THE INTERPLAY BETWEEN BOTTOM-UP AND TOP-DOWN PROCESSES UNDERLYING THE PRE-REFLECTIVE AND REFLECTIVE SENSE OF AGENCY: AN INTEGRATIVE APPROACH

ZEYNEP BARLAS

BOĞAZİÇİ UNIVERSITY

2012

THE INTERPLAY BETWEEN BOTTOM-UP AND TOP-DOWN PROCESSES UNDERLYING THE PRE-REFLECTIVE AND REFLECTIVE SENSE OF AGENCY: AN INTEGRATIVE APPROACH

Thesis submitted to the

Institute for Graduate Studies in the Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Cognitive Science

by

Zeynep Barlas

Boğaziçi University

2012

Thesis Abstract

Zeynep Barlas, "The Interplay between Bottom-up and Top-down Processes Underlying Pre-reflective and Reflective Sense of Agency: An Integrative Approach"

Sense of agency is commonly defined as the sense that one is the author of one's actions and their consequences. The underlying mechanisms have long been ignored until certain disorders and experimental cases proved it necessary to develop an understanding of how we normally experience agency. Two major accounts have been proposed to address this issue. The predictive account underlines the role of intrinsic and sensorimotor cues, whereas the inferential account posits the contribution of extrinsic cues and high level inferences. The present study is an attempt to combine the two views in the light of the integrative approach that accommodates a dynamic relationship between intrinsic and extrinsic cues. We therefore conducted two multi-phased experiments to examine the purported role of multiple cues in both pre-reflective (intentional binding) and reflective (subjective judgments) sense of agency. In Experiment 1, we found that the congruency between subliminal primes (extrinsic cues) and the predictions (intrinsic cues) influenced the intentional binding effect. In Experiment 2, we rendered the source of the action-outcomes ambiguous. The results showed that the consistency between predictions and actual outcomes of an action along with the time interval between actions and outcomes are important determinants of explicit judgments of agency. We conclude that the underlying mechanism of the sense of agency, in both pre-reflective and reflective forms, has a complex nature and operates upon multiple agency cues.

Tez Özeti

Zeynep Barlas, "İçsel ve Dışsal Süreçler Arasındaki Etkileşimin Önceden-yansıtmalı ve Yansıtmalı Eylemlilik Hissi Üzerinde Etkisi: Bütünleyici Bir Yaklaşım"

Eylemlilik hissi genel olarak insanın kendi eylemlerini ve bu eylemlerin sonuçlarını sahiplenmesi olarak tanımlanır. Belirgin bazı bozukluklar ve deneysel durumlar eylemlilik hissini normalde nasıl yaşadığımıza yönelik bir anlayış geliştirilmesini gerekli kılana kadar bu deneyimin altında yatan meknizma önemsenmemiştir. Bu mekanizmayı açıklamak üzere iki ana görüş sunulmuştur. Öngörüsel görüş içsel ve duyusal-motor ipuçlarının rolünün önemini vurgularken, çıkarımsal görüş dışsal ipuçlarının ve üst düzey çıkarımların katkısını öne sürmektedir. Bu çalışma, içsel ve dışsal ipuçları arasındaki dinamik ilişkiyi barındıran bütünleştirici yaklaşım ışığında bu iki görüşü bir araya getirmek üzere bir girişimdir. Buradan yola çıkarak, öne sürülen çoklu ipuçlarının rolünün hem önceden-yansıtmalı (yönelimsel bağlanım) ve yansıtmalı (öznel yargılar) üzerindeki etkisini araştırmak üzere iki çok-aşamalı deney yürüttük. İlk deneyde, bilinçsiz algılanan eşikaltı yönlendiricilerin (dışsal ipuçları) ve eylemin sonuçlarına yönelik öngörülerin (içsel ipuçları) arasındaki uyumluluk durumunun yönelimsel bağlanım üzerinde etkin olduğu gözlenmiştir. İkinci deneyde ise eylemlerin yaratabileceği sonuçların kaynağını belirsiz kıldık. Elde edilen sonuçlar, öngörüler ile bir eylemin sonuçları arasındaki uyumluluğun yanısıra bir eylem ile sonucunun oluşması arasında geçen sürenin öznel yargılar üzerinde önemli belirleyiciler olduğunu gösterdi. Araştırmalarımızın sonuçlarına dayanarak, önceden-yansıtmalı ve yansıtmalı formlarındaki eylemlilik hissinin altında yatan mekanizmanın karmaşık olduğu ve çoklu ipuçları üzerinde işlediği sonucuna vardık.

ACKNOWLEDGMENTS

I am deeply grateful to Dr. Hasan Bahçekapılı and Assist. Prof. Esra Mungan, who have always given a tremendous support to explore my research interests and encouraged me to work on this fascinating topic. Their thoughtful advices on both experimental and theoretical issues have paved my way to complete my research with great motivation and inspiration.

Prof. Stephen Voss has always welcome new perspectives and opened his door for stimulating philosophical discussions. His guidance throughout my research and MA study along has shaped my critical thinking and creativity.

My participation in the Autumn School on "Perception, Action, and Control" has provided me a valuable experience and enriched my scientific vision; many thanks to the organizers from Radbaud University and Donders Institute for Brain and Cognition in Nijmegen. I owe special thanks to Prof. Berna Kılınç for helping me to earn the scholarship that enabled my attendance to the school. I would like to express my gratitude to her and Prof. Fikret Gürgen for kindly accepting to take part in the research committee.

I am sincerely indebted to Assist. Prof. Cenk Erdil, whose professional manner and excellent management skills have given great confidence and relief while carrying out my position at Bilgi University. I would not be able to take the time to conduct my studies smoothly without his gentle tolerance and support.

I would like to thank Prof. Patrick Haggard for his thoughtful comments on the earlier draft of the experiments. I am also grateful to Assoc. Prof. Sukhvinder Obhi who has given extraordinary support throughout the entire process of my research and PhD admission.

Among many others, I am thankful to my friends Aysu Mutlutürk, Turgut Coşkun, and Ergün Koçak for being always there with their warm friendship and patient ears.

I can never thank enough to my sister, Fatoş Barlas, for her perceptive and encouraging attitude toward every step I took in my life. I would not be able to make my dreams come true without her constant and invaluable support in all means.

CONTENTS

CHAPTER I

INTRODUCTION

Agency refers to the capacity to control actions and what these actions cause in the external world (Haggard & Tsakiris, 2009). As this capacity in practice is accompanied with the sense that we are the author of both our actions and their consequences, we experience the sense of agency. In everyday life, the sense we experience when performing actions appears to be beyond the shadow of a doubt. In fact, the stance that sense of agency is unquestionable has long hindered the scientific enquiries from delving into the mechanisms behind it. However, the impoverished conditions observed in anarchic hand syndrome, denial or misattribution of agency in schizophrenia, and recent experimental studies with healthy individuals have betrayed the fallibility of self-agency. More consideration has therefore been given by the psychological and philosophical realms to shed light on the underpinnings of the “Who?” system (Georgieff & Jeannerrod, 1998).

One facet of sense of agency is suggested to rely on causality (e.g. Bayne & Levy, 2006). The causality involved in sense of agency can be of two types. At one level, intentions are perceived to cause the actions and at the second, actions cause some effect in the external world (Frith, 2005). Accordingly, Sebanz and Lackner (2006) suggest that the experience of mental causation and the experience of acting are two different aspects both involved in our experience of agency. The former includes the belief that some conscious intention or will is the origin of acting, whereas the latter refers to the experience while performing an action that produces some effect in the external world.

However, there seems to be more to the phenomenology of agency than a sole ground of causality (Bayne & Levy, 2006). Gallagher (2007), for instance, claims that mere belief causation does not entail the sense of agency unless being the source of actions is consciously available to the actor's sense or knowledge. This conscious sense is part of the immediate subject of instantaneous experiences, which Gallagher (2000) calls the "minimal self". Gallagher (2007) further notes that "the kind of conscious knowledge involved in agency does not have to be of a very high order; it could be simply a matter of a very thin phenomenal awareness, and in most cases it is just that" (p.1). On this view, the subjective experience of agency may occur at both first order (pre-reflective) and higher order (reflective) levels of consciousness. Similarly, Bayne and Pacherie (2007) distinguish between low level (primitive) and high level (interpretive) awareness of agency.

The distinction between different levels of consciousness steers into the question whether sense of agency is originated at the lower level of sensorimotor processes or at a higher level of interpretive mechanisms. In order to address this issue, two main accounts have been proposed. On the one hand, researchers suggest that sense of agency is aroused through a matching process between prior-to-action predictions and the actual events (Frith, Blakemore, & Wolpert, 2000; Blakemore, Wolpert, & Frith, 2002; Frith, 2005; Sato & Yasuda, 2005; Gallagher, 2007). On the other hand, high level interpretive processes have been viewed as the main contributor to how we experience sense of agency (Wegner, 2002; Wegner, 2003; Wegner & Wheatley, 1999). A recently growing approach, however, attempts to integrate both the predictive and inferential accounts (Bayne & Pacherie, 2007; Moore & Haggard, 2008; Moore, Wegner, & Haggard, 2009; Pacherie, 2008; Synofzik, Vosgerau, & Newen, 2008a; Wegner & Sparrow, 2004).

Most of the research testing these accounts has used explicit judgments of the participants in order to measure the sense of agency. These explicit measures most commonly required the subjects to state how much control they felt over the effects (e.g. Balslev, Cole, & Miall, 2007; Ebert & Wegner, 2010; Linser & Goschke, 2007; Metcalfe & Greene, 2007; Sato & Yasuda 2005; Wenke, Fleming, & Haggard, 2010) or their actions (e.g. Wegner, Sparrow, & Winerman, 2004; Sebanz & Lackner, 2007). Alternatively, in ambiguous contexts, they were asked to indicate how much they think they themselves or another potential agent (e.g. confederate, computer) might have caused the effects (e.g. Aarts, Custers, & Marien, 2009; Aarts, Custers, & Wegner, 2005; Dijksterhuis, Preston, Wegner, & Aarts, 2008; Spengler, Cramon, & Brass, 2009; Wegner & Wheatley, 1999).

However, applying only such explicit measures is highly prone to be contaminated by other factors such as performance judgments of the subjects (Metcalfe & Greene, 2007). Alternatively, other methodologies have employed the 'intentional binding' effect as an implicit measure of the sense of agency. As will be explicated further in this chapter, the intentional binding effect refers to the attraction between the perceived times of actions and effects observed in voluntary actions (e.g. Haggard, Clark, & Kalogeras, 2002; Haggard & Clark, 2003; Moore, Wegner, & Haggard; 2009).

In what follows, we review the predictive, inferential, and integrative accounts in more detail and present some of the studies that diverge in their interpretation of the findings. We then move on to the two multi-phased experiments conducted to explore the interplay between intrinsic and extrinsic contributors of pre-reflective (intentional binding) and reflective (subjective judgments) sense of agency.

Based on the results, we argue that the integrative approach that emphasizes the role of both sensorimotor and high level processes is more promising for the quest to understand the nature of sense of agency.

The Predictive Account: The Role of Intrinsic Cues

According to the predictive account (Frith et al., 2000; Blakemore et al., 2002; Frith, 2005; Sato & Yasuda, 2005; Gallagher, 2007) internal predictions produced prior to the actions are compared to the actual outcomes, the result of which is the main contributor to generating the sense of agency. If the internal predictions made before the movement match with the perceived outcomes of the movement then the agency is attributed to the self. On this account, Comparator Model (CM) is one influential model that is based on the computational theory of motor control and motor learning (Wolpert, Ghahramani, & Jordan, 1995; Wolpert, 1997). According to CM, the central nervous system includes two internal models, namely forward and inverse models, which compute the motor commands and sensory feedback in order to achieve a desired state and also improve motor learning (Frith et al., 2000). The main function of the inverse model (also known as controllers) is to produce the appropriate motor command in order to achieve a specific goal. The forward model, also called the predictor, receives the efference copy of the motor command and generates the anticipations toward the consequences of a self-generated action.

As shown in Figure 1, predictors and controllers function along with the comparators between the representations of current and future states. Among these states, the desired state refers to the goal to be accomplished. The predicted state includes the anticipated state of the body and the consequences of a movement. The actual state represents the estimated current state of the body with the limb and muscle positions as well as the sensory feedback from the outcomes of actions. Additionally, there are three comparators in the central nervous system, each serving for the improvement of predictors and controllers. The first comparator checks if the desired state matches the predicted state. In the case of a discrepancy, an error signal is sent back to the controllers so that correct adjustments can be made. Similarly, the comparator between desired state and actual state informs the controllers in the case of a mismatch. Of more interest is the third comparator that computes the discrepancy between predicted state and actual state. The result of this comparison is suggested to have two crucial functions. First, it helps the predictors to improve their functioning in case of a mismatch between predictions and actual outcomes. Second, and more importantly, it allows distinguishing between self and other produced actions. That is, the agency is attributed to the self if there is no discrepancy as a result of the comparison. If the predictions and the outcomes do not match, on the other hand, the agency is attributed to others. In sum, CM suggests that the comparator between the predicted state and actual state takes an important role in attribution of agency to the self or to others (Blakemore et al., 2002; Frith et al., 2000; Frith, 2005; for a critical review see, De Vignemont & Fourneret, 2004; Synofzik et al., 2008a).

