Yet it is argued by Kirsch & Lynn that both forms of suggestibility are highly correlated.

Social Cognitive Theories run into difficulties with explaining why hypnotised subjects misattribute their responses as involuntary in nature when the act is supposed to be an intentional act in response to social demands (Kirsch & Lynn, 1997). Kirsch & Lynn account for this by proposing "response sets," which are states of readiness to respond to particular cues in specific ways. Such response sets are related to sets of "cognitive and action schemas." According to Kirsch & Lynn, highs are motivated to intentionally respond in clearly defined ways while under hypnosis but expect those responses to occur automatically, creating a difference between intention and expectation in hypnotic experience. Similar to Dissociated Experience Theory, this account posits that hypnotic responses are voluntary, but it also has some similarity with Dissociated Control Theory by endorsing the idea that behavioural responses under hypnosis are triggered automatically.

Hypnotic Suggestibility, Sense of Agency and Task Processing

These three theories of hypnosis have different accounts of how sense of agency is changed. While Dissociated Experience Theory suggests that the reduced sense of agency is due to a reduction in ability to attend, monitor and recall during hypnosis, Social Cognitive Theory suggest that reduced sense of agency during hypnosis is essentially a deliberative process of allowing one's responses to conform to the social demands of the task and social context. Both these interpretations of hypnosis imply that hypnosis affects the judgement of agency rather than sub-personal processes that may be associated with the feeling of agency. On the other hand, Dissociated Control Theory suggests that alterations in agency occur at the level of the feeling of agency, as hypnosis causes a disconnection in the control of processing tasks occurring at sub-personal levels below awareness of agency. One way to test these ideas to see if hypnosis can alter peoples' capacity to perform tasks that would not normally seem to be under the influence of reflexive awareness.

Sensorimotor functions in the brain are posited to operate in a functional hierarchy, determined by sensorimotor schemas sometimes referred to as "action schemas." Action schemas are triggered in our daily activities of performing certain perceptual-motor tasks. These schemas are thought to be able to be combined by the brain in possibly an infinite number of ways to perform both novel and routine motor tasks such as driving a car or writing with a pen (Kirsch & Lynne, 1997). The Dissociated Control Theory posits that hypnosis may enable more direct activation of decentralised information processing systems and this would involve influencing these action-schemas (Woody & Sadler, 2008). Furthermore, the Dissociated Control Theory suggest that under hypnosis, these action schemas may automatically perform tasks disconnected from the modulation of more centralised and flexible executive attentional systems, located at the personal system level and routinely associated with consciousness awareness and deliberation. In the hierarchical structure of sensori-motor functions, supervisory attentional systems are thought to select and bias the selection of certain acts or behaviours to be performed (Norman & Shallice, 1986). While this may help with processing and control in novel situations, it may also sometimes hinder our capacity to perform certain tasks, as higher-level supervisory control may interfere with more automatic lower level sensori-motor schemas. If the Dissociated Control Theory is correct, hypnosis could selectively inhibit the interference effects caused by such higher-level supervisory systems and this could be observed as changes in hypnotised subjects in terms of their capacity to perform certain cognitive tasks where interference is created by conflicts between automatic decentralised, sub-personal schemas and the higher order supervisory, personal level control systems.

There is some evidence that hypnosis can selectively inhibit interference effects from higher-level supervisory systems. For example, Raz et al. (2005) found that post-hypnotic suggestion given to those who were identified as highly hypnotisables showed reduced susceptibility to cognitive interference or “Stroop” interference in the so-called “Stroop Task.” Stroop interference occurs when participants demonstrate a slower reaction time and less accuracy in responding to an incongruent word in a word naming task, where these words may be congruently or incongruently matched by colour to the word names. The hypnotic suggestion given to Highs that the words in the task appeared to them as untranslatable foreign words was shown to reduce Stroop interference, so that the written word description of the colour did not interfere with participant’s capacity to recognise and articulate the word by its visually presented colour alone. The finding reinforces the possibility that hypnosis may be able to “de-automatize” tasks or abilities that have become automatic schemas previously thought to be unalterable to higher level supervisory and executive functions. Although, it should be noted that studies looking at how hypnosis affects the Stroop Task and to what degree remain inconsistent (Jamieson & Sheehan, 2004; Raz et al., 2005). Hypnosis has also been shown to effect other automatic processes not thought to be open to higher-order supervisory control, such as the process of sensory integration from the different sensory modalities (Lifshitz, Aubert Bonn, Fischer, Kashem, & Raz, 2013) and other processing tasks which involve conflicting information, similar to the Stroop Task. For example, (Iani, Ricci, Gherri, & Rubichi, 2006), found that highly hypnotisables (Highs) were able to perform better on a “Flanker Task” that required Highs to ignore or inhibit incongruent stimuli that surrounded or “flanked” the target stimuli that needed to be accurately responded too. A post-hypnotic suggestion to aid in visualising the target and ignore the irrelevant flanking stimuli was found to significantly facilitate Highs in their capacity to focus only on the relevant target stimuli. Hypnotic suggestion has also been found to be able to alter sub-personal processes not considered under voluntary control such as the atypical cross-modal sensory associations known as synaesthesia. Hypnotic suggestion shown to be able to induce synaesthetic experiences in those who do not usually have such experiences (Kallio, Koivisto, & Kaakinen, 2017) and also, in one case, inhibit synaesthetic experiences in a person who frequently did experience synaesthesia (Terhune, Cardeña, & Lindgren, 2010)

Hypnosis seems also to be able to affect cognitive processing that people may not necessarily be able to influence with conscious effortful control. Wegner, Fuller & Sparrow (2003) found that when people are given a series of easy and hard questions and told to respond to them in a purely random manner, participants show a tendency to respond accurately above chance levels on the easy questions. Participants were unaware of their tendency to provide correct answers, and this bias toward correct responding persisted despite the imposition of time limits or offering financial rewards for correct responding. Wegner et al., concluded that this pattern of responding was not open to conscious alteration. Polito, Barnier & Conners (2018) examined if hypnotic suggestions could alter this bias. They administered a range of hypnotic suggestions aimed at systematically changing how participants responded in the Wegner et al. quiz paradigm. These included a suggestion that participants' responses were under the influence of "alien control", and a suggestion that participant responses were a product of "thought insertions." They found that the hypnotic suggestion of "alien control" was able to cancel out participants' unconscious response biases in the quiz task.

Effects of Hypnosis on Self-generated Actions

As indicated earlier, the effect of hypnosis on agency is perhaps most explicitly exemplified by the capacity of hypnosis to reduce the sense of voluntariness in subjects. This effect is most explicitly seen in the context of self-generated actions and the felt voluntariness of self-generated actions (Hilgard, 1977). It has long been suggested that hypnosis has a close connection with ideomotor functions (Cussen, 2015). The term "ideomotor" action refers to a mechanism in which an involuntary action can arise from ideas. Pioneers in psychological research such as William James, suggested that highly hypnotisable people had access to "less inhibitory thoughts" to prevent ideomotor actions (Cussen, 2015). This is to say that motor imagery may be less inclined to be inhibited in highly hypnotisable people. In support of this notion, Cussen (2015) found that hypnotic susceptibility corresponds to a decreased capacity to inhibit unwanted motor actions that have been primed by a visual cue such as a hand movement. In their experiment, participants were measured for their level of hypnotic suggestibility and then asked to perform a task where they were to raise either their middle or index finger whilst simultaneously observing an image of a hand matched to look similar to their own. This matched hand would also raise either its middle or index finger. Errors arising from an incongruence condition where the observed hand raised fingers that were different from the fingers the participant were asked to raise, were found to correlate significantly with hypnotic suggestibility. That is, Highs were less able to inhibit their responses due to observing an incongruent movement of the fingers on the imaged hand, and therefore showed greater errors in the task and slower reaction times then those low in hypnotisability. Such responses may be seen as an indicator that Highs show increased tendencies to struggle to inhibit actions not connected with self-agency and therefore reduce their sense of control over body actions.

Ironically, however, this reduced ability to inhibit ideomotor responses during hypnosis, while reducing a sense of agency may also, ironically, facilitate some intentionally desired motor responses, particularly those motor responses related to postural control. Carli et al. (2006); (Santarcangelo et al. (2010; 2005) and Scattina et al., (2012) have found that

Highs demonstrate an increased ability to modulate their own postural movements, even when not under hypnosis, possibly through a superior capacity to generate an internal “feedforward” visual model of their body in space. In these studies, highs were compared to lows, on a task where they were required to maintain balance and posture on an unstable platform while having their eyes either open or closed. The amount of postural sway between Highs and Lows was measured by looking at the amount of stable positions required to maintain postural stability between the two groups. Less of postural sway is a marker of better postural adjustments and postural sway was measured by looking at the Centre of Pressure, or the sum of all forces acting on areas of the foot and its supporting surface. For the eyes closed condition, Highs appeared to show less postural sway and more stance positions in which they were stable, possibly indicating that they were more easily able to use an internal, “feedforward” model to stabilise their posture, while Lows were more dependent on proprioceptive feedback to help stabilise themselves while their eyes were closed. That Highs may have been using an internal spatial model to help with postural control was further supported by Santarcangelo et al., (2004) findings that Highs also scored higher on a visual imagery questionnaire when compared to Lows. This research, showing an increased capacity of Highs to generate internal models of the world that create postural changes similar to those seen by real external effects on the body can be seen to support the original William James hypothesis that hypnotic suggestibility in Highs may be associated with a lack of motor inhibition normally associated with motor imagery. Carli et al. (2006) found that when suggestions were given to both Highs and Lows (both during and outside of hypnosis), that a carpet was being pulled from underneath them, Highs differed significantly from Lows in terms of body sway response. Highs showed body sway responses similar to real-life situations where postural stance was actually disturbed by the moving of a carpet beneath them. Hypnotic induction of leg pain via a guided imagery task in Highs has been shown to cause body displacements similar to body displacements caused by non-hypnotically induced "real" pain responses (Scattina at al., 2012). Once again, these responses were measured by looking at the amount of Centre of Pressure seen on a force platform, with the body displacements seen in Highs similar to those associated with the natural noceptive reflex - a non-voluntary spinal reflex intended to protect the body from damaging stimulus (Scattina at al., 2012). Conversely, no such response was seen for those who were low in hypnotisability. Such findings reinforce the possibility that hypnotic suggestion does more than just make highs act "as if" their motor responses are altered. Instead, it appears these suggestions actually create conditions of motor behaviour similar to those experienced in real life sensorimotor routines. In highly hypnotisable people, it appears to at least to some significant degree, that sensorimotor imagery can become translated into something very similar to actual sensorimotor perception (Santarcangelo et al., 2010).

Models of how Hypnosis Effects Self Agency

The findings regarding hypnosis' capacity to alter control can be seen as support of the Dissociated Control Theory and the ability of hypnosis to free-up sub-personal motor control function. More specifically, Jamieson (2016), has suggested two possible models of how hypnosis may bring about the changes in sense of agency. The first model Jameison outlines is the Motor Control Theory of Sense of Agency which contends that felt voluntariness of a motor action comes about due to the pre-supplementary motor cortex of the brain sending an efferent signal to a feedforward mechanism in the cerebellum. The cerebellum, in turn, produces the comparator matching between expected sensory output to actual sensory input. Under this model, hypnosis alters agency by effecting the efferent signal from the pre-motor cortex. Consistent with the idea that the pre-supplementary cortex may provide an efferent signal in intentional action, Haggard & Whitford (2004) used transcranial magnetic stimulation to produce an electrical pulse over the pre-supplementary cortex while participants were engaged in a voluntary motor task. They found that this pre-pulse abolished the sensory attenuation effects from sensory feedback which are usually seen when a voluntary motor act is executed. Another finding consistent with the pre-supplementary cortex's role in voluntary or agentive action comes from Deeley et al., (2013). Deeley et al., used hypnosis to induce a state of loss of hand control and used fMRI and self-questionnaires to explore the psychological and neural markers of hypnosis during a motor task which involved voluntary and involuntary hand control conditions as well as hypnotic and non-hypnotic conditions. They found that the involuntary hypnotic condition resulted in reduced brain activity between the pre-supplementary motor cortex and the primary motor cortex.

An alternate model of how hypnosis affects sense of Agency is the Active Inference model (Jamieson, 2016). Active Inference theory suggests cortical representations make proprioceptive predictions, rather than predictive motor commands like an efferent signal, to minimize proprioceptive prediction errors and that this is carried by adjusting skeletal muscle movements. Under the Active Inference model perceived involuntariness is due to a failure of immediate top-down predictive processes to cancel unexpected proprioceptive signals, which in turn leads to updated models of action in which a performed action is represented as involuntary. The model also suggests a hierarchy of control mechanisms so that lower order control errors are noticed by higher-order models of motor control. Jameison (2016) contends that under hypnosis, these errors must in some way be suppressed from being included in higher order models as recognition of such feedback errors would lead to reduction in the hypnotic illusion or delusion.