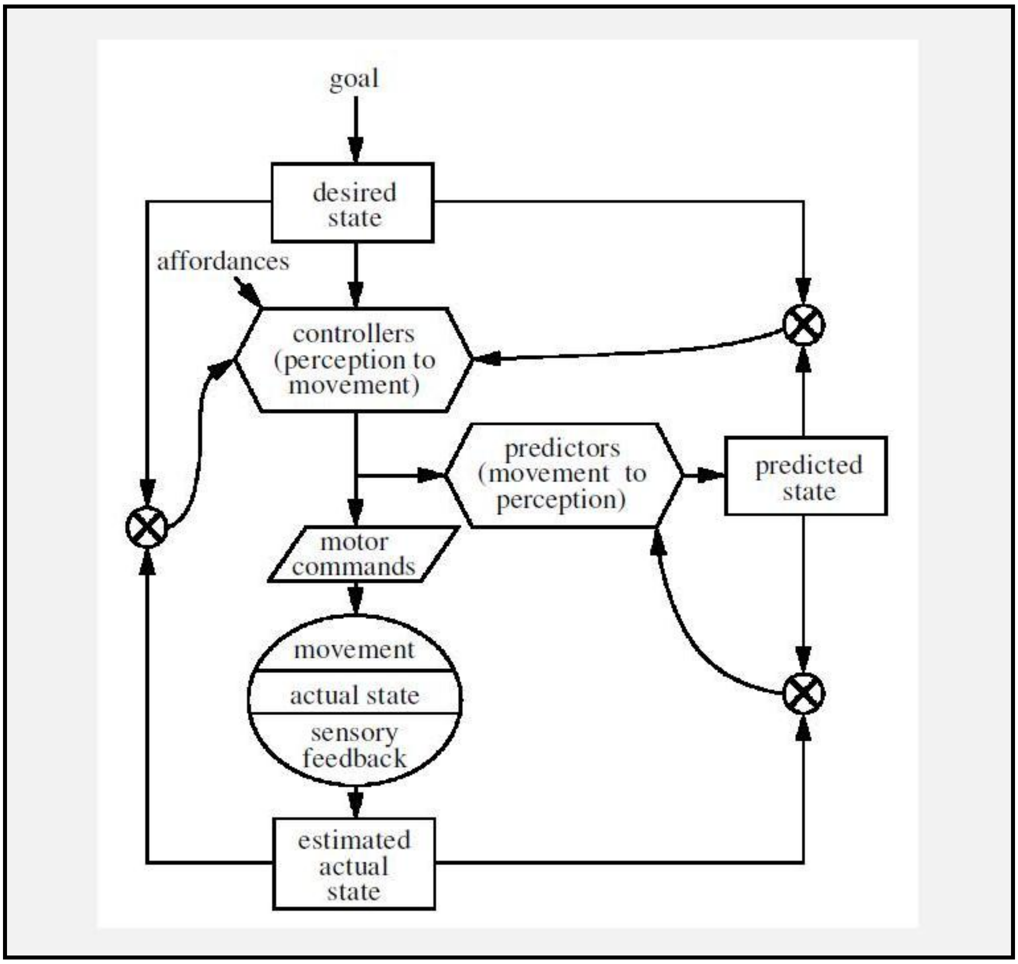


Fig. 1 Comparator model (adapted from Frith et al., 2000)

One line of research probing into CM focused on the comparators between goal, actual, and predicted states. Sato and Yasuda (2005), for example, investigated if the sense of agency is modulated by the forward model which produces the predictions of sensory consequences of actions (Frith et al., 2000). Participants first learned the associations between left and right key press that produced high or low auditory tones. In the experimental phase, the auditory tones produced by the key press were either congruent or incongruent with the learning phase in terms of their frequency and onset times. Participants reported how much they would agree with the statement; “I was the one who produced the tone” (p.6). According to the results, the sense of agency was reduced when the tones were incongruent with those learned in the learning phase and when the timing of auditory stimuli was unpredictable. The following experiment included the "other agency" condition in which timing of the auditory tones matched the learning phase but the tones were produced externally rather than by the participants. As the results showed, participants again rated their being the cause of the tones with higher scores when the tones were congruent and when the delay was shorter under both self-generated and other agency conditions. In the final experiment, participants could make unintended wrong responses which enabled testing the comparator between intention and actual sensory information. It was found that sense of agency was reduced when there was a discrepancy between predicted and sensory outcome whether the intended action matched the actual response or not. Overall results favored the hypothesis that sense of agency depends strongly on the result of comparison between predicted and actual outcomes.

In a similar vein, Linser and Goschke (2007) used subliminal priming of action outcomes to examine the influence of congruency between the anticipated representations of action effects and the sensory feedback from the actual effects. In the first experiment, participants pressed the corresponding key (left or right key) as indicated by the cue stimulus, which in turn produced the display of left or right pointing arrows. Prior to each key press, one of the action effects was subliminally primed by briefly displaying left or right pointing arrows. After each trial, subjects rated on a scale how much control they felt over the effect stimuli. In the second experiment, the effects were semantically primed with the color words and the subjects could freely choose their action which produced unpredictable effects. On the basis of their findings, the authors concluded that both perceptual and semantic primes that are congruent with the actual effects enhanced the experienced sense of agency by strengthening the representations of anticipated effects.

Wenke, Fleming, and Haggard (2010) focused on the impact of the action selection process on sense of agency. In particular, they investigated the effect of subliminal priming on both cued and free-choice actions. In the first experiment, participants were presented with a priming arrow pointing to the right or left and then with masking arrows that directed them to choose pressing the right or the left key. The mask arrows consisted of those pointing to the right or left (in cued-choice trials) or both (in free-choice trials). In cued-choice trials, participants made a key press following the direction of the arrow cue. In others, they were free to choose which key press to make if the cues pointed to both right and left simultaneously. All key presses were followed by the display of a circle, the color of which depended on the compatibility between the priming arrow and the response action. However, the color of the circle was not predictable to the participants. At the end of each trial, participants rated their sense of control over the color effects on a 100 point Likert scale. The overall results showed the response times were faster in the cued-choice trials when the action primes and cues were compatible. Participants' choice of action in the free-choice trials was also found to be biased by the action prime. Finally, the ratings for the feeling of control were higher over the effect colors preceded by prime-compatible actions than that appeared after by prime-incompatible actions. The authors concluded that subliminal priming of actions facilitates the selection process among alternative actions, which in turn increases the feeling of control over the effects of action.

The research reviewed so far highlighted the contribution of internal models by measuring directly the explicit judgments about the sense of agency. Another line of support for the predictive account has emerged presenting a novel method to measure the sense of agency indirectly through the perceived times of actions and effects.

In their seminal study, Haggard et al. (2002) compared the perceived times of actions (key press) and effects (auditory tone) in the baseline and operant conditions. In the baseline condition, subjects fixated on a conventional clock as in Libet's experiment (Libet, Gleason, Wright, & Pearl, 1983) and reported the onset times of four single events: pressing a key at a time of their choice, a TMS (Transcranial Magnetic Stimulation) induced movement, the click heard during sham TMS application, and the auditory tone. In the operant conditions, voluntary and involuntary movements were followed 250 ms later by the auditory tone and subjects were again asked to note the onset times of these events and the auditory tone. The results showed that temporal awareness of voluntary and intentional actions and their effects are bound or attracted together in perceived time. Involuntary movements, on the other hand, yielded a perceptual repulsion in the opposite direction.

The temporal compression they found between perceived times of voluntary actions and effects was termed "intentional binding", which, as the authors state, is produced by a specific cognitive mechanism in the central nervous system. In a second experiment, they included three different delays between the key presses and the tones and also varied the predictability of the onset when the tone occurred. They found that the intentional binding effect was reduced at longer delays and when the tone occurred at an unpredicted time. On the basis of these findings, Haggard et al. (2002) concluded that temporal contiguity and predictability are two important determinants of intentional binding. A more intriguing conclusion made by the authors is that intentional binding can be deployed as an implicit measure of the sense of agency.

Since it was first introduced, intentional binding has sparked great interest in its relationship with the sense of agency and the mechanism that produces this effect. The link between intentional binding in voluntary actions and the predictive processes was supported by the following studies.

Haggard and Clark (2003), for example, investigated if the disruption of intentions would affect the intentional binding effect. In their study, subjects viewed a conventional clock and were asked to make a voluntary key press. In some trials, however, the TMS was preset to stimulate the subject's motor cortex to disrupt the intentional action. Each key press was followed by an auditory tone and subjects judged the onset of either the key presses or the auditory tones. The results showed that there was a perceptual shift reflecting the intentional binding of actions and effects in the voluntary movements. On the other hand, this effect was repulsed in the involuntary (intention disrupted) movements induced by the TMS. Based on their findings, Haggard and Clark (2003) concluded that the intentional binding effect requires not only the intentional preparation but also the completion of action and the match between intention and the action outcome, favoring the role of predictive mechanisms.

The role of intention in intentional binding effect was scrutinized in a further study that sought the impact of inhibiting the intended actions. In this regard, Haggard, Poonian, and Walsh (2009) conducted a study that allowed the comparison of the intentional binding effect when intentional actions are completed and when they are intended but not completed due to self-inhibition. Participants were asked to make a voluntary key press with either their right or left hand, which would produce an auditory tone in low or high frequency, both in congruent and incongruent conditions. In addition, they were asked to cancel their actions in some trials while the inhibited actions were still followed by the auditory tones. In order to measure the binding effect, subjects judged the perceived times of the tones. The results showed that the perceived times of tones were shifted earlier when the intended actions were completed and followed by the tone. However, the shift was in the reversed direction when the intentional actions were endogenously inhibited but still produced the tone. Haggard et al. (2009) concluded that the process of predicting outcomes of action is continuous until the sensory feedback upon the completion of the action is available. Accordingly, this process yields the binding of action and outcomes when it is voluntarily performed. However, a reversal of this binding occurs when the outcome is not predicted or predicted not to happen when actions are inhibited.

A more recent study as an additional support to the compelling link between intentional binding and sense of agency showed that the causal beliefs regarding the source of the actions were also influential on the binding effect (Desantis, Roussel, & Waszak, 2011; see also Moore & Obhi, 2012 for a review and discussion of intentional binding research).

The Inferential Account: The Role of Extrinsic Cues

> Believing that our conscious thoughts cause our actions is an error based on the illusory experience of will- much like believing that a rabbit has indeed popped out of an empty hat (Wegner & Wheatley, 1999, p. 490).

The inferential account holds the view that the sense of agency results from the retrospective inference that we make relying on our perception of causal relationships. According to Wegner (2002), the interpretation of causal relationships leads us to the illusory belief that our conscious intentions are the cause of our actions and their consequences. It is illusory in the sense that our conscious will and actions might be produced by other thoughts or processes that we are not aware of. We experience the illusion of being the origin of our actions since we infer the causal paths between only the events that are perceivable to us.

In this regard, Wegner and Wheatley (1999) proposed a theory that was based on the Humean analysis of perception of causality. On this analysis (Hume, 1888), contiguity and consistency are the basis of inferred causal relations between events (actions) and outcomes (effects). According to the so called 'apparent mental causation' theory, thus, we experience conscious will when priority, consistency, and exclusivity principles are met concerning the thoughts and actions. Priority implies that thoughts must occur before or at the same time with the effects. Consistency requires the prior thoughts about the goals or actions to match with the actual events. Exclusivity principle holds that there should be no other agents that potentially may cause the effect (Wegner & Wheatley, 1999; Wegner, 2003).

In defense of the apparent mental causation theory, Wegner and Wheatley (1999) conducted an experiment by rendering the exclusivity principle ambiguous. In their study, the participant and the confederate placed their fingers on the same board that was mounted upon a mouse. The circular movements on the board caused the cursor to travel across pictures of objects (e.g. swan, car) displayed on the screen. They were told to stop moving their finger at around every 30 seconds. Through the headphones, they also received music and words (e.g. swan) serving to cause thoughts about the pictured items on the screen. In some trials, the experimenter told the confederate to make the stop on the object that was primed to the participants. In this way, the participants would be fooled to believe that they themselves made the stop. In other trials, the confederate was not instructed so that the participant could actually make the stop. After each stop, participants indicated the degree they felt they were the cause of the stops. The results showed that even if it was the confederate that actually made the stops, participants inferred a false sense of agency when the prime words were consistent with the effects and when they were presented 5 or 1 s before making the stops. Although Wegner and Wheatley's (1999) study cannot vindicate the view that conscious will thoroughly is an illusion, they suggest the fallibility of self-agency.

In an attempt to test the priority and consistency principles, Aarts et al. (2005) asked the participants to stop the movements of two grey squares that traversed in opposite directions. Once the subjects saw the stop sign, they had to press a key to stop the movement of the square. The key press would then turn one of the grey squares black, representing the final location where it stopped. On the participants' belief, stopping the square could be caused by either the computer or the participant. However, the location of the square in reality was always determined by the computer. In some trials, participants were primed with the position of the square before they stopped the movement. In the subliminal priming condition, the position was briefly presented, whereas in the supraliminal priming condition participants were explicitly given the goal to stop the square on a certain location. The results showed that both subliminal and supraliminal priming of the position enhanced the participants' feeling of causing the squares to stop. Aarts et al. (2005) concluded that having merely prior and consistent thoughts about the effects may lead one feel as the causal origin of these effects.

Similarly, Ebert and Wegner (2010) tested the effect of the consistency principle on both intentional binding and explicit reports of sense of agency. In their study, participants saw pictures of objects on the computer screen and were asked to push or pull the joystick according to their choice. The direction of the joystick movement would result in either consistent or inconsistent movement of the object. Participants gave their estimation of the time elapsed between the action (pushing and pulling the joystick) and the movement of the picture (forward or backward). They also rated how much they felt in control of the movements of the object. With respect to the intentional binding effect, it was found that the perceived delays between joystick and picture movements were significantly shorter for the consistent trials. In addition, subjects' ratings for the authorship over the consistent movements were significantly higher than the inconsistent ones. These results suggested that action-event consistency can affect both implicit (intentional binding) and explicit (self-reported authorship) measures of agency.

To recap, as opposed to the predictive account that admits the role of intrinsic cues available in the internal models (Blakemore et al., 2002; Frith et al., 2000; Wolpert, 1997), the inferential account emphasizes the contribution of higher level interpretive processes that operate on the extrinsic and situational cues.

The Integrative Approach

Rather than favoring one view over the other, what can alternatively be inferred from the aforementioned studies is that both predictive and inferential processes might contribute to the sense of agency. Accordingly, the recent approach to understand the complex nature of sense of agency attempts to formulate a dynamic relationship between predictive and inferential processes (e.g. Bayne & Pacherie, 2007; Moore & Haggard, 2008; Moore et al., 2009; Pacherie, 2008; Synofzik et al., 2008a; Wegner & Sparrow, 2004). For instance, the two-level account of sense of agency suggests that sense of agency is determined by the dynamic interaction of bottom-up (sensorimotor) and top-down (beliefs, context) cues (Synofzik et al., 2008a). On a lower level, CM serves to generate the feeling of agency by comparing the internal predictions of action consequences and the sensory feedback. On a higher conceptual and meta-representational level, feeling of agency is further processed together with the contextual cues, rational thoughts, and beliefs to form the judgment of agency (see also Synofzik et al., 2008b). In this view, the extent to which feeling and judgment of agency contribute to the sense of agency depends on the context. In everyday life, one may not always need to make inferences or form causal beliefs to experience the sense of agency. If I am alone in the room and switch on the light, for example, my feeling of agency would be so pervasive that I may not even need to enquire into the causal source. In more ambiguous situations, however, the judgment of agency might be at work to attribute the agency either to the self or the others by making inferences from the action relevant external cues. In this case, judgment of agency may even override the feeling of agency. In Wegner and Wheatley's (1999) study, for example, participants seem to have relied more likely on the consistency between the induced prior thoughts and actual effects when they falsely attributed the agency to themselves.

In an attempt to investigate the link between predictive and inferential processes, Moore and Haggard (2008) conducted a study by manipulating the probability of action-effects to occur. In their study, participants were asked to press a key which sometimes produced an auditory tone. They also viewed a conventional clock and reported the onset time of either their key press or the auditory tone when present. The probability of the action to cause the effect was either 75% or 50% under different conditions. According to the results, the "action-only" trials revealed the binding effect when the probability of the effect to occur was higher (75%), which indicated the role of predictive processes. When this probability was lower (50%), on the other hand, the "action + tone" trials revealed a binding effect as well, which can be ascribed to the contribution of inferential processes. Moore and Haggard (2008) thus concluded that depending on the context, both predictive and inferential processes can dynamically contribute to sense of agency.

In another study, Moore et al. (2009) found that supraliminal priming of action-effects had a stronger binding effect on involuntary movements than on voluntary movements. Their finding suggested that when intrinsic cues such as motor commands are absent as in involuntary movements, the impact of extrinsic cues such as the effect primes was more pronounced on the implicit measure of sense of agency. However, as the internal motor cues are already present in voluntary movements, the external cues were less influential than in involuntary movements.

Although the integrative account has not yet bestowed a full-blown theory of how and to what extent these processes are combined to produce the sense of agency, accumulating research on this approach appears more promising and tenable.

Present Study

The goal of the current study is to test the assumption of the integrative approach which dwells on the view that both predictive and inferential processes can modulate the sense of agency. In particular, we aimed at exploring the effect of manipulating the extrinsic cues on both implicit (intentional binding) and explicit (subjective judgment) measures of the sense of agency when the effects produced by the actions were well learned and predicted. Hence the intrinsic cues were also present.

Two experiments were conducted to scrutinize the influence of a comprehensive set of factors on the intentional binding effect and the subjective judgments of self-agency. The factors we manipulated consisted of action relevant unconscious percepts, temporal distance between actions and their consequences, and causal beliefs regarding the source of the action-effects. The first experiment examined the effect of subliminal priming (unconscious percepts) and the prime-response congruency on the perceived delays between actions and effects, whereas the second experiment investigated this effect on the subjective judgment of self-agency in an agentive-ambiguous context.

In both experiments, participants performed a computer task in which pressing one of two keys (circle and triangle keys) caused an effect on the screen (i.e. left or right movement of a blue square). The experiments were conducted through learning, time estimation training (only in Experiment 1), test, and experimental phases. In order to complete these phases, participants came to the laboratory on two consecutive days.

The learning phase was designed for the subjects to acquire the associations between two actions (circle and triangle key press) and two effects (right or left movement of the square). We assumed that the acquisition of action-effect relationships would enable the representations of predictions, or the intrinsic cues, produced by the forward model (Frith et al., 2000; Blakemore et al., 2002; Wolpert, 1995; Wolpert et al., 1997). Subjects also underwent the test phase to ensure that the action-effect associations were consolidated. The time estimation training administered in Experiment 1 prepared the participants to give temporal judgments in the experimental phase. Finally, in the experimental phase, subjects were subliminally primed with representative images of either actions or effects before the voluntary actions were taken.

Previous studies have found that subliminal effect primes can modulate judgments of agency (e.g. Aarts et al., 2005, 2009; Linser & Goschke, 2007). Moreover, the influence of supraliminal priming on intentional binding was explored including the effect primes (e.g. Moore et al., 2009). In accordance with Moore et al.'s (2009) study, we considered that the action and effect primes served as the unconscious extrinsic cues. We thus presumed that these extrinsic cues should affect the sense of agency through their act of distorting or strengthening the representations of predictions (i.e. the intrinsic cues) produced by the forward model.

In Experiment 1, we measured the estimations of the temporal interval between actions and effects. In Experiment 2, subjects believed that the source of the effects could either be themselves or the computer and reported on a scale how much they felt their actions caused the effects. Our expectation was that the congruent primes (i.e. when the primes were consistent with the subjects' responses or with the internal predictions) would enhance the sense of agency while the incongruent ones would have a reducing effect, which would be reflected on both implicit and explicit measures obtained in the two experiments.

CHAPTER II

EXPERIMENT 1

Experiment 1 examined the effect of subliminal priming on the perceived durations between actions and effects. On the first day, participants performed the learning phase to acquire the action-effect relationships and went through a training session to improve the ability of estimating durations between 50 and 1000 ms. On the second day, a briefer version of the learning phase took place to consolidate the previously acquired action-effect mappings. Afterwards, participants performed the test phase and depending on their performance, they repeated the time estimation training before proceeding to the experimental phase (see Fig. 2).

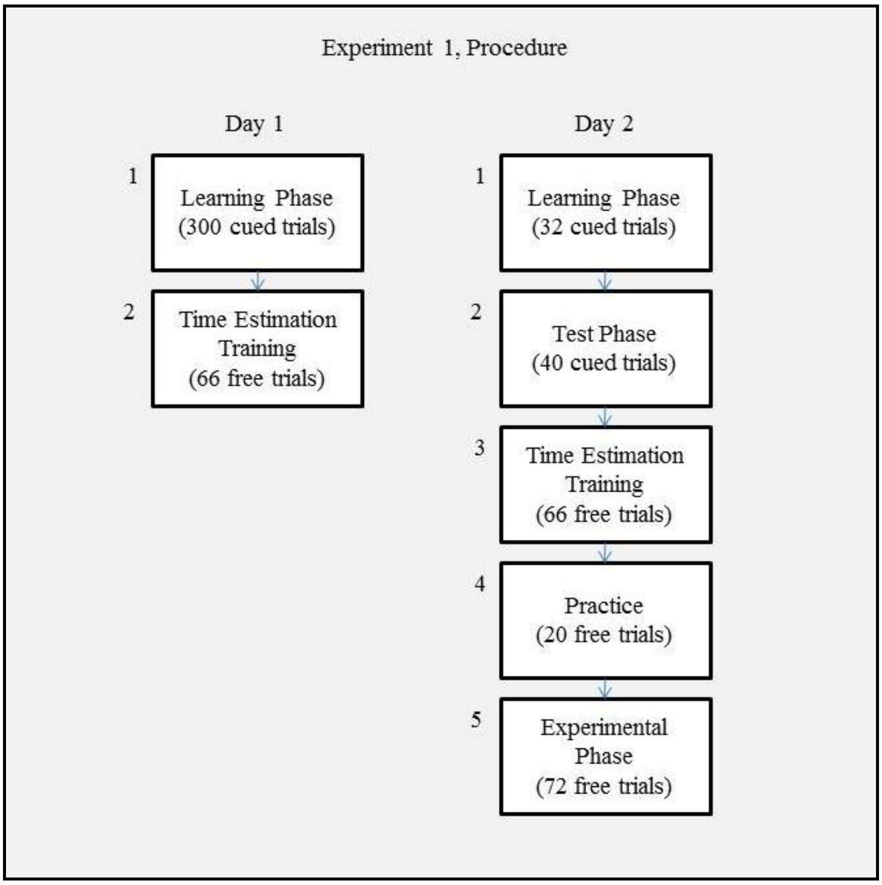


Fig. 2 The procedure in Experiment 1.

Method

Participants

Sixty-one undergraduate students (45 female, 16 male: Mean Age=20, *SD*=3.03) from Bogazici University participated in the experiment. All participants had normal or corrected-to-normal vision and were native Turkish speakers. They gave written consent prior to all sessions and received 2 course credits in return for their participation. The study was approved by the Research Ethics Board of Boğaziçi University.

Apparatus

All of the phases of Experiment 1 were developed on E-Prime Software (Version 1.2, Psychology Software Tools, Inc) and ran on the computer with an Intel Core 2 Duo processor, ATI Radeon X300/X550/X1050 Series graphics card, and a 17-inch color CRT Philips 107S6 monitor. All the tasks were run at 1024 X 768 pixels resolution at an 85 Hz refresh rate. Participants sat in front of the computer at an approximately 75 cm distance and used the keyboard, mouse, and the earphones during the experiment.

Procedure

Day 1

Upon their entrance at the laboratory, subjects were welcomed and briefly informed about the progression of the experiment. After the experimenter introduced the definition of the sense of agency, participants were told that the current study aimed at exploring how people report their subjective temporal judgments regarding the time delay between their actions and the outcomes of these actions. Although not in technical details, it was also noted that subjective temporal judgments could implicitly reflect their sense of agency.

Learning phase

In the learning phase, subjects were expected to acquire the associations between two actions and two effects. The actions consisted of pressing the circle or triangle keys which were respectively replaced with the “s” and “r” keys on a standard keyboard. The effects were the left or right movement of a blue square centered on the screen. The mapping between the two actions (pressing the circle or triangle key) and the movement effects (right or left) was counterbalanced across participants. It was previously shown that action-effect relationships can readily be learned after 300 trials (e.g. Elsner & Hommel, 2001, Spengler et al., 2009). The learning phase on day 1 thus included three blocks of 100 cued trials each. Between blocks, there were 2-minute breaks during which subjects were prompted to wait until the next block started.