Hypnotic Effects on the Basic Physiology of Movement and the Sense of Agency

Alterations in a sense of voluntary motor action and control may manifest as measurable changes in basic physiological functions, along with the neural changes in function. Williamson et al. (2002) found that under hypnotic suggestion, highly hypnotisable people displayed significant increase in muscle activity, as measured by electromyography (EMG), blood pressure and heart rate when compared to lows, in a task where it was suggested to participants that they were exerting increased effort gripping an imaginary object. By referencing EMG activity to an electroencephalographic (EEG) brain activity marker commonly associated with voluntary movement known as the 'readiness potential," systematic calibration of electroencephalographic (EEG) brain activity with muscle activity (EMG), has shown that muscle activity differs depending on whether it is under voluntary control versus involuntary control. The readiness potential has somewhat controversially been described as a neural electromagnetic brain wave signature event that precedes in time conscious intentionally initiated motor actions (Guggisberg & Mottaz, 2013; Jo et al., 2014). Peckeham & Hallet (2016) have found that the readiness potential cannot be seen in involuntary muscular jerks but can be seen in muscular jerks of a psychogenic nature and they have contended that EMG can therefore stand in as a measure of seemingly pathological, non-voluntary movements that have a psychogenic, rather than organic basis. However, whether or not the readiness potential really can be seen as a predetermining signature of intentional or volitional actions remains controversial. Schlegel et al. (2015) found that a posthypnotic suggestion given to highly hypnotisable participants to squeeze a ball was associated with the EEG "readiness potential" despite lack of awareness by the Highs of performing this action voluntarily. Interestingly, in this experiment, EMG activity was found to be delayed under post hypnotic suggestion when compared to non-hypnotic conscious actions. Although unclear why EMG activity showed these response latencies under the hypnotic condition, the finding that differences in EMG response depended on whether or not participants were aware of their actions would indicate that EMG may potentially be used as a signature for changes in a felt sense of agency, even when the more accepted but controversial EEG measure of the readiness potential fails to mark such differences in sense of agency.

Agency and Postural Control

A more basic function of motor control that is linked to self-agency is postural control, or the maintenance of postural stability against perturbations from the environment and one's own actions (Yiou, Caderby & Hussein, 2012). One line of research has focused on the phenomenon of Anticipatory Postural Adjustments (APAs). APAs are anticipatory muscle movements that occur just prior to self-generated actions. APAs appear to be modulated by dual processes depending on their temporal timing with cognitive demands (Slipjer, Latash & Mordkoff, 2002) and are assumed to be connected with feedforward predictive models of action like those associated with an efferent signal in the Comparator model (Miall & Wolpert, 1995). While postural control requires motor actions to be maintained over periods where cognitive control is directed towards other tasks (De Havan 2016 p.100), research has shown that the visual detection of postural adjustments in observing the actions of others serves as a significant indicator of other people's intentional actions. In cases of limited visual information, the act of pretending to engage in an action, such as picking up a suitcase and walking, can automatically be identified by others as a pretend action due to the lack of recognisable postural adjustments, both anticipatory and compensatory in nature (Runeson & Frykholm, 1983). Visual feedback on changes in body posture is also found to significantly influence body self-identification, even when the visual feedback is impoverished or limited in nature (Hoogkamer & Meyns, 2014). APAs play a fundamental role not only in maintaining error free posture and balance, but they may also help co-ordinate our actions with others and therefore provide an example of how an implicit sense of self agency is developed. For example, Reddy, Markova, & Wallot (2013) have shown how two-to-four- month-old infants display APAs directed toward their mother and her actions to pick up the child. APAs appear to be connected with fast feedforward mechanisms occurring at sub-personal levels of control but also appear to be modulated by cortical areas involved in voluntary control of actions (Ng et al., 2013).

One way of measuring postural control is by using a Bimanual Load Lifting Task (BMLL). This task involve comparing the muscle activity of a person while they lift an object from their own hand or have someone else lift the object from their hand. In a BMLL task, an APA can be measured by a reduction in bicep muscle activity in the arm holding the object, with this reduction in muscle activity occurring around 50ms prior to the participant performing the self-lift. This anticipatory drop in muscle activity occurs in order to reduce the force produced by the muscle to counteract the resistance of the weight (Diedrichsen et al., 2005). The anticipatory postural response of bicep activity reduction seen in BMLL tasks has been previously used to explore whether it is a marker of cerebellum damage (Diedrichsen et al., 2005) and even whether it is a marker of disorders such as Autism (Witherington, 2015). In terms of neural activation pathways, the BMLL task appears to be modulated by both centrally organised voluntary processes and more automatic feedforward motor schemas (Ng et al., 2013), however, the degree to which the automatic motor schemas associated with the bicep anticipatory or other natural postural responses can be manipulated by changes in a felt sense of voluntary action or agency is unknown.

No previous research has explored whether or not hypnosis can affect postural control responses in a BMLL task. With this in mind we looked to see if using hypnosis might impact these postural control responses. Specifically, we investigated a suggestion previously shown to influence low level motor actions: a suggestion of alien control (Polito et al., 2018). Our first experiment was an exploratory investigation to identify physiological and kinematic markers of postural control in a BMLL task setting. Our second experiment then investigated whether or not these markers could be changed by a hypnotic suggestion that altered participant's sense of agency.

Experiment 1

The aim of this experiment was to see if we could identify basic kinematic and physiological markers that can be used as measures of purposeful agentive action. Both the kinematics of body movements and muscle activity are key markers of postural control (Enoka, 2002). We collected kinematic data by using a goniometer which determines the angle of movement or flexion in the limbs, such as an arm. We collected physiological data using electromyography to determine levels of muscle activity. A Bimanual Load Lifting Task (BMLL), in which a participant lifts a weight from one hand (the postural hand) with their other hand (the lifting hand) for one condition and an experimenter lifts the weight from the participant's postural hand in another condition, was used to explore any significant differences in postural adjustments that could be identified. These postural adjustments, both anticipatory and compensatory adjustments, were used in this study as a measure of postural control in participants. We were looking to find both optimal and sub-optimal markers of postural stability or control with an interest in seeing how these markers would be altered by a hypnotic condition in Experiment 2. An accelerometer sensor, that measures the rate of change with respect to velocity during movement was also used in the experiment to act as a reference measure to record the time of lifting of the weight in the BMLL task. The design of the experiment would therefore involve two conditions: an Experimenter Lift condition, where the experimenter would lift a weight from the participants' postural hand and a Subject-Lift condition where the participant would lift the weight from the postural hand with their other hand.

Experiment One Method

Participants

Twenty adults, 12 female, 8 male, aged from 21-58 years with a mean age of 27.5 years, age mean was affected by one older participant aged 58, all other participants were aged between 21 and 31. All participants were recruited from Macquarie University and took part in exchange for financial reimbursement. All participants reported normal or correct to normal vision. 18 of the participants were right handed and 2 were left-handed, as measured by the Edinburgh Handedness Scale.

Apparatus and Procedures

BMLL tasks involve a participant holding or supporting a weight in one hand, the “postural” hand, and then lifting the weight with their other hand, the “lifting” hand. In most BMLL task experiments this “self-unloading” condition is accompanied by an “external unloading” condition where another person or machine lifts the weight from the participant’s postural hand. In this experiment, participants held the weight in their right postural hand and performed the self-unloading, the “Subject-Lift” condition, with their left hand. The experimenter performed the external unloading condition, referred to in this study as the “Experimenter Lift” condition, by lifting the weight from the participant’s right postural hand with their right hand.

Participants sat in an upright position in a chair and were directed to place the tip of their right elbow on the right arm of the chair armrest where a line of white tape had been placed across the arm-rest. A 1.5 kilogram weight was placed onto the upheld palm of the right “postural” hand of the participant (see Figure 1).

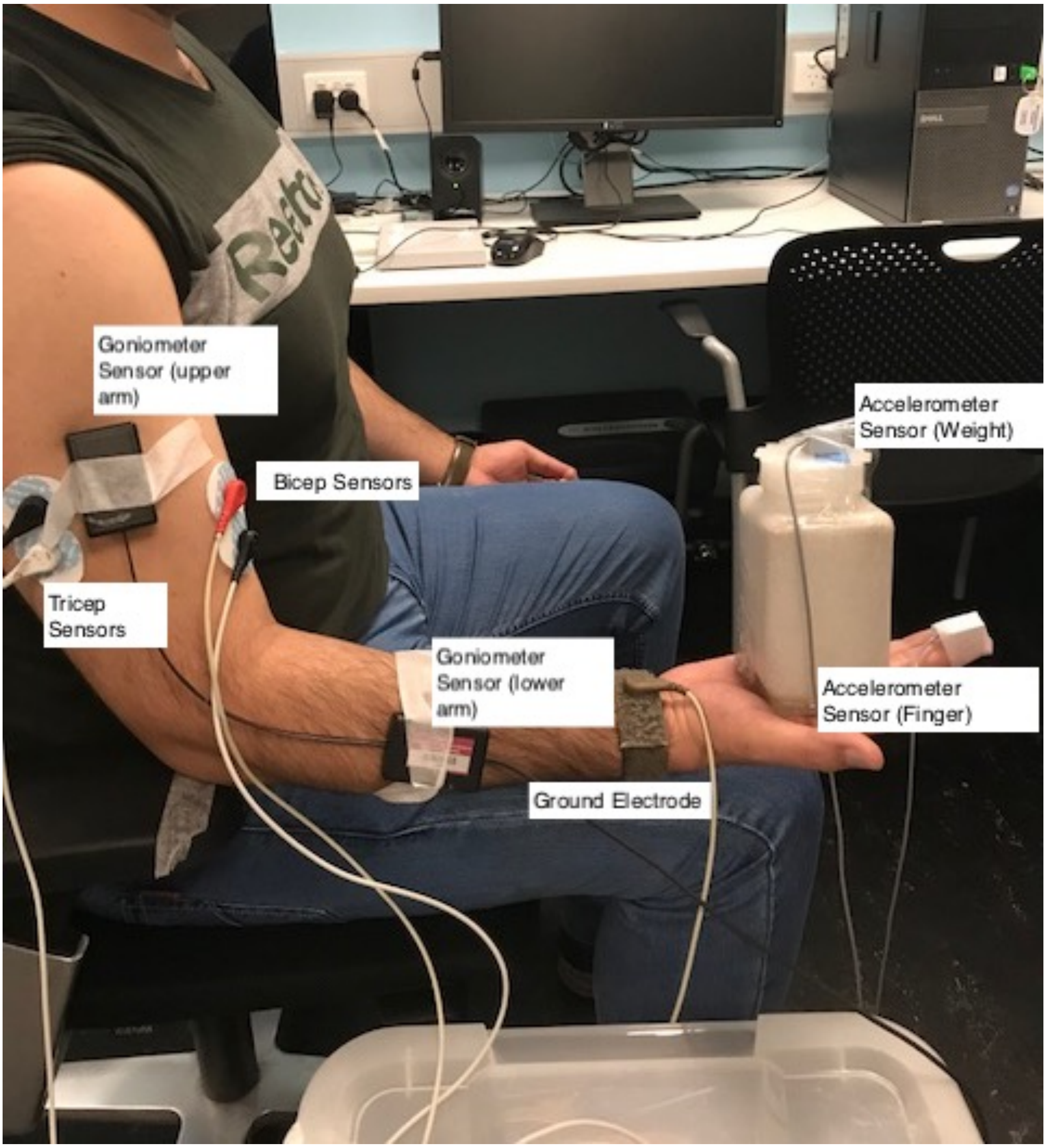

Figure 1. Participant seating while participating in the BMLL loading lifting task.

The participant was directed to a red mark located on the wall directly in front of them and advised that they were to focus their visual attention on this target throughout the experiment. Participants were advised to avoid looking directly at their postural hand and weight during the self and experimenter lifts and to look directly ahead at a red marker located on the wall directly ahead of them. The experimenter routinely checked that participants looked directly ahead and not directly at their postural hand. All participants were able to do this during experiment.

An auditory cue was used to indicate the type of trial to be carried out. A high pitch sinusoidal tone of 1100 hertz was a cue for the experimenter to lift the weight, and a low pitch tone of 500 hertz was a cue for the participant to the lift the weight. Both tone cues had a duration of 150ms. Participants were advised that for each trial they were to reach for, grab and lift the weight from their postural hand in one continuous motion. Similarly, the experimenter also reached for, grabbed and lifted the weight from the participant's postural hand in one continuous motion on every trial.