Each trial in the learning phase was initiated with the fixation cross that remained on the screen for 500 ms and was followed by the display of the blue square below which one of the four cues (i.e. triangle, circle, right pointing arrow, and left pointing arrow) was presented. The circle and triangle cues represented the actions that instructed which key to press. The arrows, on the other hand, referred to the movement direction of the blue square and subjects were asked to press the appropriate key that would produce the cued effect. The response time window on these cued trials was set to 2000 ms. Should they press an incorrect key or exceed the time window, they received a negative feedback on the screen (i.e. “Incorrect response” or “Late response”, respectively). Correct and timely responses resulted in the display of the blue square with its new location at either the right or left side of the screen. The delay between the key press and the movement was set constant to 500 ms and the effect remained on the screen for 500 ms, which was then followed by a 1000 ms inter-trial interval (see Fig. 3).

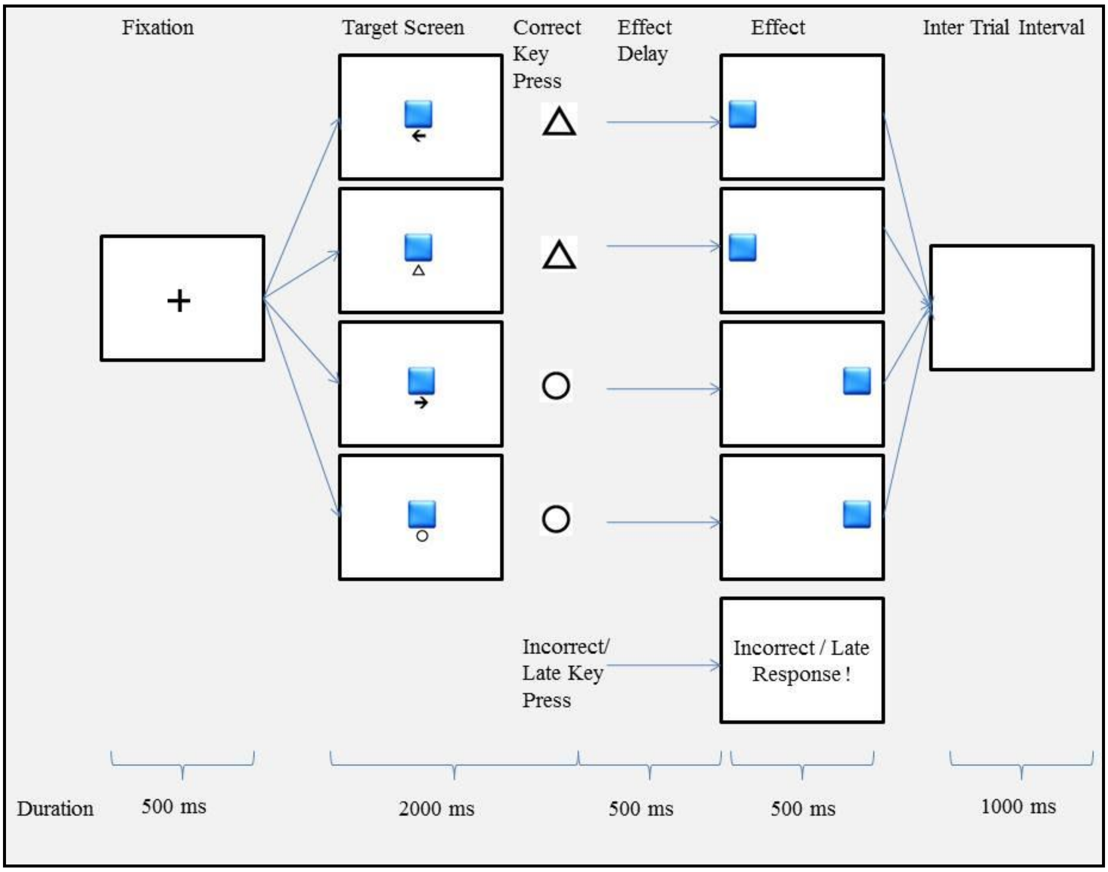


Fig. 3 Illustration of a sample trial in the learning phase.

<u>Time Estimation Training</u>

The goal of the time estimation training was to facilitate the task in the experimental phase in which participants were to give an estimation of the time elapsed between the key press and the movement of the square. The time estimation training consisted of 66 free-choice trials on which subjects were asked to press either the circle or the triangle key to move the blue square on the screen and report the delay between the key press and the movement.

Each trial was initiated with the fixation cross displayed for 500 ms and followed by the response screen. On the response screen, the blue square appeared alone without the cues and the subjects were at their own will to press either the circle or the triangle key with their left hand. Consistent with the previously learned action-effect mapping, the key press moved the square either to the right or left after a delay between 50 ms and 1000 ms. After the delay, a short beep sound was given through the earphones as the square moved on the screen. In this way, subjects could have both visual and auditory cues to perceive the timing of the movement. At the end of each trial, subjects were asked to report an estimation of the delay between key press and the movement on a time scale ranged between 0 ms and 1000 ms. Upon their response, a feedback screen was displayed for 2000 ms to reflect upon the accuracy of their time estimation (see Fig. 4). Estimations within +/- 20 ms range of the actual duration were regarded as the correct response and the feedback screen informed accordingly (i.e. Correct!). Otherwise, the actual duration was displayed together with the message that indicated that the estimation was wrong (e.g. Incorrect! Actual Delay: 200 ms).

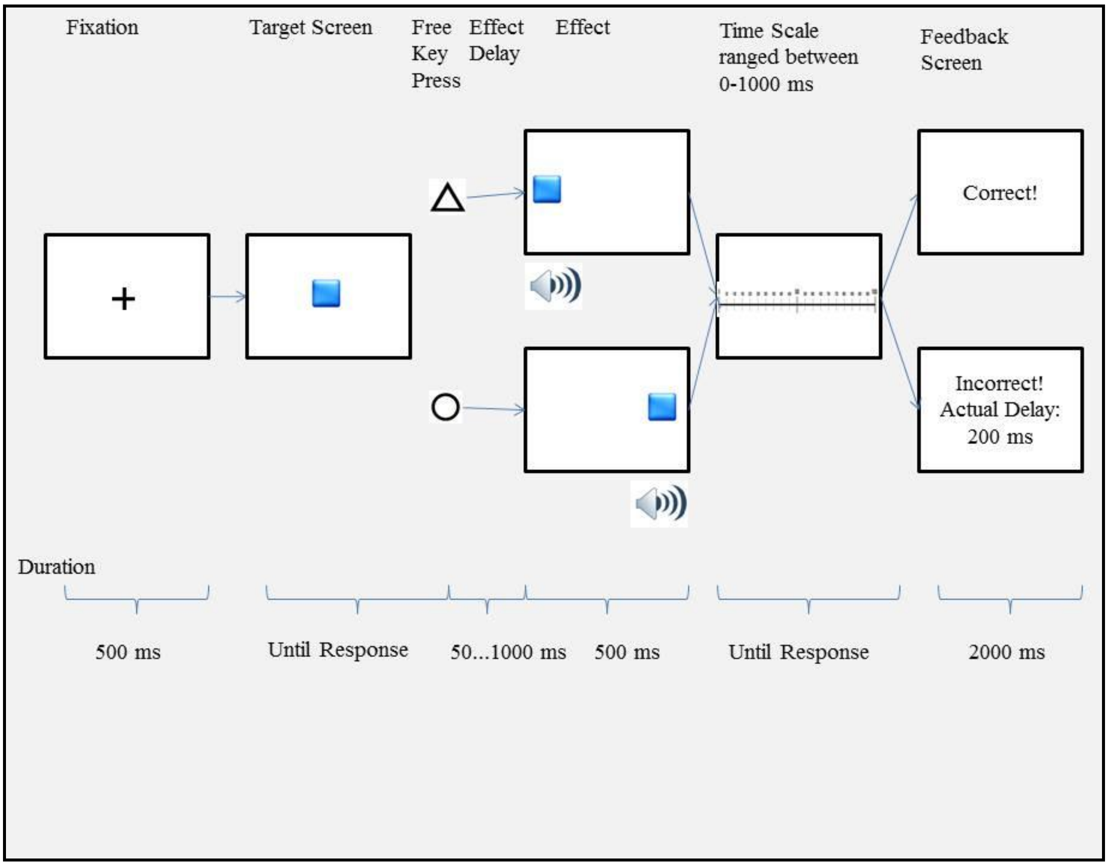


Fig. 4 Illustration of a sample trial in the time estimation training

Day 2

On the second day, subjects first repeated a shorter version of the learning phase with 32 trials in order to consolidate the action-effect mapping. This was then followed by the test, time estimation training (repeated), and experimental phases.

Test Phase

The goal of the test phase was to make sure that participants had readily learned the relationships between actions and effects. The setting in the test phase was the same as in the learning phase except that the response window was set to 1500 ms and the performance of the subjects was evaluated upon the completion of 40 trials. Accordingly, participants having performed less than 90 percent of correct responses were intended to be excluded from further experimentation. Prior to the experimental phase, participants who successfully completed the test phase repeated the time estimation training with 66 trials.

Experimental Phase

In the experimental phase, subjects were told that the time elapsed between the two events (i.e. key press and the movement of the square) can be any delay between 50 ms and 1000 ms. In reality, however, there were only three different delays at 100, 400, and 700 ms. The reason why these delays were unknown to the subjects was to make the subjects pay more attention to the delay between actions and effects so as to avoid reporting regularized estimates of time and not to rely on temporal predictability (Haggard et al., 2002).

After they received the instructions and completed a set of 20 practice trials, participants performed 3 blocks of 24 trials each. Each trial was initiated with a fixation cross for 500 ms and followed by the 23 ms display of a prime image that pertained to one of two actions (circle, triangle) or two effects (right pointing arrow, left pointing arrow). A neutral mask image immediately followed the prime and displayed for 250 ms. The response screen then appeared with the blue square centered on the screen, requiring the subjects to use their left hand to press freely either the circle or the triangle key as fast as possible. Depending on the subject's response and compatible with the previously learned mapping, the square moved either right or left after one of three different delays (100, 400, 700 ms). In addition, subjects heard a short beep sound at the time the square moved to its new position. The effect screen was presented for 500 ms and was followed by the time scale ranged between 0 ms and 1000 ms. Subjects used the mouse with their right hand to indicate their estimate of duration between the key press and the movement of the blue square. Their response was then followed by the blank screen serving as the 1500 ms inter-trial interval (see Fig. 5).

After subjects completed the experimental blocks, they filled out the demographic questionnaire and were debriefed. Finally, in order to test awareness of the primes, they were asked whether they had seen or noticed anything other than the fixation cross, blue square, and the time scale on the screen. Their responses indicated that 89% of the participants had noticed the mask image only and they found it non-distracting. The remaining 11% did not recall the presence of the mask image and none of the participants reported being aware of the prime images.

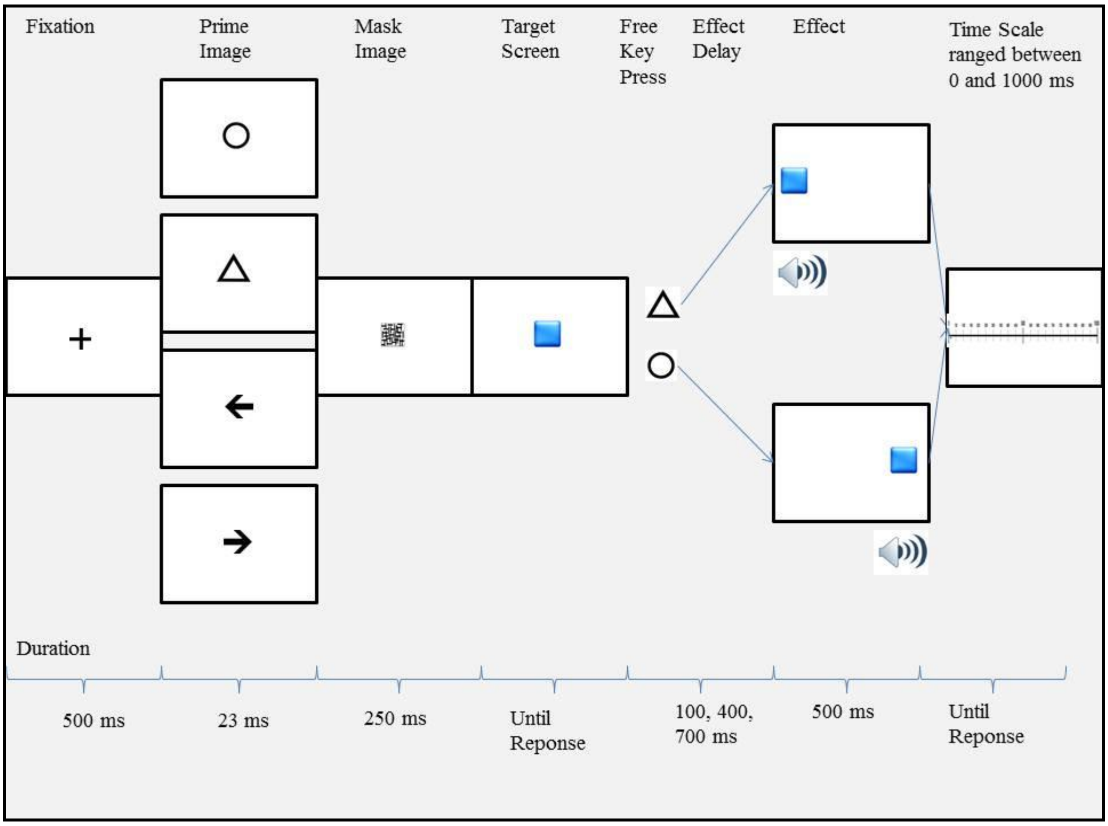


Fig. 5 Illustration of a sample trial in the experimental phase. The inter-trial interval is set to 1500 ms.