The experimenter was seated slightly behind the participant on the participants' right-hand side, so the experimenter was within comfortable reaching distance from the weight held in the participant's hand. When the high tone sounded, the experimenter reached over with their right hand and lifted the weight from the right postural hand of the participant. When the low tone sounded, the participant reached over with their left hand and the lifted the weight from their right postural hand. Both the participant and the experimenter lifted the weight straight up in a direction as vertical as possible, and then straight down, placing it back directly on the participant's postural hand. After explaining the task, the experimenter checked to ensure that participants understood the instructions and were able to make consistent lifting actions.

Participants first completed a series of 3 practice trials for both the Subject-Lift and Experimenter-Lift conditions to familiarize themselves with each of the condition cues. This was followed by a series of five additional randomized practice trials to ensure the participant was familiar with the task before commencing the study. The experimenter provided feedback to the participant during the practice to ensure the participant performed consistent, smooth movements when lifting.

For the experiment proper, there were 120 randomised trials, consisting of 60 Experimenter Lift trails and 60 Self-Lift trials, presented in blocks of 10. After each block, participants were offered a brief break to rest or stretch their arm if they felt they needed to do so. Trials were presented in a random order within each block.

Participants were advised to keep the elbow flexion of their postural arm at a 90 degree angle and to try to hold their postural arm as steady as possible during both the self and experimenter lifts. For the Experimenter Lift trials, the experimenter intentionally varied the time delay between hearing the tone cue and lifting the weight, in order to reduce the capacity of the participant to predict or anticipate the precise moment that experimenter lifting would occur.

Data Acquisition

Physiological measures of Subject-Lift versus Experimenter-Lift trials were recorded using three different sensors: 1) angle of joint movement in the postural arm using a Goniometer/Joint Angle Sensor; 2) muscle activity using electromyography (EMG); 3) hand and weight movement acceleration using an accelerometer.

Electromyographic (EMG) sensor recordings were taken for the bicep brachii muscle activity and the tricep brachii muscle activity. A ground electrode was attached to the participants' wrist via a water dampened Velcro strap. EMG sensors were first attached to the participants' bicep and tricep brachii on their right postural arm. Two EMG sensors were attached for the recording of the bicep muscle and two sensors also attached for the recording of the tricep muscle. EMG sensors were attached to the participants arm with a conductive gel placed on the electrode to facilitate conductivity for the sensor recordings.

Goniometer/Joint Angle Sensor recordings, which measured the angle of flexion and extension around the elbow were taken of the right postural arm. The Goniometer (Adinstruments, Model: S700), has a sensor output of 2.5 volts when straight with plus or minus 1 volt for an angle of plus or minus 90 degrees. Observation of the goniometer activity indicated that 1 degree of elbow flexion was equivalent to about .05 of a volt. The elbow Goniometer sensor was attached to the participants' right postural arm. The participant was asked to place their arm out straight and the cantilever of the goniometer was lined up so that the center of the sensor was directly in line with the flexion point of the elbow. The two ends of the goniometer were taped to participants' upper and low arm respectively using micropore tape. One end of the goniometer was taped to the antibrachial region of the forearm and the other end of the goniometer was taped to the brachial region of the upper-arm.

In addition, accelerometer sensors were used as timing markers for each trial. Accelerometer sensor recordings were taken from the right postural hand motions by taping the accelerometer sensor to the middle finger of the participant's hand. The Accelerometer (Biometrics Ltd, Model: ACL 300), measures acceleration along three independent axes of movement with a low pass filter. A second accelerometer sensor was attached to the top of the weight. In both conditions, the movement to displace the weight was a rapid action of short duration. We took the time at which the weight experienced its maximum acceleration as the starting point of each trial.

All sensor data of postural activity was recorded on PowerLab 8/30 using LabChart software. The sampling rate for all the channels of data was 4K/s. The goniometer activity was sampled at a range of 5V. EMG signal amplitude recordings from the tricep brachii and bicep brachii sampled at the 0-10mV range (peak-to-peak). Accelerometer activity was sampled at a range of 10V.

Experiment One Results

Previous research suggests that the unexpected effects of someone else lifting the weight in a BMLL task should be accompanied by distinct physiological responses. In this exploratory analysis we sought to identify kinematic and physiological responses, measured by the Goniometer and EMG sensors, that would distinguish the Experimenter-Lift and Subject-Lift conditions.

Goniometer Data

Goniometer and EMG data were epoched from 1000ms prior to the mean peak accelerometer response to 1000ms after the mean accelerometer peak. To find areas of significance in both Goniometer and EMG data a permutation test was performed. Using the platform MATLAB (Mathworks Inc), a two-sample non-parametric test using the statcond function of the EEGlab toolbox was applied to the single trial data for the epoch -100ms to +100ms. 2000 permutations were ran and a statistical significance was set at a p-value of 0.01, false discovery rate corrected.

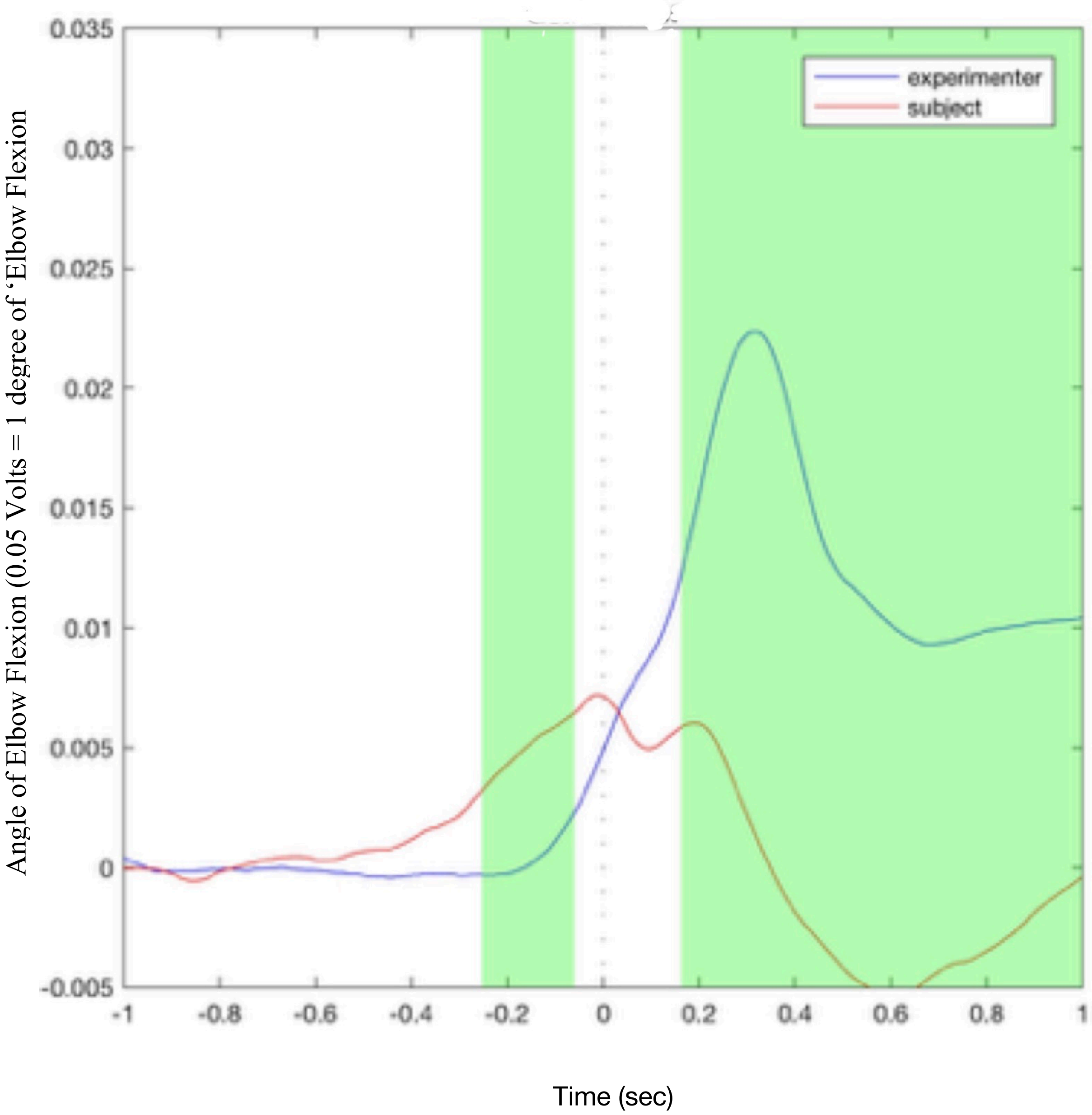

Figure 2. Participant (N=20) Mean Elbow Flexion (0.05 volts = 1 degree of arm flexion) for the two conditions of Experimenter Lift and Subject Lift as a function of time with Zero (0) the time of maximum acceleration of the lift. Green shaded areas identify areas of significant difference between Angle of Elbow Flexion for the two conditions.

Visual inspection of the goniometer graph for peak angle of elbow flexion across all participants appeared to occur in the 200-400ms time window. Therefore, to analyse the goniometer data we investigated peak-to-peak, or the difference between the maximum positive and maximum negative amplitudes in a wave form, for responses in elbow flexion for the peak flexion moment located between the time period 200ms-400ms. Peak elbow flexion in the Experimenter Lift condition ($M = 0.022$, $SD = 0.001$) was significantly greater than peak elbow flexion in the Subject Lift condition ($M = 0.006$, $SD = 0.010$), $t(19) = 5.82$, $p < .001$, $d = 0.841$, 95% CI[0.055, 0.019].

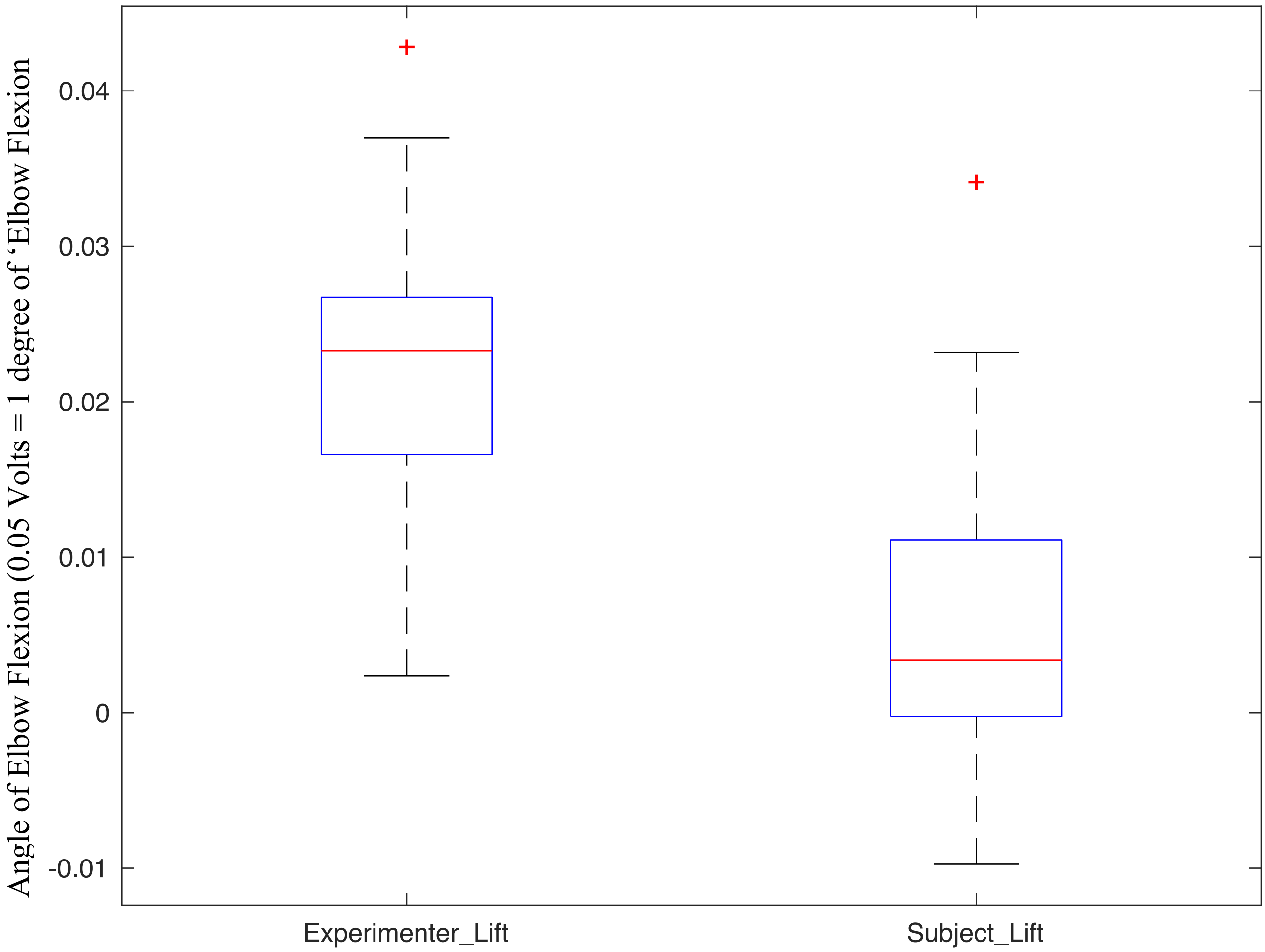

Figure 3. Peak-to-peak responses in Goniometer Elbow Flexion for Subject Lift and Experimenter Lift.