Results

All subjects finished the training phase with a correct response rate of at least 90% over all trials. The mean performance of the subjects was 97.7% (*SD* = 2.38) and we therefore included the data of all subjects (N=61) in the experimental analyses. Only the trials with response times of two standard deviations above the mean were excluded from the data.

<u>Bias in the action selection</u>

We analyzed whether the subliminally primed images of actions and effects biased the subjects' free choice of actions. For the action primes, we found that subjects performed the primed actions on 49% of all trials (*SD* = 7.58). For the effect primes, the percentage of performing effect compatible actions was 51% (Table 1). We ran one sample t tests to compare the observed percentage of choosing prime-consistent actions to the chance level (i.e. 50%). The tests for both action and effect primes revealed that the difference was not significant (all *ps* >.05). In addition, paired samples t test showed that the difference between action and effect primes in their effect on action selection was not significant (*p*>.05).

Table 1 Statistical Data Representing Ratio of Choosing Prime-Consistent Actions as a Function of Prime Type

Prime Type	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	61	31.43	70.59	48.82	.97	7.58
Effect	61	37.14	72.22	51.02	1.00	7.82

Perceived Durations as an Implicit Measure of Sense of Agency

We conducted a 2(Prime Type: Action, Effect) x 2(Prime-Response Congruency: Congruent, Incongruent) x 3(Action-Effect Interval: 100 ms, 400 ms, 700 ms) repeated measures ANOVA to investigate the differences in the perceived intervals between actions and effects as an implicit measure of sense of agency. Since all experimental blocks consisted of free-choice trials, congruency between the subliminal primes and the actual responses was recorded by an E-prime software during the experiment. The test yielded that the main effects of prime type (F(1,59 = .89), $p > .05$) and congruency ($F(1,59) = .23$, $p > .05$) were not statistically significant. However, we found a significant main effect of action-effect interval ($F(2,118) = 473.37$, $MSe = 32701.80$, $partial\text{-}\eta^2 = .89$, $p < .001$), showing that as action-effect intervals increased, participants' perceived durations increased as well. The interactions between the factors, on the other hand, failed to reach significance (all ps >.05).

Table 2 Statistical Data Representing Perceived Durations as a Function of Prime Type, Congruency, and Interval Conditions

Prime Type	Prime-Response Congruency	Action-Effect Interval	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	Congruent	100	61	57.00	504.83	192.43	12.49	97,55
	Incongruent	100	61	54.80	502.50	195.65	16.24	126.83
	Congruent	400	61	97.25	832.00	440.89	15.58	121.65
	Incongruent	400	61	147.67	775.33	427.15	14.32	111.86
	Congruent	700	61	300.00	970.14	704.79	19.84	154.96
	Incongruent	700	60	351.29	1000.00	706.73	18.34	142.05
Effect	Congruent	100	61	54.63	429.00	188.40	11.91	93.04
	Incongruent	100	61	39.25	600.00	210.82	15.39	120.23
	Congruent	400	61	118.60	700.00	426.87	14.74	115.15
	Incongruent	400	61	174.50	675.00	406.42	15.59	121.75
	Congruent	700	61	269.60	937.75	687.59	20.08	156.84
	Incongruent	700	61	137.00	1000.00	710.49	21.88	170.86

We ran paired samples t tests to further investigate the effect of priming and congruency at all levels of interval. The analysis revealed that perceived durations were significantly lower in congruent trials than the incongruent trials in the effect prime condition at the 100 ms level ($t(60)=-2.33$, $p<0.05$). All other paired samples t tests between congruent and incongruent trials across action-effect intervals and for both action and effect prime conditions turned out nonsignificant (see Fig.6 & Fig.7).

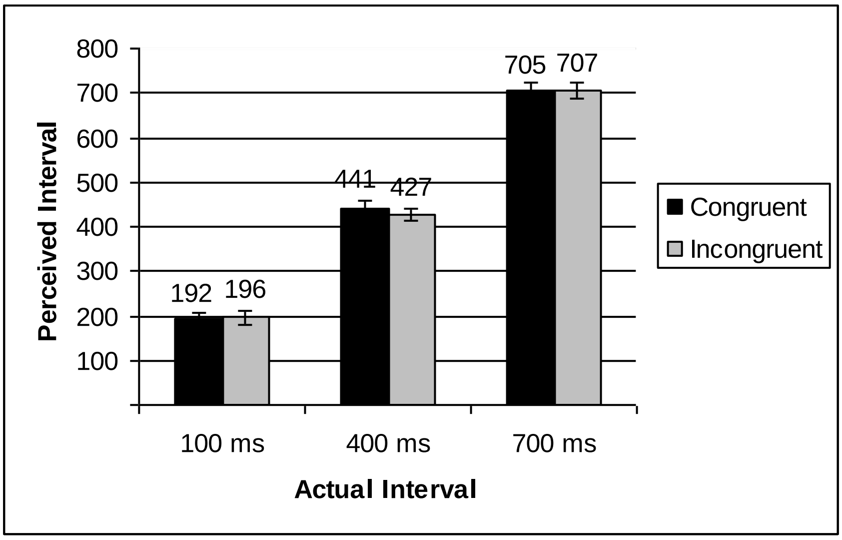


Fig. 6 Mean perceived durations and standard errors as a function of prime-response congruency and actual interval in the action-prime condition.

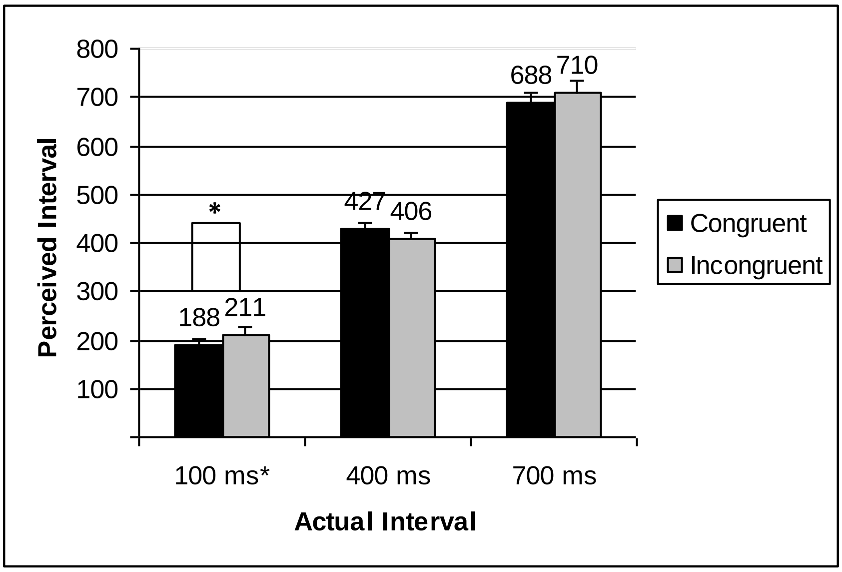


Fig. 7 Mean perceived durations and standard errors as a function of prime-response congruency and actual interval in the effect-prime condition (* $p<.05$).

Response Times

A 2 (Prime Type: Action, Effect) x 2 (Prime-Response Congruency: Congruent, Incongruent) repeated measures ANOVA on response times did not yield any significant main effects (all *p*s >.05), as can be seen in Figure 8.

Table 3 Statistical Data Representing Response Times as a Function of Prime Type and Congruency Condition

Prime Type	Prime-Response Congruency	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	Congruent	61	181.13	831.00	448.00	18.49	144.38
	Incongruent	61	171.13	994.44	448.30	20.91	163.30
Effect	Congruent	61	231.07	977.41	452.67	17.87	139.57
	Incongruent	61	160.43	892.36	449.90	19.77	154.41

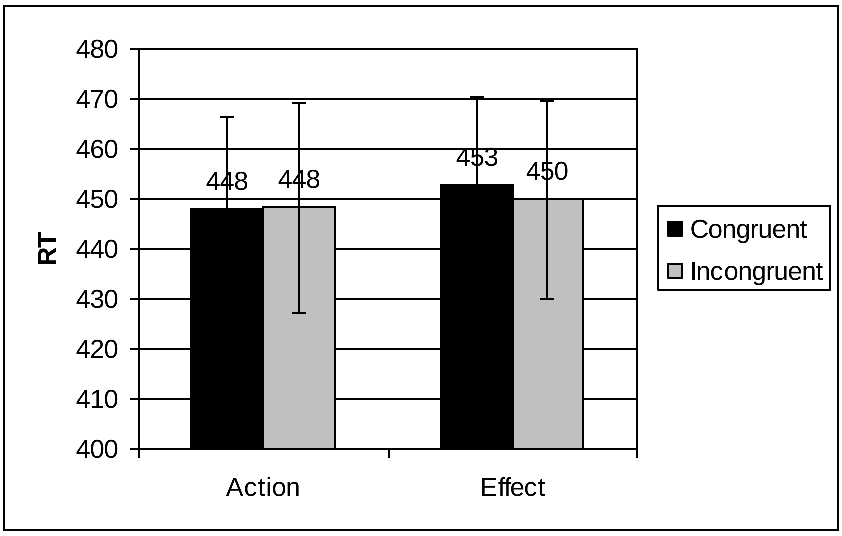


Fig. 8 Mean response times and standard errors as a function of prime-response congruency in the action-prime and effect-prime conditions.

Discussion

Since it was first presented, the intentional binding effect has been purported to be an implicit measure of the sense of agency (Moore et al., 2009; Moore & Haggard, 2010). Although the mechanism behind the intentional binding and its exact relationship with the sense of agency has not been fully unraveled, the involvement of efferent information and the predictive processes (Haggard & Clark, 2003; Tsakiris & Haggard, 2003) suggest a parsimonious explanation of how intentional binding can implicitly reflect the sense of agency. As mentioned before, the two level account of sense of agency (Synofzik et al., 2008a) embodied in the integrative approach points out the contribution of internal motor processes to the low-level (pre-reflective) sense of agency. In this context, it is feasible to suggest a parallel between intentional binding and pre-reflective sense of agency. Experiment 1 therefore targeted the determinants of the intentional binding as the index of low level sense of agency. In the particular quest to present evidence for the integrative account, we sought whether the internal predictions per se are the main contributor of the intentional binding or the externally induced unconscious percepts relevant to these predictions could also influence the pre-reflective sense of agency.

To reiterate our hypothesis, we expected that the perceived durations between actions and outcomes would be shorter when the primes and the actual responses were consistent compared to when they were not. The results supported this hypothesis in the effect-prime condition at 100 ms interval. That is, subjects perceived the 100 ms interval to be significantly shorter when their voluntary actions were compatible with the effect primes. In other words, the unconscious percepts of their intentions strengthened the perceived binding of action and effect onsets. The reason why the prime congruency affected the intentional binding might be explained by the time sequence of the forward model producing the prediction and the unconscious perception of the primes. One possibility is that the prediction of the consequence of an action was activated before the subliminal perception. In this case, the unconscious percepts that are either matching or inconsistent with the predictions could have affected the strength of the predictions. The stronger the predictions the more salient was the binding effect, as reflected by the briefer durations reported with the congruent effect primes. When the primes were conflicting with the predictions, on the other hand, the perceived duration between the action and outcome onsets exhibited repulsion due to the distortion over the predictions, which caused the weakening of the intentional binding effect. Another conceivable cause is that the timing of the subliminal primes preceded the prediction formation and played their role further in biasing the action selection. According to the results the ratio of selecting the effect congruent action is, although not significantly, above the chance level (i.e. 50%). We therefore speculate that the priming might have smoothed the action selection process which in turn influenced the binding effect (Wenke et al., 2010).