EMG Data

Raw EMG signals were subject to low and high pass filtering, with high filtering pass band frequency at 400 Hz and low pass band frequency at 20 Hz. The EMG data were normalised in order to obtain the mean EMG amplitude for participants across the two conditions.

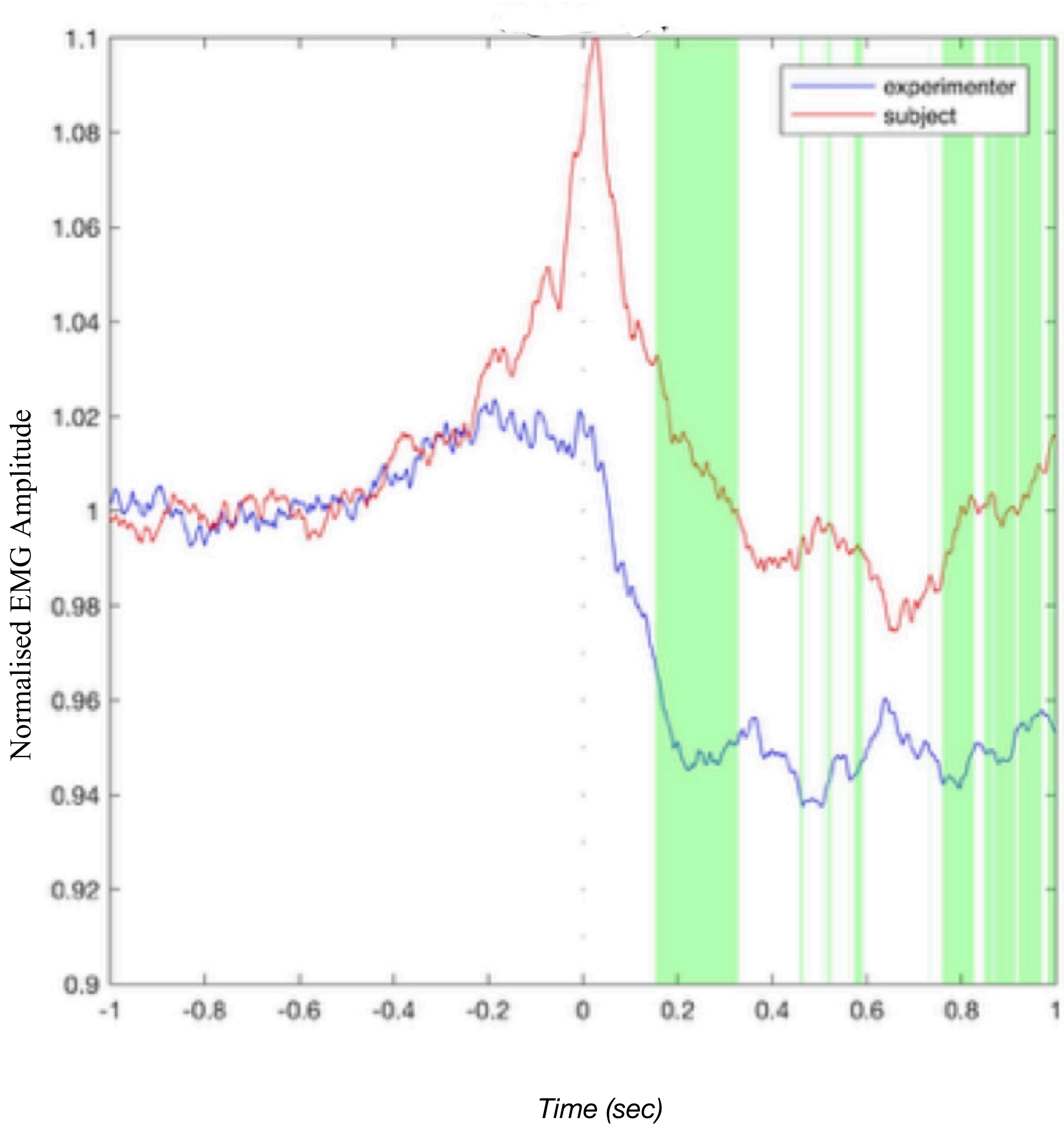

Figure 4. Mean EMG Bicep data for conditions of Experimenter Lift and Subject Lift as a function of time. Zero (0) equals maximum acceleration time of lift as measured by an accelerometer. Green shaded areas identify areas of significant difference between EMG amplitudes for each condition.

We tested two time periods from -25ms to +25ms and 0-40ms for evidence of physiological markers of postural adjustments as measured by EMG Bicep activity for the Experimenter Lift condition versus the Subject Lift condition. We looked at the time period from -25ms to +25 ms because we were interested in seeing if there were differences around the time period of the lift where postural adjustments would presumably be most significant. We looked at the time period from 0-40ms to see if there were significant differences in muscle activity over the time course of movement as postural changes would unfold with the lifting action. For the -25 to +25 millisecond time period, EMG bicep amplitude for Experimenter Lift ($M = 1.02$, $SD = 0.052$) was not significantly different from the Subject-Lift condition ($M = 1.08$, $SD = 0.169$) with no $t(19) = -1.82$, $p > 0.05$), $d = -0.407$, 95%, CI [-0.145, 0.0102].

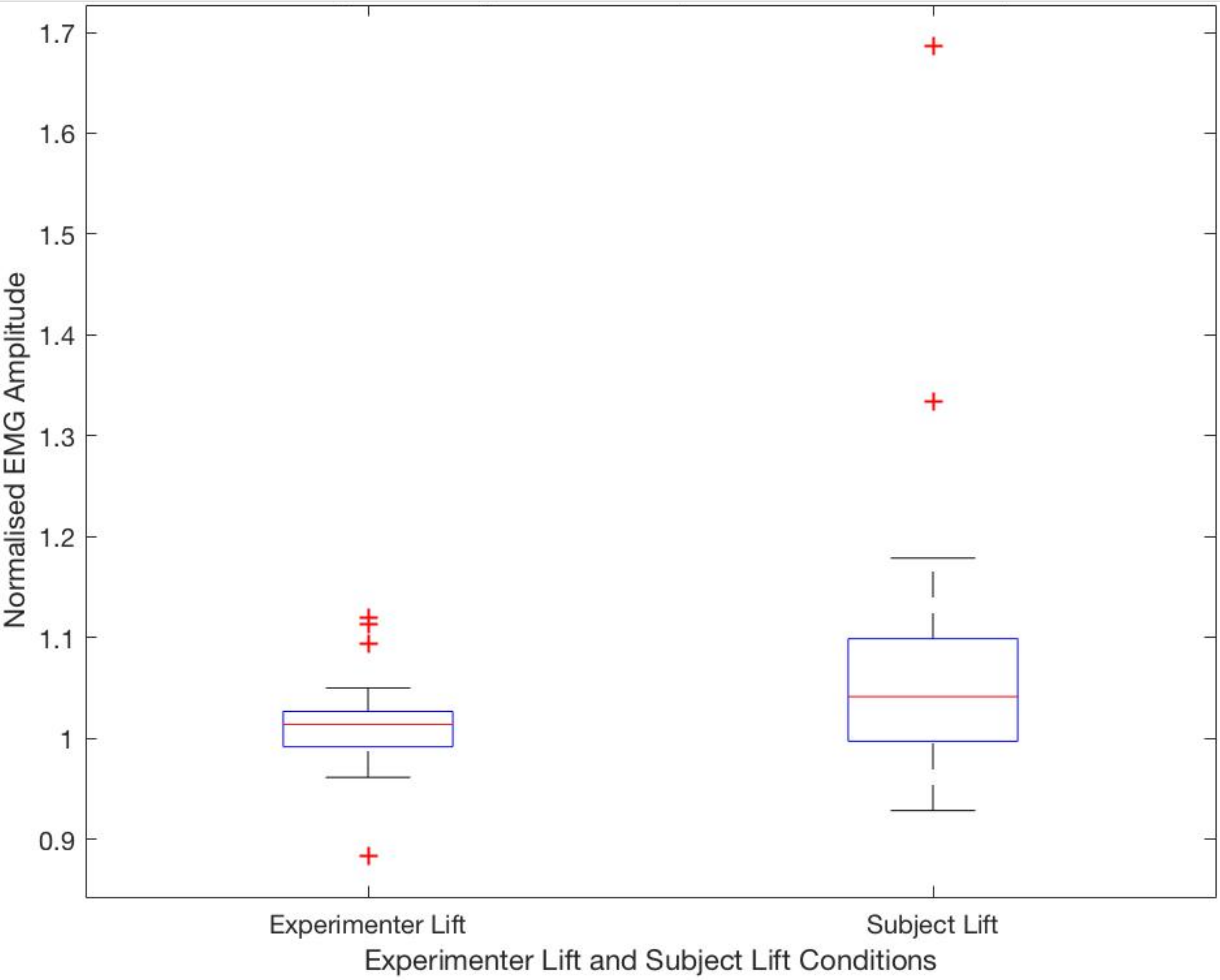

Figure 5. Mean Group Bicep EMG amplitudes for Experimenter Lift and Subject Lift for the time window = -25ms to +25ms.

For the 0-400ms time period a paired sample t-test was used to compare bicep EMG in in the Experimenter Lift (*M*=0.251, *SD* = 0.010) and Subject-Lift conditions (*M*=0.013, *SD* = 0.0124) with no significant difference found $t(19)$ =-1.866 p>.05, d =-0.417, 95% CI [-0.169, 0.00968].

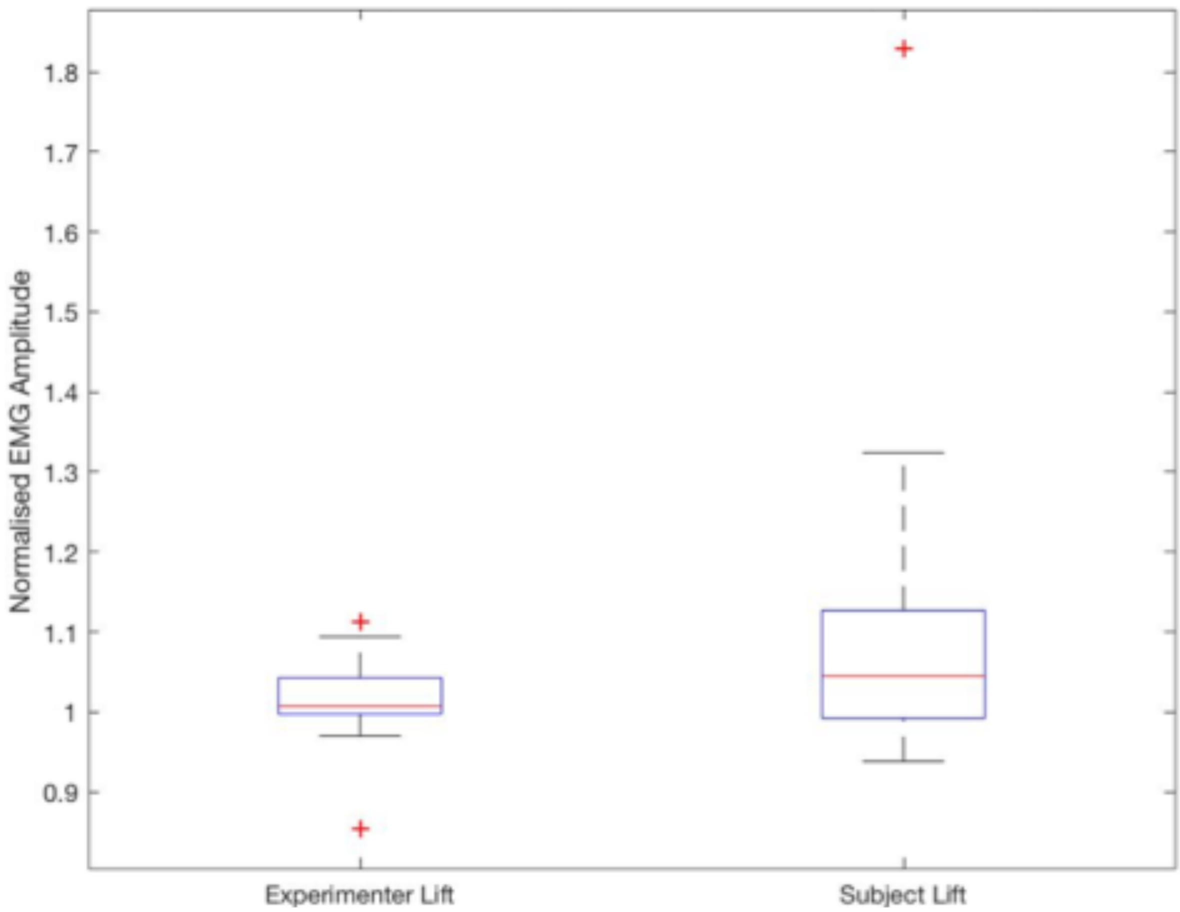

Figure 6. Mean Group Bicep EMG amplitudes for Experimenter Lift and Self Lift for the time window = 0ms to 400ms.