Nonetheless, we did not observe the same significant effect of prime-response congruency at longer intervals (400 ms and 700 ms) with effect primes. Based on the previous findings, we suggest two reasons that might have caused the absence of the priming effect. Haggard et al. (2002), for instance, compared the intentional binding effect at three different intervals (250 ms, 450 ms, 650 ms) and concluded that the effect was relatively weaker at longer action-effect durations. This finding might help us explain why our analysis did not reveal a difference between effect congruent and effect incongruent primes at 400 ms and 700 ms intervals. To be clear, if the binding effect itself has become weaker at 400 ms and 700 ms then it naturally is unlikely to observe a significant effect of prime congruency. Another cause might reside in the concern for how long the effect primes could be operative. That is, the activation of the representations that the subliminal primes have invoked might have decayed progressively from the onset of the primes to the response screen to which subjects made time estimations. In fact, there are a few studies that support this speculation. Aarts et al. (2009), for example, compared the subliminal priming effect of goal relevant words on the subjective judgments of agency at 1 s and 20 s time lags and the priming effect was observed only when the duration between prime onset and the target object was 1 s. Furthermore, even when the primes were supraliminal as employed by Moore et al. (2009), the perceived durations were found to be shorter if the primes were presented 1 s before the actions than at a longer lag. Having then a closer look at the durations between prime onset and interval estimations in our study, we note that the average lag is approximately 2 s (250 ms: mask display, 495 ms: response to move the square, 100/400/700 ms: action-effect interval, 500 ms: effect display, 670 ms : response to time estimation) when the action-effect interval is 100 ms. As the interval was longer at 400 ms and 700 ms, the lag became nearly 3 s, which leads us to presume that the strength of the prime representations diminished by then. Should the primes be no longer active at the time when subjects made interval estimations; it is reasonable that their congruency with the actual responses has not affected the intentional binding.

The interpretation we covered so far has been concerned with the effect primes and their influence on the intentional binding. Another important issue that requires careful assessment is that congruency of the action primes had no role in the perceived durations. We in fact expected that both action and effect primes could be saliently effective through their congruency with the actual responses. As mentioned earlier, our expectation relied on the assumption that the primes would engage in modulating the strength of the predictions. One way to address why the results have not fully met our expectations could be due to the distinctive nature of the action and effect primes. Specifically, the effect primes targeted directly the representations of the consequences of the actions and thus were more likely to be effective via their congruency. Action primes, on the other hand, would be influential on the predictions provided that they also caused a second order activation of the associated outcomes. In this sense, action priming was an indirect way to manipulate the activation strength of the predictions produced by the forward model. At this point the question is whether the action primes could evoke the associated effect representations or not. Since the action primes were not found to have influenced the binding as much as the effect primes did, either the associated representations were not evoked at all or they were not salient enough to distort or strengthen the predictions.

In sum, our first study showed that subliminal primes serving as the external cues could affect the implicit measure of sense of agency by modulating the strength of internal or motor cues produced by the forward model. In accordance with our expectation, the intentional binding effect was stronger when the predictions and the primes matched, suggesting that the representations of the predictions are vulnerable to the externally induced effect of the primes. As discussed above, however, the prime type and the action-effect interval play important roles in this relationship between internal and external cues.

CHAPTER III

EXPERIMENT 2

Experiment 2 investigated the impact of subliminal priming on the subjective judgments of self-agency when the source of the effects was rendered ambiguous. On the first day, participants performed the learning phase to acquire the action-effect relationships as in Experiment 1. On the second day, a briefer version of the learning phase took place to consolidate the previously acquired action-effect mappings. Afterwards, participants performed the test phase and depending on their performance, they proceeded to the experimental phase (see Fig. 9).

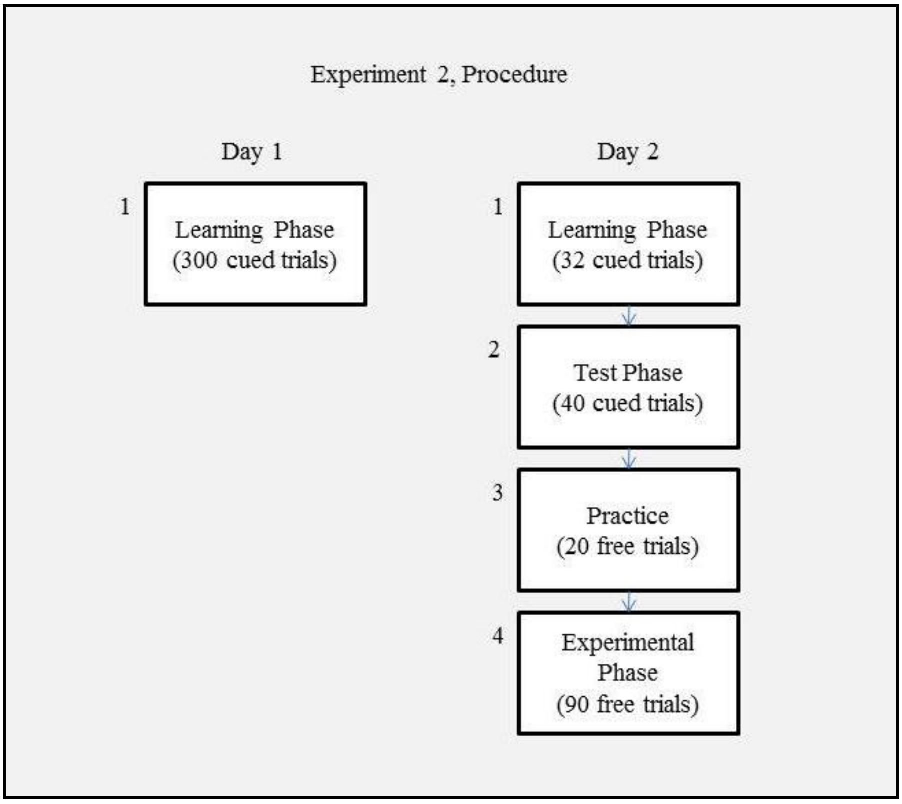


Fig. 9 The procedure in Experiment 2.

Method

Participants

Sixty-five undergraduate students (39 female, 26 male: Mean age=20, *SD*= 3.03) from Boğaziçi University participated in the experiment. All participants had normal or corrected-to-normal vision and were native Turkish speakers. They gave written consent prior to all sessions and received 2 course credits in return for their participation. The study was approved by the Research Ethics Board of Boğaziçi University.

Apparatus

All of the phases of Experiment 1 were developed on E-Prime Software (Version 1.2, Psychology Software Tools, Inc) and ran on the computer with an Intel Core 2 Duo processor, ATI Radeon X300/X550/X1050 Series graphics card, and a 17-inch color CRT Philips 107S6 monitor. All the tasks were run at 1024 X 768 pixels resolution at an 85 Hz refresh rate. Participants sat in front of the computer at an approximately 75 cm distance and used the keyboard, mouse, and the earphones during the experiment.

Procedure

Upon their entrance at the laboratory, subjects were welcomed and briefly informed about the progression of the experiment. After the experimenter introduced the definition of the sense of agency, participants were told that the current study aimed at exploring how people report their sense of agency when the source of the action-effects is ambiguous.

Day 1

Learning phase

The learning phase in Experiment 2 was the same as the one in Experiment 1 (see Fig. 3).

Day 2

Test Phase

The test phase in Experiment 2 was the same as the one in Experiment 1.

Experimental Phase

In the experimental phase, the source of the effects was rendered ambiguous. That is, subjects were told that after they make a key press, the computer would also attempt to move the square at any time in any of two directions (i.e. left or right). To the subjects thus the movement of the square could be caused by either themselves or the computer. In reality, however, all effects were produced by the subjects' actions. In order to help the ambiguity be more convincing, 6 trials of each block were to produce incompatible effects with what subjects acquired in the learning phase.

After they received the instructions and completed a set of 20 practice trials, participants performed 3 blocks of 30 trials each. Each trial was initiated with a fixation cross for 500 ms and followed by the 23 ms display of a prime image that was one of either two actions (circle, triangle) or two effects (right pointing arrow, left pointing arrow). A neutral mask image immediately followed the prime and displayed for 250 ms. The response screen then appeared with the blue square centered on the screen, requiring the subjects to use their left hand to press freely either the circle or the triangle key as quickly as possible. Depending on the subjects' response the square moved either right or left after one of three different delays (100, 400, and 700 ms). In only 6 trials of each block, the square moved in the opposite direction to the learned action-effect mapping. In addition, subjects heard a short beep sound at the time the square got to its new position. The effect screen was presented for 500 ms and followed by a 10-point Likert scale on which subjects used the mouse to rate whether it was their key press or the computer that moved the square (0: Absolutely computer; 10: Absolutely me). They were told not to think too hard but rely on their instincts to reflect how much they felt they or the computer might have caused the movement. The inter trial interval was set to 1500 ms (see Fig. 10).

Upon the completion of experimental blocks, they filled out the demographic questionnaire and were debriefed on the prime visibility as in Experiment 1. With respect to the prime visibility, 84% of the subjects reported to have seen the mask image only and nothing else other than the fixation cross, blue square, and the judgment scale. The remaining 16% did not notice either the prime or the mask image.

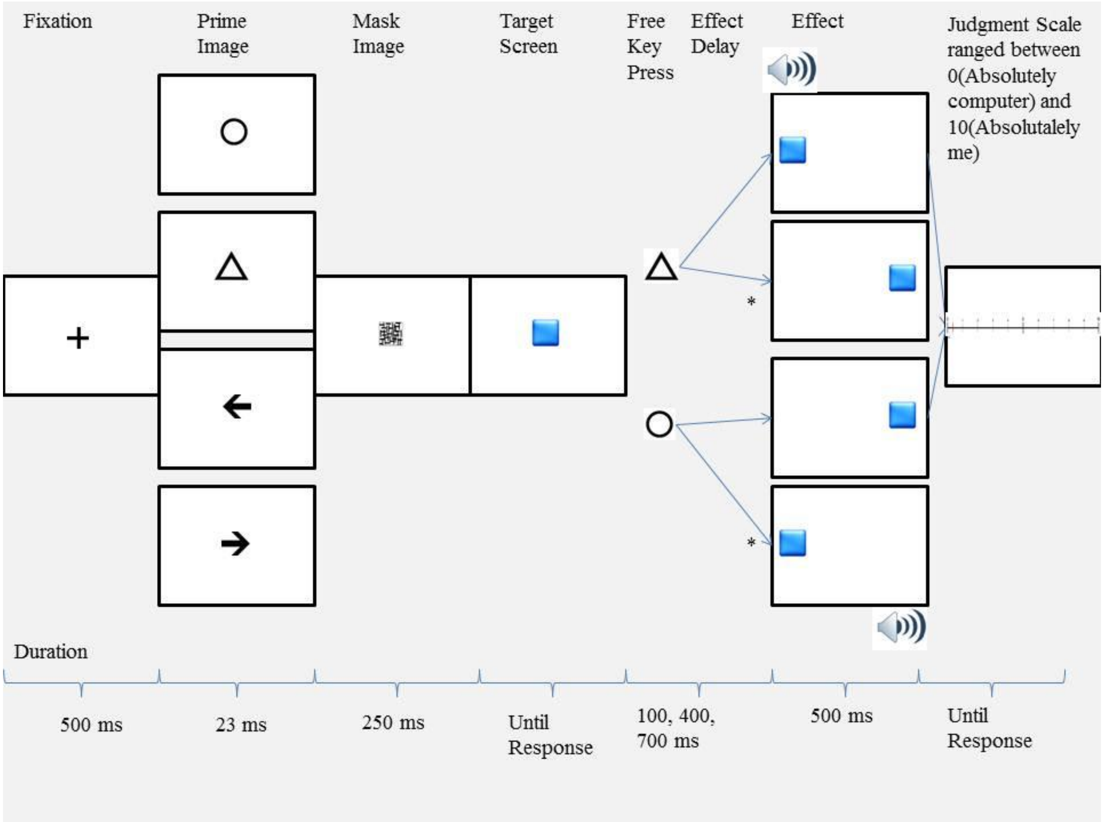


Fig. 10 Illustration of a sample trial in the experimental phase. The inter trial interval was set to 1500 ms and on some trials, the square moved toward the opposite direction to the learned action-effect mapping (*)

Results

As in Experiment 1, we first evaluated the performance in the training phase and found that none of the subjects failed to give correct responses with a percentage lower than 90% over all trials. The mean performance of the subjects was 98.1% (*SD*= 2.42). During the debriefing, three of the subjects reported that they thought the trials were interrelated although they were asked to give their judgments for each trial in its own right. After excluding the data of these three subjects we were left with sixty-two subjects for the analyses. Within this sample, trials with response times of two standard deviations above the mean were excluded as in Experiment 1.