Tricep EMG for -25 to +25 millisecond time period a paired sample t-test was used to compare Experimenter Lift (*M*=1.02, *SD* =0.048) to Subject-Lift (*M*=1.02, *SD* =0.053) with no significant difference found $t(19) = -0.330$ $p > .05$, $d = -0.0737$, 95% CI [-0.0408, 0.0297].

Tricep EMG for 0 to + 40 millisecond time period a paired sample t-test was used to compare Experimenter Lift (*M*=1.02, *SD* =0.053) to Subject-Lift (*M*=1.10, *SD* =0.213) with no significant difference found $t(19) = 1.81$ $p > .05$, $d = 0.405$, 95% CI [-0.0130, 0.180].

Experiment One Discussion

The aim of experiment one was to identify specific markers of agentive action during the performance of a BMLL task. A significant difference was found between the Subject-Lift and Experimenter-Lift in the BMLL task with regards to goniometer. Participants in the experimenter lift condition had a significantly higher peak elbow flexion that participants in the subject-lift condition. This result indicates that in the experimenter-lift condition, the unanticipated lifting of the weight causes a sudden jerk in the arm of participant. According to theories based on optimal control, organisms act to minimize the “cost function” or amount of effort and energy they have to exert in order to achieve certain goals and execute certain motor actions (Franklin & Wolpert, 2011). In the case of performing the goal of reaching for an item or object with the hand, optimal control theory suggests that this aim of reaching with optimal control requires that the reaching movement be performed as smoothly as possible. This, in turn, requires that the reaching movement operates under the “minimum jerk principle” (Hogan & Flash, 1987), which states that minimizing the “cost function” of hand reaching necessitates the minimization of the rate of change in acceleration (typically referred to as jerk). No significant differences in postural control were found in relation to the EMG measure of muscle activity for either Bicep or Tricep muscles. Previous research using EMG and postural adjustments have found a difference in the BMLL task when looking at a self-unloading of a weight versus experimenter-unloading of a weight (Ng et al., 2013; Ng et al., 2011). Reasons for failure to find an EMG difference in the two conditions will be explored in the discussion section of experiment 2.

The increased angle of flexion in the postural arm during the Experimenter-Lift condition is likely due to an involuntary jerk of the arm in response to the sudden change in weight when the experimenter moves the weight suddenly, which creates a destabilisation of the arm. In the Subject-Lift condition participants were able to anticipate the upcoming change in weight and did not show this jerk response. Based on this finding peak elbow flexion is a viable marker of agentive action.

Experiment 2

In experiment 2 we investigated whether a hypnotic suggestion targeted at altering the experience of agency would lead to changes in the kinematic markers of agentive action identified in experiment 1. In this way, we sought to test the claim of dissociative control theory that hypnosis can influence low level motor control of actions rather than just influencing the monitoring of actions.

Hypnosis is known to change individuals' experiences of agency. This study investigated whether these changes in agency would also be accompanied by significant differences in postural adjustments measured by the kinematic and physiological markers of agency used in experiment one.

Experiment 1 established a clear kinematic marker of self-generated action. The aim of experiment 2 was to see if changes in self agency induced by a hypnotic suggestion would lead to changes in this kinematic marker. Specifically, it was hypothesised that a hypnotic suggestion of "Alien Control," in which it was suggested that a participant's own self-generated actions would be experienced as externally generated, would induce a kinematic response similar to that seen in the Experimenter-Lift in Experiment 1. That is, during a hypnotic condition where participants were told that it would feel as though someone else and not themselves was lifting the weight, we would see a significantly increased angle of flexion compared to a non-hypnotic Subject-Lift condition while performing the BMLL task. In addition to this kinematic marker, we also included explicit measure of agency. Participants completed the Sense of Agency Rating Scale (SOARS; Polito, Barnier & Woody, 2013) and also provided general ratings of their overall feelings of control.

We had four hypotheses for this study. First, I expected that we would replicate our finding of peak elbow flexion as a kinematic marker of postural adjustments. Specifically, I hypothesised that peak-to-peak elbow flexion would be significantly higher for the Experimenter Lift compared to the Subject Lift condition.

Second, I expected that a hypnotic suggestion for alien control would impact the kinematic marker of postural adjustments. Specifically, I hypothesised that elbow flexion following a hypnotic cue for alien control would be significantly greater than elbow flexion in the normal Subject Lift condition.

Third, I expected that a hypnotic suggestion would impact subjective experiences of agency. Specifically, I hypothesised that SOARS Involuntariness and SOARS Effortlessness scores would both be higher following a hypnotic cue for alien control compared to the normal Subject Lift condition.

Fourth, I expected a hypnotic suggestion would impact participants overall feeling of control. Specifically, I hypothesised that participants' control ratings would be higher following a hypnotic cue for alien control compared to the normal Subject Lift condition.

Experiment Two Method

Participants

A power analysis, based on the effect size goniometer results in Experiment 1 (d = 0.841) indicated that n=17 participants would be required to detect similar effects with 90% power at an alpha level of .05. Twenty adults (10 female, 10 male) were recruited from Macquarie University and took part in exchange for either financial reimbursement or student credit points. Participants in this study were high hypnotizable, having previously scored 8 or more on the Waterloo-Stanford Group Scale of Hypnotic Susceptibility (Bowers, 1998). Two participants were excluded as they asked to discontinue the experiment before completing all trials. One additional participant was excluded as they did not respond to the hypnotic suggestions (see below). In total 17 participants were included in the final analyses. Prior to the experiment, all participants complete the Edinburgh Handedness Scale with nineteen participants identifying as being right handed and one identifying as being left-handed.

Procedures

There were five phases in Experiment 2. In the first phase, participants completed the same setup and practice procedures as Experiment 1 (i.e., all the same sensors were used on participants and identical data acquisition protocols were also used). The only changes were that in experiment 2 the experimenter sat again to the side but this time in front of the participant, in contrast to behind the participant in Experiment 1. The reason for the experimenter sitting in a different location in Experiment 2 was so that the experimenter could administer the hypnotic suggestion while facing the participant. Also, in experiment 2, the auditory cues were voice recordings announcing "Experimenter Lift" or "Subject Lift" in place of the tones used in Experiment 1. The use of verbal cues rather than non-verbal tones was used to avoid possible confusion on the part of the participant as there would be a third experimental condition that the participant would have to respond to while under hypnosis. Piloting indicated that most participants had challenges discriminating reliably between three tones. A final change from experiment 1 was that the weight was reduced to from 1.5kgms to 800gms after piloting indicated that participants found the weight too heavy to complete the trials. After all sensors were attached, a practice run of the BMLL task was administered to help the participant familiarise themselves with the task. This practice run consisted of the Subject-lift and Experimenter-lift conditions as carried out in experiment 1. After the trials, the experimenter checked with the participant that they were familiar with the task before proceeding to the hypnotic induction stage of the experiment. After the trials, the experimenter checked with the participant that they were familiar with the task before proceeding to the hypnotic induction stage of the experiment.

In the second phase of the experiment, the experimenter dimmed the laboratory lights, asked participants to relax, close their eyes and administered a 12 minute hypnotic induction adapted from the Stanford Scale of Hypnotic Susceptibility (Weitzenhoffer & Hilgard, 1959). Following the hypnotic induction, participants were given three standard hypnotic suggestions taken from the Standford Scale of Hypnotic Susceptibility. (Weitzenhoffer & Hilgard, 1959). These suggestions were included as a way of establishing the hypnotic context and allowing participants to re-experience the effects of suggestions.

In the third phase of the experiment, the experimenter gave an "Alien Control" suggestion, instructing participants that "someone else" would take control of their arm. The specific suggestion was:

> In a moment when you hear this sound [PLAY CUE – "SOMEONE ELSE]
>
> you will find that this hand [TOUCH HAND] moves to pick up the weight automatically as if it is being controlled by someone else. This will not be your own movement picking up the weight, instead you will find this hand [TOUCH HAND] lifting the weight as if it were being controlled by someone else. Someone else will cause this hand [TOUCH HAND] to move and lift the weight. These movements will be automatic movements caused by someone else, directing this hand [TOUCH HAND] to lift the weight.
>
> This will only happen when you hear this sound [PLAY CUE- "SOME ONE ELSE].
>
> If you hear the tones from before, you will respond just as before. If you hear this sound [PLAY CUE- "SOMEONE ELSE"] you will pick up the weight normally and it will feel completely ordinary, just like it did before.
>
> But only when you hear this sound [PLAY CUE – "SOMEONE ELSE], this hand [TOUCH HAND] will feel like it is controlled by someone else and move automatically to pick up the weight. You may find these movements very clear and easy to identify

or they may be subtle and faint. In any case you will find this hand [TOUCH HAND] moving automatically to lift the weight.

As you sit there comfortably relaxed and deeply hypnotised, someone else, not you, will cause the movements which lift the weight. Do you understand?

During this suggestion, the experimenter played an audio recording of the cue consisting of the spoken words "SOMEONE ELSE" when the participant was prompted that the experimenter that they would "hear this sound." When the experimenter was indicating the target hand for the effects of the suggestion, the experimenter lightly touched the participant on their left, lifting hand. The experimenter then clarified with the participant that they clearly understood the suggestion by asking the participant to nod their head that they understood. Participants were advised that if they heard the previous cues from the practice phase 1 trials, they should respond just as they did during the phase 1 trials (i.e., without any experience of alien control). The experience of alien control was specifically triggered by the "SOMEONE ELSE" cue.

After getting clarification from the participant that they understood the suggestion, participants completed the modified BMLL task, with the three conditions: Experimenter-Lift, Subject-Lift and the Hypnotic-Lift condition. Please note that the Hypnotic-Lift condition refers to the condition where participants experienced the specific suggestion cue to experience the movements of "SOMEONE ELSE", and should not be confused with the fact that all participants had undergone an hypnotic induction prior to performing the three different task conditions. 180 trials (60 in each of the three conditions) were presented in random order in blocks of ten trials. At the end of every block, the experimenter would check to see if the participants were holding the weight correctly and if they wanted to have a break. At the end of 90 trials, the experimenter ensured that all participants took a longer break. During this break, the experimenter administered a brief hypnotic deepening, before asking the participant to again open their eyes, extend their postural arm and complete the remaining 90 trials.

In the fourth phase of the experiment, participants completed a final phase in order to measure explicit experiences of agency. In this phase participants first completed an additional Subject Lift trial and also an additional Hypnotic Lift trial, presented in counter-balanced order. Immediately, following each of these trials participants completed the SOARS (i.e., each participant completed the SOARS twice in total, once after a Subject-Lift trial and once after a Hypnotic Lift trial).

In the fifth phase of the experiment, the experimenter gave a cancellation for the alien control suggestion, instructing participants to once again experience normal control over their arm, and administered a hypnotic de-induction. Participants then completed a Debrief Interview consisting of seven questions: 1. What were you thinking about as I was giving you the suggestion?; 2. What did you expect to happen?; 3. What happened when you heard the cue?; 4. Did your hand movements feel different?; 5. How much control did you feel you had over your arm after the cue played?; 6. On a scale of 1 to 10, when you heard the sound recording "someone else," how much control did you feel you had over your arm following the cue?; and 7. On a scale of 1 to 10, when you heard the sound recording "self," how much control did you feel you had over your arm following the cue?

Experiment Two Results

Results are presented in five sections: Responses to standard hypnotic items; Goniometer findings from the BMLL task; EMG findings from the BMLL task; SOARS findings; Quantitative control ratings from the Debrief Interview; and Qualitative responses from the Debrief Interview.

Responses to standard hypnotic items

Although all participants in this study were previously identified as high hypnotisable, we used responses on the three standard suggestions as a check to ensure hypnotic responding during this experiment. Each of the suggestions had specific passing criteria taken from an adaptation of the (Stanford Scale of Hypnotic Susceptibility). That is, for the Hand Lowering item, participants were required to lower their raised hand at least 10cm. For the Verbal Inhibition item, participants must not have vocalised their name when prompted by the experimenter to do so. For the Mosquito Hallucination Item, participants were required to make a visible arm movement to brush the mosquito away. 17 participants passed 2 or 3 of these standard suggestions.

Goniometer findings from the BMLL task

For the goniometer peak angle of flexion was examined for the time window of 200ms to 400ms. One-Way ANOVA revealed that the peak arm flexion differed across the three conditions of Experimenter Lift, Subject-Lift and Hypnotic Lift, $F(2, 48) = 17.7$, $p <$ 0.001 $\boldsymbol{\eta}^2 = 0.424$. Follow up tests, using a Bonferroni corrected alpha value of .05/3 = .0.17 revealed that participants in both the Experimenter Lift condition (M= 0.024, SD = 0.010) had significantly differed from both Self-Lift condition (M = 0.009, SD = 0.009), t=4.893 p 0.001; and the Hypnotic Lift conditions (M=0.008, SD= 0.008), t=5.371 p = 0.001. There was no evidence of difference between Subject-Lift and Hypnotic-Lift conditions, t=0.477 p = 1.000.

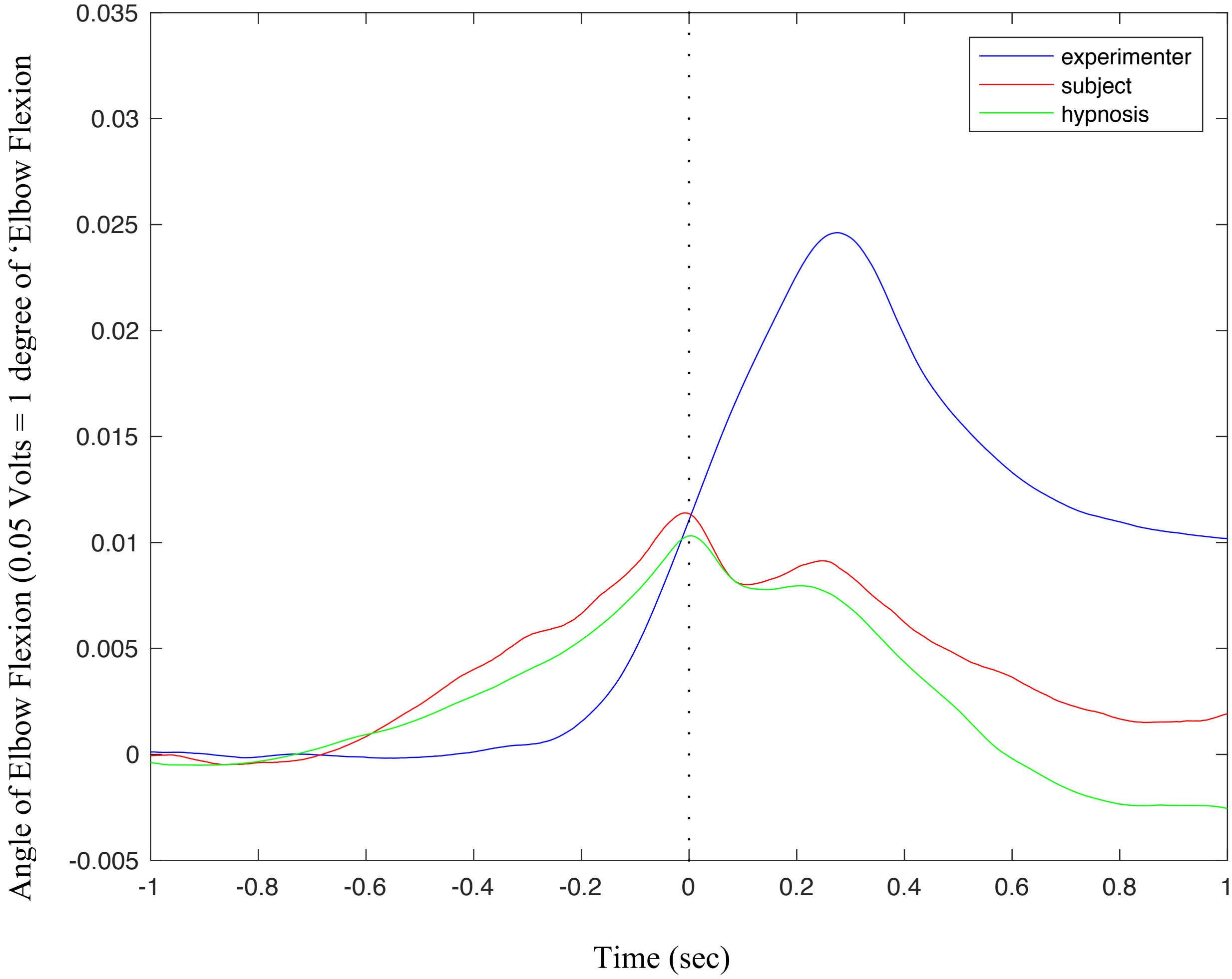

Figure 7. Goniometer angle of Flexion for Experimenter Lift, Subject Lift and Hypnotic Lift conditions.

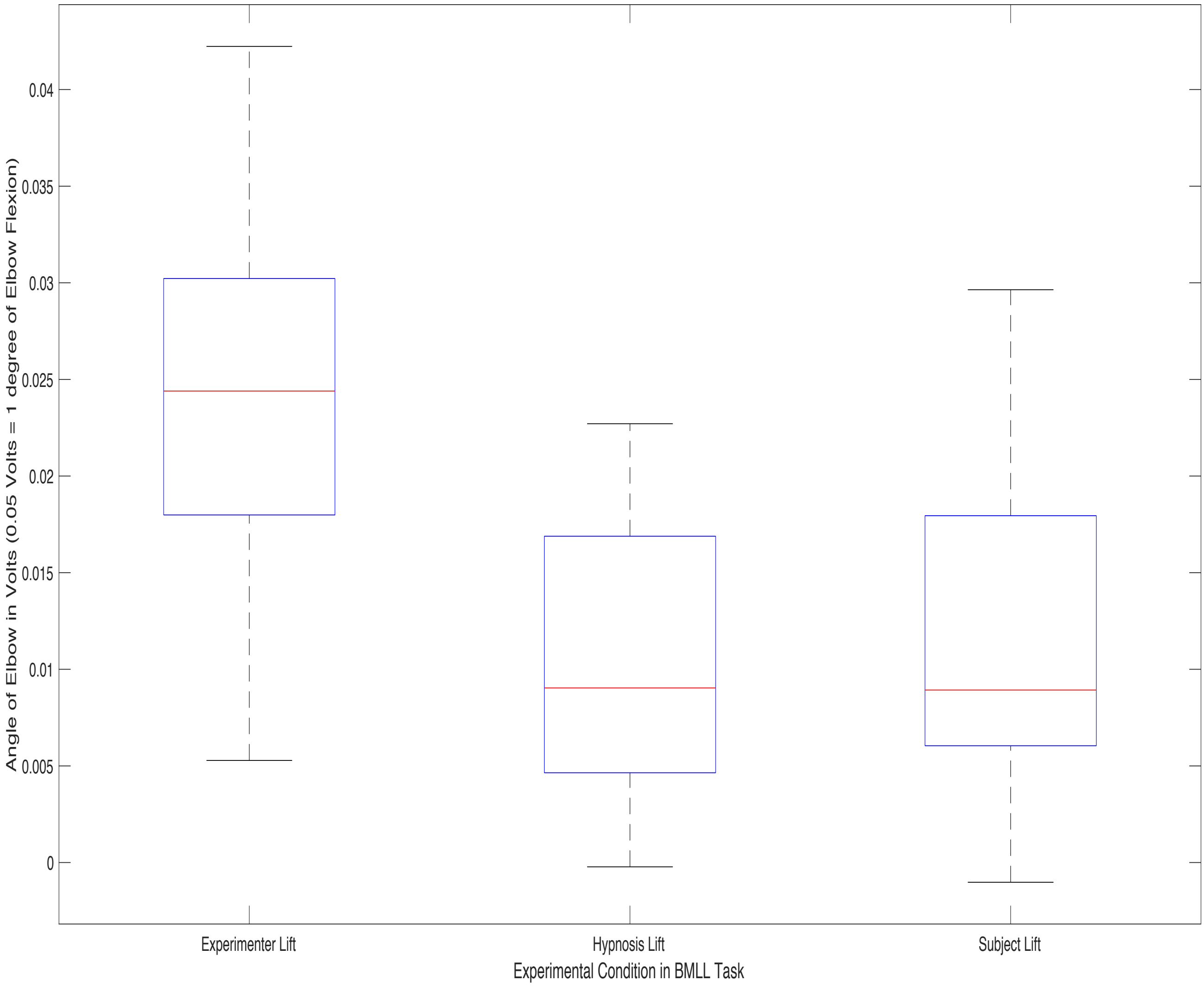

Figure 8. Peak Angle of Arm Flexion for Experimenter Lift, Subject Lift and Hypnotic Lift conditions.

EMG findings from the BMLL task

One-way ANOVA showed no differences between conditions for EMG Bicep data, $F(2, 48) = 0.132$, $p = 0.88$. η^2=0.005. Similarly, one-way ANOVA showed no differences between conditions for EMG Tricep data, $F(2, 48) = 0.001$ $p = 0.990$ η^2=0.000.

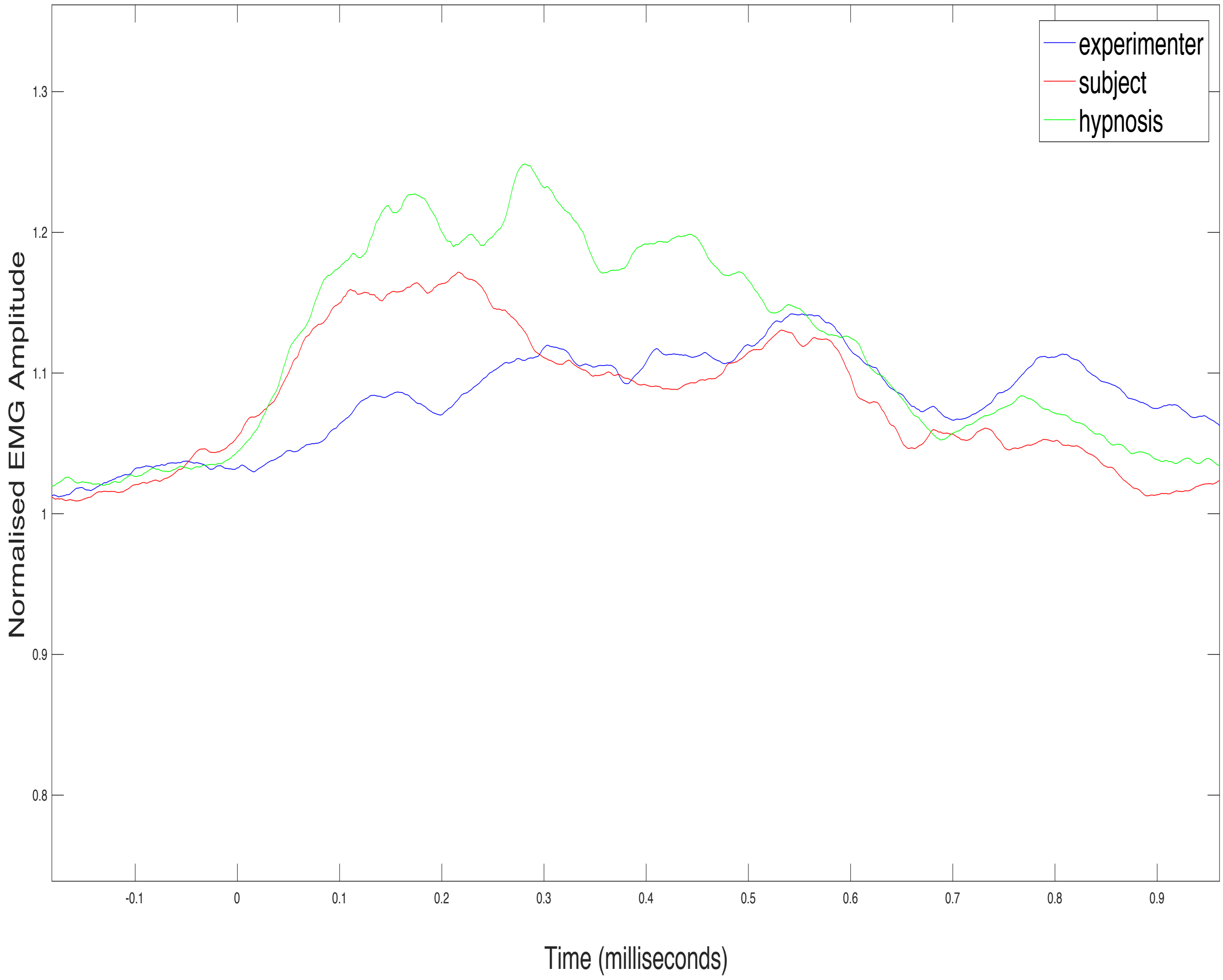

Figure 9. Participant Bicep EMG data for time period (-200ms to +1000ms) for BMLL Conditions: Experimenter Lift, Subject Lift and Hypnotic Lift

SOARS findings

The SOARS consists of two subscales: Involuntariness and Effortlessness. SOARS scores were obtained for the Self Lift and Hypnotic Lift conditions only. Involuntariness scores were higher in the Hypnotic Lift condition ($M = 22.7$, $SD = 7.92$) than in the Subject-Lift condition ($M = 12.4$, $SD = 7.92$) paired samples $t(16) = 5.19$, $p <.001$. Cohen's d = 1.258, CI [6.09-14.502], indicating that sense of involuntariness was significantly greater during the hypnotic condition comparted to the non-hypnotic condition.