Bias in the action selection

As in Experiment 1, the effect of subliminal action and effect priming on action selection was analyzed. The percentile choosing the same action primed by the action-primes was 51.18% (*SD* = 7.09). For the effect primes (Table 4), we found that in 50.16% (*SD* = 7.24) of all trials subjects chose the effect-prime compatible actions. We ran one sample t tests to compare the observed percentage of choosing prime-consistent actions to the chance level (i.e. 50%). The tests for both action and effect primes revealed that the difference was not significant (all *ps* >.05). In addition, paired samples t tests showed that the difference between action and effect primes in their effect on action selection was not significant (*p*>.05)

Table 4 Statistical Data Representing the Ratio of Choosing Prime-Consistent Actions as a Function of Prime Type

Prime Type	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	62	30.43	65.63	51.18	.90	7.09
Effect	62	33.33	67.74	50.16	.92	7.24

Judgment of Agency as an Explicit Measure of Sense of Agency

Before we removed the data of pretense trials on which the square moved to the unpredicted direction, we analyzed whether subjective judgments about the source of the effects was influenced by observing the effects being compatible with the learned mappings or not. A one-way repeated measures on subjective judgments as a function of the predictability of the effects revealed that subjects’ reported sense of agency was significantly higher when the effect they observed was compatible with the action-mapping than when it was not (F(1,61) = 527.225, MSe = 2.45, *partial*-η^2=.90, p <.001) as shown in Figure 11.

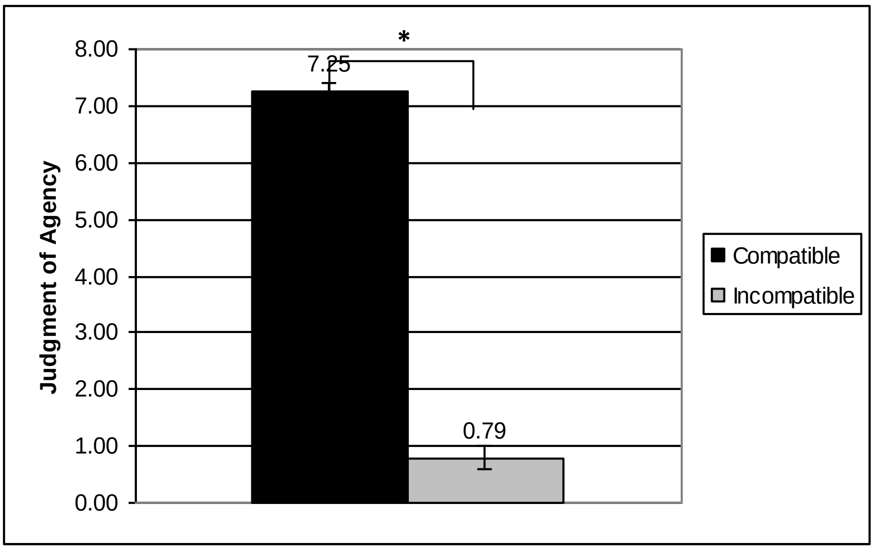


Fig. 11 Judgment of agency rating means and standard errors as a function of compatibility with the learned action-effect mapping (* indicating p<.001).

Table 5 Statistical Data Representing the Judgment of Agency as a Function of Prime Type, Congruency, and Interval Conditions

Prime Type	Prime-Response Congruency	Action-Effect Interval	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	Congruent	100	62	.27	10.00	7.76	.24	1.90
	Incongruent	100	62	.14	10.00	7.85	.23	1.80
	Congruent	400	62	.00	9.99	7.16	.22	1.74
	Incongruent	400	62	.29	10.00	7.16	.21	1.68
	Congruent	700	62	.00	10.00	6.89	.26	2.07
	Incongruent	700	62	.00	9.99	6.67	.26	2.07
Effect	Congruent	100	62	.18	10.00	7.67	.24	1.93
	Incongruent	100	62	1.55	10.00	7.81	.23	1.78
	Congruent	400	62	.00	9.98	7.24	.22	1.72
	Incongruent	400	62	1.61	10.00	7.29	.22	1.71
	Congruent	700	62	.00	9.96	6.79	.24	1.90
	Incongruent	700	62	.00	10.00	6.81	.27	2.16

In order to examine the subliminal priming and interval effect on the judgment of agency we first removed the pretense trials (Table 5). A 2 (Prime Type: Action, Effect) x 2 (Prime-Response Congruency: Congruent, Incongruent) x 3 (Action-Effect Interval: 100, 400, 700 ms) repeated measures ANOVA on measured ratings of the judgment of agency in the remaining regular trials revealed only a significant main effect of action-effect interval ($F(2,122) = 7.55$, $MSe = 7.95$, $partial\text{-}\eta^2 = .11$, $p < .001$). Post hoc tests of comparison with an overall alpha level of .05 revealed that sense of self agency decreased with increasing action-effect interval (see Fig.11).

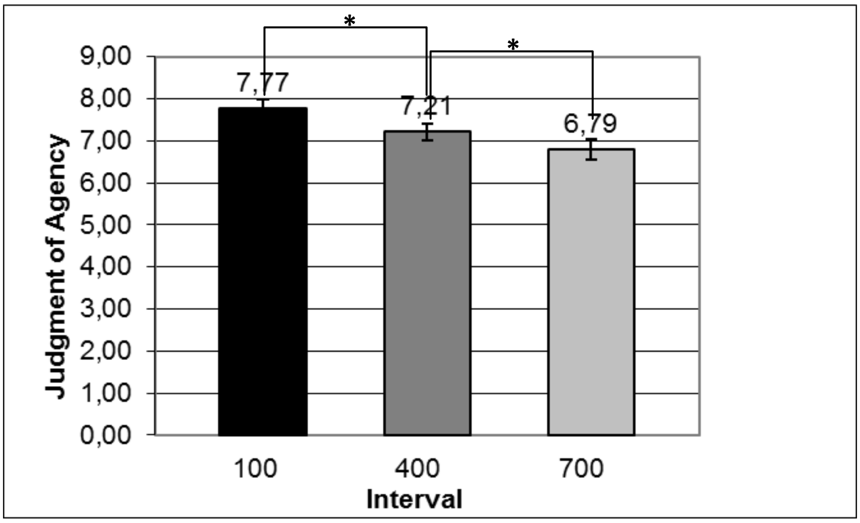


Fig. 12 Judgment of agency rating means and standard errors as a function of time interval (* indicating $p<.05$).

Prime type and congruency were not found to have any significant effect on the subjective judgments (all *ps*>.05, see Fig. 13 & Fig. 14).

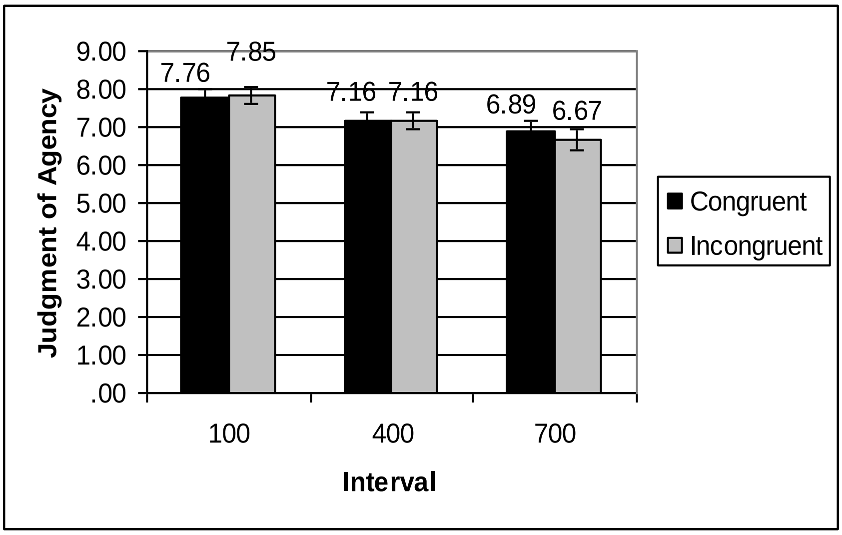


Fig. 13 Judgment of agency rating means and standard errors as a function of prime-response congruency and interval in the action-prime condition.

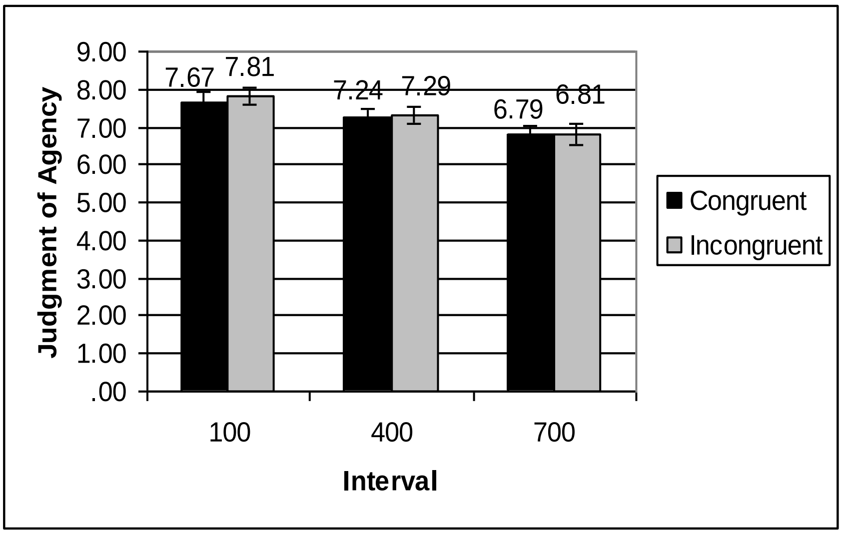


Fig. 14 Judgment of agency rating means and standard errors as a function of prime-response congruency and interval in the effect-prime condition.

Response Times

A 2(Prime Type: Action, Effect) x 2 (Prime-Response Congruency: Congruent, Incongruent) repeated measures ANOVA on response times did not show any significant effects (*p*s >.05). See Table 6 and Figure 15.

Table 6 Statistical data representing Response Times as a Function of Prime Type and Congruency Condition

Prime Type	Prime-Response Congruency	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Action	Congruent	62	139.63	739.00	386.15	17.06	134.34
	Incongruent	62	153.86	683.41	390.66	15.49	121.94
Effect	Congruent	62	139.59	730.78	385.95	16.04	126.32
	Incongruent	62	174.75	731.33	386.66	18.04	142.07

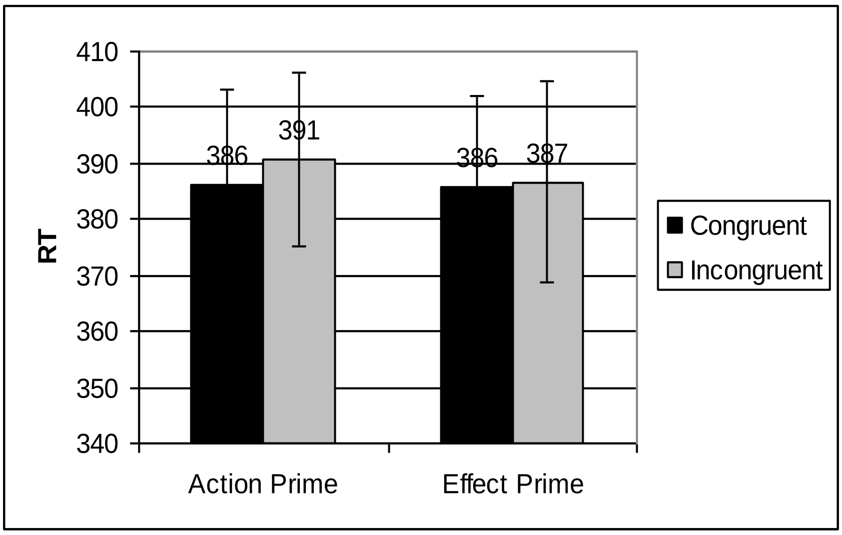


Fig. 15 Mean response times and standard errors as a function of prime-response congruency in the action-prime and effect-prime conditions.

Discussion

The explicit (reflective) form of sense of agency explained in the two-level account is aroused from both low level motoric signals and high level inferences made upon the contextual cues (Synofzik et al., 2008a). In Experiment 2 we assessed the explicit judgment of agency under conditions such that both internal motor signals and external cues were present. As in Experiment 1 the major intrinsic cue to our concern was the predictions produced by the forward model. As the participants went through the learning session to acquire the action effect associations, it is viable to assert that the predictions were made available by the forward model before they observed the actual consequences. The extrinsic cues, on the other hand, consisted of the unconscious percepts induced by the primes, the causal belief given in the experimental setting, and the varied durations between actions and outcomes. Having the participants believe that they were not the only cause of the movements enabled us to measure their judgment of agency. Participants therefore were required to rate on a 10-point Likert scale how much they thought the effect was caused by their own actions and we examined whether the prime-response congruency and the action-outcome durations affected their judgments.

With respect to the prime congruency factor, our findings showed that subliminal priming of actions and effects and their consistency with the actual responses did not influence the judgment of agency, which in fact conflicts with our preliminary expectation. The study by Wenke et al. (2010) we reviewed earlier also used subliminal priming of actions and found that their measure of ‘sense of control’ was higher when the primes and responses were congruent. There are a few differences pointing to why our results did not replicate the previously found subliminal priming effect on explicit measure of self-agency.