There was no significant difference in Effortlessness scores between the Subject Lift (M= 31.2, SD=3.76) and Hypnotic Lift (M= 29.6, SD= 4.42) conditions, t(16) = 1.56, d = 0.378, 95% , CI [-0.532 – 3.61].

Quantitative control ratings from the Debrief Interview

In the Debrief Interview, participants gave a score from 1 to 10, rating their subjective level of control in the Subject Lift and Hypnotic Lift conditions. Control ratings were differed in the Hypnotic Lift (M = 4.00 SD = 1.84) compared to the Subject-Lift condition (M = 9.47 SD = 1.01) with $t(16) = 13.27$ $p < .001$. $d = 3.218$. 95% , CI [4.597, 6.34].

Qualitative responses from the Debrief Interview

Analysis of qualitative responses from the Debrief Interview revealed fairly consistent experiences during this experiment. A majority of participants reported that they were not aware of having many expectations when the hypnotic suggestion was being given. Responses by participants included: “that they were not fully aware (when suggestion was being given,” that “they could not recall (the suggestion being given).” Typical responses given by participants were that they “were not thinking much.” Of those who did report expectations about what would happen, two reported that they thought there would be an effect as described by the experimenter based on their previous experiences of hypnosis. One person reported an inverse effect to what their expectations were, stating that they expected the suggestion to have an effect but reporting subsequently that the suggestion had failed to do so. Two other people reported an inverse effect, stating that they thought there would be no effect from the suggestion, with stating that they did not see (understand) how the effect could work. Interestingly, both these participants experienced significant effects from the suggestion.

A number of participants reported feelings consistent with the idea that their responses on the hypnotic suggestion of "someone else" moving and lifting the weight came with less effort. Responses of this nature included:

"(I felt) more alert, more casual."

"I moved without trying."

"My arm would move then I would realise (that it had moved)."

"It (arm moving) happened without (me) trying."

Other participants also reported that lifting the weight on the hypnotic condition felt "smoother and less energetic," "more fluid, relaxed and slow," and "lighter."

Three participants reported that responses felt more "automatic."

Interestingly, one respondent stated that not only did his arm move "more easily and freer" under the hypnotic condition but that he subsequently found it harder to move his arm under the non-hypnotic "subject lift condition." This participant was observed to have started to respond more slowly under the Subject Lift condition as the experiment continued and reported that he started to find it hard to initiate his own movements during the subject-lift. Many of these responses are not surprising given that part of the hypnotic suggestion for the "someone else" cue was that participants may find their responses feeling "more automatic." However, the self-reports of sense of effortlessness seem to contradict the SOARS results that indicated no significant difference between a sense of Effortlessness in the non-hypnotic and hypnotic conditions.

Paradoxically, many participants also reported some internal conflict during the hypnotic trial condition. Comments regarding this reported experiential state included:

"(I) felt like I was forcing myself, (I had a) conflicting mind."

"(I) had a minor feeling of going against it (the arm movement)"

"(I) tried to lift differently but could not."

"(It felt) a little bit more forced, then the self-lift."

"I tried not to respond, (I) tried to challenge my feeling but it did not work out."

"(I) don't feel I could have stopped it."

Finally, some participants reported on the unusualness of hypnotic experience. Two participants responded that they felt that hypnosis in general felt "weird." One person reported that they felt "a little strange" even while performing the non-hypnotic trials. Some of this unusualness of experience may be connected participants reports of ambiguity in what they were feeling. Examples include a participant stating that they "new it was me but not me that told it (their hand) to move," another participant stated that they felt more "confused" on the hypnotic condition and one participant stated that "when the hand started moving, I knew it was sort of me and sort of not (me)." A participant also stated that "I knew it was me in my body, but not me that told it (her hand) to move."

Experiment Two Discussion

Experiment 2 investigated the impact of a hypnotic suggestion for alien control on the physiological marker of agentive action identified in experiment 1. The first hypothesis was that we could replicate the finding of a significant difference between the Experimenter Lift and the Subject Lift conditions for peak-to-peak elbow flexion, found in experiment 1. This finding was replicated, with significantly greater elbow flexion in the Experimenter Lift condition, indicating that elbow flexion is a reliable marker of postural adjustments.

The second hypothesis was that a hypnotic suggestion for alien control would impact elbow flexion, such that responses in the Hypnotic Lift condition would become more like those in the Subject Lift condition. Contrary to this hypothesis, there was no evidence of a difference between the hypnotic lift and self-lift conditions. This null finding indicates that the hypnotic suggestion for alien control was not an effective influence on this form of postural adjustments.

Our third hypothesis was that SOARS scores would be higher in the Hypnotic Lift condition, compared to the Self Lift condition. This hypothesis was partially supported, with participants' reporting significantly greater Involuntariness during the hypnotic-lift compared to the subject-lift condition but reporting no difference in Effortlessness. This indicates that the alien control suggestion impacted some aspects of subjective sense of agency, leading participants to feel in particular that their actions were less internally generated.

Our fourth hypothesis was that participants would report lower levels of subjective control in the Hypnotic Lift trials compared with Subject Lift trials. This hypothesis was supported, indicating that the alien control suggestion did influence the way participants experienced movements of their arm.

Overall the findings from Experiment 2, confirm that a targeted hypnotic suggestion can markedly influence subjective feelings of agency and control. However, we found no evidence that hypnosis had an impact on the low-level mechanisms associated with postural control.

General Discussion

A key motivation for this study was to test whether a hypnotic suggestion specifically targeted change in sense agency would influence physiological markers of postural adjustments. Here we review the current findings in light of three major theories of hypnosis: Dissociated Control Theory, Dissociated Experience Theory, and Social Cognitive Theory. Although, this study was not designed to specifically test these theories, the current results are considered to explore which accounts may be compatible with these findings. These analyses are presented as exploratory investigation and no strong claims are made about how alterations in postural control relate to these theories of hypnosis.

Dissociated Control Theory

In general, it would seem that the findings from this study did not support Dissociated Control Theory. Dissociated Control Theory suggests that the hypnotic effect is associated with reduced higher order executive control mechanisms in action and the freeing up of lower level sub-personal functions from this higher order control (Woody & Sadler, 2008). In our experiment, we expected to see the hypnotic suggestion of "Alien Hands" would lead to postural destabilising effects similar to those seen when the experimenter lifts the weight from the hand of the participant, a result which we did not find. It could be argued, however, that the while this study did not show evidence for Dissociated Control Theory, it was also not sufficient to disprove the theory. Establishing ways to disprove Dissociated Control Theory relies on demonstrating the mechanisms by which the theory relates hypnosis to alterations in sense of agency and control mechanisms. This will be explored in more detail below.

Dissociated Experience Theory

In our findings participants showed clear evidence of a change in experience and no evidence of any change in postural control, this closely fits with the Dissociated Experience account. Disassociated Experience Theory predicts that while experiences may change via reduced attentional monitoring under hypnosis, actual executive control is not changed. The findings may also be interpreted as consistent with the theory that self-agency is comprised of two different aspects, a Feeling of Agency and a Judgment of Agency (Synofzik, Vosgerau & Voss, 2013). A Feeling of Agency is presumed to be generated by internal motor command signals that may, in turn, influence higher level Judgements of Agency (Synofzik, Vosgerau & Voss, 2013). In the context of this experiment, participants judgements of agency appeared to be that sense of control and voluntary action were reduced, while measures of actual postural control, possibly related to the effective performance of internal motor command signals, appeared to be unaltered by the hypnotic suggestion.

Another finding supportive of Dissociated Experience Theory is that many participants in Experiment Two reported that the Hypnotic-Lift condition felt automatic even though physical exertion, as measured by the amplitudes for muscle activity between Hypnotic Lift and Subject-Lift, would indicate that the amount of effort exerted while doing the hypnotic task was not reduced. Dissociated Experience Theory claims that due to impaired action monitoring under hypnosis, task demands may be experienced as easier, even though actual processing demands of the task are not significantly changed (Woody & Sadler, 2008). Dissociated Experience Theory also contends that hypnosis involves fundamental alterations in states of consciousness that are different from normative experience (Kihlstrom, 2008). Consistent with this, some of the participants reports of feeling an altered or unusual state of consciousness, such as reporting that hypnosis feels “weird.” One participant stated that he felt hypnosis was like being in a “waking sleep.” Also, some participants reported after the experiment only vague or limited memories of events during hypnosis, although whether or not these were just a minority of participants was not quantitively evaluated. Surprisingly however, we found no difference in SOARS Effortlessness ratings between conditions in Experiment Two. Dissociative Experience Theory should predict that participants would have found actions in the hypnotic condition less effortful as a result of their dissociated experience and an inability to monitor the postural demands of the BMLL task. Notwithstanding this however, overall, Dissociation Experience Theory appears to be the account most compatible with the experiment 2 results.

Social Cognitive Theories

Perhaps the strongest indicator of whether or not Social Cognitive Theory can account for the current findings comes from the questionnaire regarding participant expectations of what would occur with regards to the hypnotic suggestion. Social Cognitive Theories of hypnosis emphasise the important role of expectancies, especially in social interactions, in explaining hypnotic phenomena (Kirsch, 1985). The general response from a majority of the participants in this study is that they had little expectation regarding what would happen for the hypnotic suggestion. Of the seventeen participants, only four reported having clear expectations about what would happen for the hypnotic suggestion condition and of those who reported expectations about what would happen, three of the four expected no effect consistent with the suggestion (even though they subsequently reported actually experiencing the hypnotic suggestion). However, it should be noted that participants had already gone through the hypnotic induction when undergoing the suggestion, so perhaps a more accurate way to determine the effect of expectancy on the hypnotic process would have been to ask participants about what their expectations were with regards to undergoing hypnosis in general, rather than just their expectations were about the specific suggestion for the hypnotic condition. It should also be noted that participant expectations were already primed by undergoing hypnosis at the pre-screening (Nash, 2005). As noted above, several participants reported feeling that hypnosis was an unusual feeling for them, a result that would suggest, that at least for some of these highly hypnotisable participants, hypnosis is not an everyday experience, contrary to what Social Cognitive Theory would suggest (Kirsch, 2000).

Motor Control Accounts of Hypnosis and Agency

The key aim of this study was to find evidence for hypnotic effects on motor control that accompany changes in sense of agency. As noted above, the Dissociated Control Theory contends that during hypnosis sub-personal control systems are able to operate unencumbered by executive control mechanisms (Woody & Sadler, 2008). The current results did not support this theory. However, our study looked only at the effects of a specific suggestion on postural control. Based on previous findings, it may be that other suggestions or the general effect of a hypnotic induction alone may have influences on postural control or action generation that were not picked up in this study. For example, hypnotic influences on postural control seems well supported by the research of Santarcangelo et al. (2008, 2004), cited above. In those studies, Highs appeared to show evidence of superior postural control in a variety of tasks, both when hypnotised and not hypnotised. These postural control abilities also seem to be modulated independently of voluntary awareness and control. Huffman et al., (2009), using Centre of Pressure measures with a Force Plate, have found that certain aspects of postural adjustments, such as direction of leaning are under conscious control, while other aspects of postural control, such as the amplitude and frequency of adjustments, are not. Postural adjustments also seem to involve some dual processing depending on the complexity of the task. More complex tasks appear to involve cognitive processes that use higher level, slower, control mechanisms then simpler tasks that performed by a fast feedforward mechanism (Slijper, Latash, & Mordkoff, 2002). The dual processing of postural changes possibly also relates to the degree to which such tasks may be “cognitively penetrable” (Pylyshyn, 1999), that is, how open they are to modulation by higher level cognitive processes such as beliefs. Stins & Beek (2012) concluded that fast online postural adjustments were probably cognitively impenetrable, or mostly unalterable by higher level beliefs and intentions, although higher level control may be possible, within limitations, in cases such as voluntary balance and safety. If this is the case, it is possible that hypnosis is able to access the more automatic, postural adjustments in participants and disconnect the higher-level processes creating a situation where participants ironically had efficient postural control under the hypnotic condition but felt less aware of it. The specific hypnotic suggestion of alien control may have altered beliefs about the degree of self-agency and control but not individuals’ actual control, which, at least at the level of fast, automatic, postural control could have remained relatively unaltered by the suggestion.

In this study, the aim was to alter postural control by changing person-level judgement about agency and control, rather than change postural control directly. Yet, theories of how hypnosis changes sense of agency at the level of motor control mechanisms may be consistent with the findings of this research. Santarcangelo et al. (2005), found that Highs under hypnotic suggestion of involuntary action showed significantly different changes in postural arm displacements when compared to a non-hypnotisable (Lows) group simulating involuntary action. This indicates that hypnotic suggestion can entail genuine changes in motor control by effecting executive motor control functions. These changes in executive motor control seem to be associated with changes in attentional control caused by hypnotic induction (Egner et al., 2005). Such changes may be related to a dissociation between the conflict monitoring processes and cognitive control processes of the frontal lobe. When asked to imagine changes in their body, such as feelings of pain or changes in the position of their heads, Highs compared to Lows also show significant differences in postural responses. (Santarcangelo, 2010; Scattina et al., 2012). Significantly, the changes in postural response seen in Highs entail changes in reflexive postural adjustments typically unmodulated by volition or agency.

Jameison's (2016) has outlined of two theories of the underlying mechanisms that may affect self-agency: the Motor Control Theory and Active Inference. The Motor Control Theory of Sense of Agency suggests that hypnosis reduces the sense of agency by effecting the efferent copy signal coming from higher order pre-frontal motor areas. While the Active Inference model, suggests that Sense of Agency is reduced by the inhibition of unexpected proprioceptive signals (Jameison, 2016). In relation to Motor Control Theory, if the alterations in the sense of agency as seen in this study are due to an alteration in an efferent signal coming from pre-frontal motor areas, it is not clear that alterations in the efferent signal, in itself, would alter postural control as we chose to measure it, since these postural control mechanisms may operate below the level of higher level control and personal awareness.

The Active Inference model also suggests that sense of agency and postural control may operate relatively independently. For example, Feldman (2016) suggests that postural control-related muscle activity, while possibly being modulated by higher-order brain activity, is not directly controlled by higher level executive motor control functions. Feldman contends that postural control is largely determined by a dynamic process that unfold according to changes in postural parameters such as muscle, kinematics and EMG signals. As the Active Inference model suggests that reduced sense of agency comes from the suppression of proprioceptive signals, information regarding the dynamic changes in postural control could be dissociated from a personal level sense of agency. In short, postural dynamics may be able to operate independently of higher order awareness of executive control and hypnosis may reduce awareness of these lower level postural changes creating a reduced sense of agency. Both the Motor Control Theory and Active Inference suggest reduced sense of agency via disassociations in levels of control in action, but both models can support the possibility that postural control, as a sub-system of motor control, could remain independent of changes in sense of agency. Furthermore, both these models could also be seen as giving some outline of the mechanisms involved in the Dissociated Control Theory.

Our findings that changes in self-agency did not relate to changes in EMG data also could be understandable if sub-systems of postural control can operate relatively independently of the higher level control mechanisms associated with a personal level sense of agency. De-Havas (2016) has explored an easily induced, but unusual experience in proprioceptive feeling and sense of agency called the “Kohnstamm phenomenon.” This phenomenon occurs when someone exerts muscular force against an external resistant force. When the external resistant force is removed, people feel that their arm moves or “floats” involuntarily into a new position. The phenomenon is commonly explained in terms of postural muscles finding new points of equilibrium in muscle activation and movement (Enoka, 2002). De Havas found arm EMG activity similar to that seen in both Experiment 1 and Experiment 2 of this study. Specifically, in both DeHavas' research and in the current experiments, EMG activity increased when a resistant force was removed. De Havas, suggests that this burst in muscle activity is due to the gating of the muscle activity determined by afferent signals, so that the muscle adjusts to a lower level of activity when there is external resistance, and increases in activity when this resistance is removed. As noted before, the Kohnstamm phenomenon is routinely associated with a feeling of reduced sense of self-agency over an arm when it is released from exertion against a resistance force and "floats" or adjusts to a new position. DeHavas, speculates that this may be because of lack of an efferent signal accompanying the circuit generating the muscle activity. If the muscle activity found in this study is a product of this muscle circuit, it may be mostly unrelated to voluntary control. That is, if DeHavas' "Kohnstamm phenomena" model of muscle activity is correct, it may give us some indication as to why we did not see differences in EMG activity between the Subject-Lift and Hypnotic Lift conditions. Specifically, muscle activity as measured in the participants' postural arm was gated in response to the resistance of the weight, and was relatively unmodulated by an efferent signal, which according to the Motor Control Theory of sense of agency is associated with voluntary action.

One of the main aims of this study was to see if hypnosis could influence processes outside of cognitive control. The current results do not seem to fit with previous findings that hypnosis, at least sometimes, seems to be able to modify processes typically outside of deliberate cognitive control (Polito, Barnier & Conners, 2018; Raz et al., 2006). Comparisons between this study and studies such as Polito et al. (2018) and Raz et al. (2006) are limited by notable differences in the nature of the suggestions given to participants. In the Raz et al.

(2006), Stroop Task a suggestion was made to participants that they should respond accurately to the task and that the words will appear in a foreign language that would seem to participants as if they were "gibberish." In the Hypnotic Clever Hands task, participants were not told to directly respond randomly to the task, but they were advised that their responses "would be neither correct or incorrect" (Polito, Barnier & Conners, 2018). Therefore, in both studies, the suggestion specified not only how they would experience the hypnotic suggestion but also how they will respond to the task while under the hypnotic suggestion. By contrast, in this study, participants were not told to explicitly respond under the hypnotic lift condition in a manner that would interrupt postural control, but it was hoped that the suggestion of alien control would have this effect. A more specific hypnotic suggestion in which participants are not only told that "someone else" would control their arm, but that this "someone else" would lift in a manner whereby they had less control over the arm movement, would have made the structure of the suggestion more similar to the hypnotic suggestion in both Raz et al. (2006) and Polito et al., (2018).

Limitations of Study

One limitation of the study is that the BMLL task implemented here differed from previous versions of BMLL tasks. Previous studies usually involve participants resting the weight on their postural hand rather than directly holding the weight (Ng et al., 2011). In our study, participants were made to hold the weight in their postural hand. While this request made the task more ecologically real, it also meant that the postural adjustments required for participants to perform the task were less controlled. Participants actively holding the weight made measurement of postural responses such as EMG measurements more susceptible to noise created by postural movements that were not part of the more limited reaching movement we were intending to measure. Differences in muscle fatigue (Yiou, Caderby & Hussein, 2012) from extended periods of holding the weight and more subtle differences in the way that participants held the weight, were also more difficult to control as a result of the participants holding the weight. The requirement that participants hold the weight also made the task more physically challenging, which in turn, may have affected hypnotic responsiveness, especially as the number of experimental trials progressed. Some participants reported that physical demands of the task did reduce their feeling of being hypnotised, particularly toward the end of the experimental trials.

The hypnotic procedure in this study was conducted in a physiological science laboratory, and participants were required to sit in an unusual setting with multiple sensors connected to them during the hypnotic induction. This setting is quite different to a typical hypnosis session and may have attenuated hypnotic responsiveness for at least some participants.

Additionally, the kinematic marker used to identify changes in postural control may not have been as sensitive to some more subtle alterations in postural control, such as measures of the amount of postural adjustments required to perform a task effectively or the timing of the postural adjustments (Santarcengelo, 2004; Ng et al., 2013).

Finally, Experiment 2 only used highly hypnotisable participants and future research of a similar nature would benefit from having a design where Highs are matched with a low hypnotisable control group. Similarly, a “waking” versus “hypnotic” design would be beneficial to determine what effects are due to “neutral” hypnosis without suggestion and which effects are due to the specific suggestion. Given that, hypnotic induction of Highs has been shown to reduce motor neural excitability (Santarcangelo et al., 2003), the fact that all participants were subject to hypnotic induction prior to performing the three trial conditions could have reduced the possibility of finding an effect from the specific hypnotic suggestion.

Conclusion and Future Directions

This was the first study to investigate whether a hypnotic suggestion for alien control could also create changes in the co-ordination of postural control of action. In Experiment 1 we identified a kinematic marker of postural control that occurred during a bimanual load lifting task and used this as a marker of agent-related postural control. In experiment 2 we used a hypnotic condition to see if a suggestion of alien control could alter this agent-related kinematic marker of postural control. We also gave participants a series of questions to evaluate factors measuring the level of change in sense of agency during the alien control suggestion. The findings of this study seem to be most supportive of the Dissociated Experience Theory of hypnosis, which claims that hypnosis influences the experience of agency but not necessarily sub-personal control mechanisms. Results showed that while there were clear changes in participants with regards to their judged agency due to the hypnotic suggestion, but this did not seem to be connected with any significant postural changes as measured by goniometer and EMG data. Our findings indicate that some postural control functions remain relatively independent of hypnotically induced changes in beliefs about sense of agency. Future research to determine under what psychological, biological or environmental circumstances hypnotically induced changes in sense of agency may facilitate or inhibit postural control will shed valuable light on the nature of both hypnosis and sense of agency.

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MACQUARIE University
SYDNEY·AUSTRALIA

10 October 2017

Dear Dr Polito

Reference No: 5201700862

Title: *Electrophysiological markers of sense of agency and body ownership*

Thank you for submitting the above application for ethical and scientific review. Your application was considered by the Macquarie University Human Research Ethics Committee (HREC (Medical Sciences)).

I am pleased to advise that ethical and scientific approval has been granted for this project to be conducted at:

- Macquarie University

This research meets the requirements set out in the *National Statement on Ethical Conduct in Human Research* (2007 – Updated May 2015) (the *National Statement*).

Standard Conditions of Approval:

1. Continuing compliance with the requirements of the *National Statement,* which is available at the following website:

http://www.nhmrc.gov.au/book/national-statement-ethical-conduct-human-research

2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol.

3. All adverse events, including events which might affect the continued ethical and scientific acceptability of the project, must be reported to the HREC within 72 hours.

4. Proposed changes to the protocol and associated documents must be submitted to the Committee for approval before implementation.

It is the responsibility of the Chief investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Ethics Secretariat on 9850 4194 or by email ethics.secretariat@mq.edu.au

The HREC (Medical Sciences) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics

The HREC (Medical Sciences) wishes you every success in your research.

Yours sincerely

Professor Tony Eyers
Chair, Macquarie University Human Research Ethics Committee (Medical Sciences)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.

Details of this approval are as follows:

Approval Date: 6 October 2017

The following documentation has been reviewed and approved by the HREC (Medical Sciences):

Documents reviewed	Version no.	Date
Macquarie University Ethics Application Form		Received 28 Aug 2017
Correspondence responding to the issues raised by the HREC (Medical Sciences)		4 Oct 2017
Study notice for Experiments 1 & 3	1*	28 Aug 2017
Recruitment script for Experiment 2	1*	28 Aug 2017
Macquarie Participant Information and Consent Form (PICF) (Sense of Self Scale and APA - for Experiments 1 & 3)	2	4 Oct 2017
Macquarie Participant Information and Consent Form (PICF) (Hypnosis Research - for Experiment 2)	2	4 Oct 2017
Participant Questionnaires including: • Sense of Self Scale	1*	28 Aug 2017

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