The first and the most important difference is that the action outcomes were unpredictable in Wenke et al.'s study and participants therefore did not know which consequences their actions would produce. In our study, in contrast, subjects were exposed to substantial amount of practice to concretize the action-effect associations by the help of the learning phase. The predictions as the internal cues were therefore strongly salient. Furthermore, subjects seem to be aware of what their actions would bring about so that they could explicitly compare their expectation to the outcomes to figure the causal source. With respect to the subjects' awareness of their inferences based on these two important cues, it is worth stating that all of the participants during the debriefing reported having relied primarily on the prediction-outcome compatibility. We thus speculate that if they did not undergo the learning phase and the outcomes were not predictable, the subliminal primes would be influential on their judgments as in Wenke et al. (2010). Second, Wenke and colleagues measured how much control the participants felt over the outcomes while there was only one potential agent in their experimental context: the participant themselves. On the contrary, we measured their judgments concerning straightforwardly who the agent was in a context that included two potential causes linked to the outcomes: the participants and the computer. Third, the subliminal priming paradigm used by Wenke et al. was metacontrast masking and we employed pattern masking using a neutral mask image that did not include any features of the primes to avoid inverse priming effect (Jaśkowski & Przekoracka-Krawczyk, 2005).

On the one hand, the fact that our results did not justify the effect of subliminal priming on the judgment of agency might be ascribed to these methodological issues. On the other hand, it might also suggest the possibility that higher order or inferential processes outweighed the impact of unconscious percepts when the context included such ambiguity regarding the source of the outcomes. Based on the current findings, we posit that subjects derived inferences by virtue of their predictions and the temporal distance between actions and their consequences. Accordingly, subjects attributed the cause of the movements to themselves with higher ratings when the direction of those movements matched what they acquired earlier in the learning phase. When the outcomes were incompatible with their predictions, on the other hand, they gave lower ratings indicating that they believed it was the computer that caused the movements.

Interestingly, the predictability was not the only decisive factor in their judgments. Subjects knew that even if the movement direction was the same as they intended it was still possible that the computer might have caused it. Apparently, this in turn directed their attention to the length of the action-outcome durations. Among the trials with prediction-consistent outcomes, subjects gave significantly stronger self-agency judgments when the outcome followed their actions after 100 ms than 400 ms and 700 ms intervals. The finding that their ratings were significantly reduced from 100 ms to 700 ms indicates that subjects felt themselves more of a causal source when the outcomes followed immediately after their actions. The more the actions and their outcomes were bound together in time the stronger the sense of agency aroused, which points to an intriguing link between perceived durations and judgment of agency. The temporal distance effect we found on the judgment of agency becomes even more interesting if we take the 500 ms constant interval in the learning phase. That is, participants could have given higher ratings at 400 ms interval in the experimental session, which was the closest delay to the one they were accustomed to in the learning phase. As a result, they inferred the most immediate occurrence of the outcomes, rather than relying on the temporal predictability, as having a higher degree of agency.

In sum, Experiment 2 revealed the dual contribution of intrinsic and extrinsic cues when part of the situational information was the co-occurrence of a second agent. Although the subliminal primes were not found to prominently affect the predictions as in Experiment 1, predictions we regard as an internal cue were the primary component that determined the judgment of agency. The second efficacious component was found to be another externally available cue: the temporal distance between actions and their consequences.

CHAPTER IV

CONCLUSION

The sense that we hold the authorship of both our actions and their consequences has been regarded as an important aspect and further, a ‘marker’ (Bayne, forthcoming) of human consciousness. Most commonly, in everyday life, we do not come up with inquiries over the sense of agency that pervasively accompanies our experience of acting. More recently, however, the fact that certain disorders and findings in experimental settings with healthy subjects have betrayed its fallibility has sparked the curiosity to gain more insight into how we ‘normally’ experience the sense of agency.

In the last few decades this quest has built up the debate between two prominent accounts that diverge in terms of the mechanisms proposed to address the nature of how the sense of agency emerges. One account, referred as the predictive view, highlights the contribution of the internal models and motor control mechanisms described in CM. According to this account, we experience the sense of agency as long as there is no discrepancy between the predictions of the action consequences and the actual outcomes (Frith et al., 2000; Blakemore et al., 2002; Frith, 2005; Sato & Yasuda, 2005). The inferential account, on the other hand, advocates that the sense of agency emerges out of the post hoc inferences we make based on the consistency, priority, and the exclusivity principles we previously described in detail (Wegner, 2002; Wegner, 2003; Wegner & Wheatley, 1999). The research conducted to test these views has measured the sense of agency by reporting either directly the explicit judgment of agency or the intentional binding effect that is proposed to index the sense of agency indirectly through the perceived durations. At this point, it is crucial to reiterate the distinction made between low level (pre-reflective) and explicit (reflective) sense of agency (Gallagher, 2010; Obhi & Hall, 2011; Synofzik et al., 2008a;b; Bayne & Pacherie, 2007). Several authors have pointed out that intentional binding and explicit judgments might reflect the pre-reflective and reflective sense of agency, respectively (Ebert & Wegner, 2010; Obhi & Hall, 2011; Moore & Obhi, 2012).

The postulate of mutually exclusive roles of the internal and external contributors has recently been challenged by the integrative approach that emphasizes the dual contribution of the both intrinsic and extrinsic sources (Bayne & Pacherie, 2007; Moore & Haggard, 2008; Moore et al., 2009; Pacherie, 2008; Synofzik et al., 2008a; Wegner & Sparrow, 2004). The interplay between multiple cues suggested here requires a comprehensive framework to specify the constraints and the degree of involvement of each cue. In order to provide additional testing and justification for the integrative view, we established two different experimental settings to investigate the extent to which lower level mechanisms and the higher level inferences determine the intentional binding effect and the subjective judgments of self-agency. In both experiments, accordingly, we set the presence of the predictions as the internal cues through learning and manipulated the external cues such as action relevant unconscious percepts, temporal delay between actions and effects, and the causal beliefs.

The goal of Experiment 1 was to examine the impact of unconscious percepts and their consistency with the predictions on the intentional binding effect. Subjects were required to press either the circle or the triangle key at their own will to move a square on the screen and estimate the time elapsed between their actions and the corresponding effects that appeared on the screen. The subliminal primes relevant to the actions or effects were presented before they made a key press. The analyses revealed a significant effect of congruency between effect primes and actual outcomes on the perceived delays. That is, the magnitude of intentional binding was stronger when the effect primes were compatible with the predictions than when they were not. Although the effect we found seems to depend on the prime type and the action-effect delay, our finding suggests that the predictive processes may not necessarily operate alone to affect the pre-reflective sense of agency. Rather, the presence of external information induced by the primes can either distort or empower the impact of the predictions, which was reflected on the intentional binding effect. Previous studies have also shown the sensitivity of this effect to whether the action is voluntary or not (Haggard et al., 2002; Moore et al., 2009), causal beliefs (Desantis et al., 2011), and supraliminal priming of action-effects (Moore et al., 2009). Experiment 1 provided further insight into the determinants of the intentional binding by the finding that both internal and external cues contribute to this effect. However, it is important to note that the underlying mechanism behind the intentional binding effect (Wenke & Haggard, 2009) and its link to the sense of agency require further research to be fully explicated.

Subjects' task in Experiment 2 was the same as in Experiment 1, except that they believed that the movements could be caused by either their actions or the computer. In this way, we rendered the source of the effects ambiguous in the context and measured directly the subjective judgments of agency on a 10 point Likert scale. In some trials, the direction of the movements was incompatible with the previously learned action-effect mapping. Action-effect delays were also varied and subjects were subliminally primed with action and effect relevant images before they made a key press. These factors allowed us to interpret the basis of the inferences derived to judge the causal source. According to the results, the agency was attributed to the self when the actual outcomes met subjects' expectations or intentions. This finding points to the greater role of the predictions as the internal cues. Moreover, within the sample in which the outcomes were consistent with the expectations, the second important contributor was found to be the delay between the actions and their consequences. The longer the time interval, the lower was the rating given for explicit agency. Regarding the influence of priming, we speculate that subjects were more aware of their intentions and anticipations (compared to the first experiment) and thus the congruency with subliminal primes did not influence the strength of the predictions (see Chapter III for more on this).

The main contribution of the consistency between the intentions and the action consequences can be explained on the basis of the views put forth both by CM (Wolpert et al., 1995; Wolpert, 1997; Blakemore et al., 2002; Frith et al., 2000; Frith, 2005) and by the apparent mental causation theory (Wegner & Wheatley, 1999; Wegner, 2003). With respect to the former, the inferences derived to judge the agency can be analyzed through the mechanism proposed in CM. To begin with, the task demanded that subjects were to choose the appropriate action according to their intention to move the square in either direction. In this scenario, the efferent copy of the motor command to press either the circle or the triangle key is sent to the predictors which then produce the anticipations of the action consequences. These anticipations are compared to the sensory feedback that conveys the actual outcomes. In case of a match, as in our subjects' reports, the effects are regarded as self-generated. If the comparator signals a mismatch, in contrast, then the agency is ascribed to the other, namely to the computer in our setting.

As mentioned earlier, the apparent mental causation theory holds the stance that when the prior intentions or thoughts are consistent with the action consequences in a context with no other potential agent, the outcomes are inferred as self-generated (i.e. priority, consistency, and exclusivity principles). In the context of Experiment 2, the exclusivity principle was violated and therefore subjects' inferences primarily relied on whether the outcomes matched their prior intentions or not. That is, if the outcomes appeared as expected they ascribed the agency to themselves with higher ratings. In contrast, they thought the cause was the computer when the movement occurred in the opposite direction.

We thus argue that both predictive and inferential accounts converge in the interpretation of Experiment 2. In this sense, subjects were aware of the comparison of predictions and actual outcomes, on the basis of which they derived explicit inferences. However, these inferences were not merely dependent on the prediction-outcome consistency as the subjects recognized that the computer could cause the same movement as their intentions. In this case, our results showed that subjects included the action-effect delays as the second contributor to their judgments. They accordingly felt themselves to be more of a causal source as their actions and the outcomes were closer in time. This finding indeed suggests the interactive contribution of internal and external agency cues. That is, the judgment of agency relies upon both the predictions and the externally manipulated temporal structure of action-effect delays.

In summary, both experiments result in siding with the integrative account that encompasses the role of both predictive and inferential mechanisms to address the nature of sense of agency. Of course, certain limitations and methodological issues in these experiments should also be acknowledged. First of all, we applied the pattern masking paradigm with the subliminal priming, the effect of which we observed in Experiment 1 but not in Experiment 2. The subliminal priming effect we found in Experiment 1 needs to be justified by further experimentation. A follow up study could have also used different paradigms (e.g. metacontrast masking as in Wenke et al., 2010) to test the validity of both our methodology and the results. Second, we measured directly the perceived durations between actions and outcomes to observe the intentional binding effect in Experiment 1. More frequently, intentional binding is measured by having participants watch a conventional clock and report the perceived times of actions and effects separately (e.g.Haggard et al. 2002; Haggard & Clark, 2003; Haggard et al. 2009, Obhi & Hall, 2011). We did not apply this methodology in order to avoid potential attention problems that might be caused if subjects had to watch the clock and complete their task simultaneously. However, we admit that it could be more informative if we could observe the specific shifts in the perceived time onsets of actions and effects.

A theoretically more important limitation is that we did not measure implicit and explicit sense of agency together in both experiments. One reason we did not measure both in the same setting is due to the caution to avoid one measure contaminating the other. Another reason is that applying both measures would increase the overall duration of a single trial, which in turn could result in the decay of subliminal primes. This limitation in fact obscured an intriguing analysis of the link between implicit and explicit measures of self-agency. The only speculation we can make at this point is the parallel between intentional binding effect and judgment of agency we observed in the two experiments. To put this more clearly, the intentional binding effect was stronger with congruent primes and outcomes (also the predictions) at 100 s interval in Experiment 1 and the highest judgment of agency was reported at the shortest interval 100 ms in Experiment 2 wherein the predictions were consistent with the outcomes. This might suggest that the perceived time intervals between actions and effects can affect both implicit and explicit sense of agency. However, this remains only as a speculation and needs to be tested by further investigation.

The methodological issues and limitations we admit here could be alleviated by the follow up studies by including both measures in the same context and employing different priming paradigms. Future studies should also enhance the manipulation of external factors such as existence of a human co-agent, causal beliefs, and the length of action-effect durations.

To conclude, our research highlights the integrative view that the underlying mechanism of the sense of agency has a complex structure involving both action control mechanisms and situational or environmental cues. Two studies reported here accordingly shows that the sense of agency, in both pre-reflective and reflective forms, operates on multiple agency cues and situational factors. We believe that our research has provided more insight into the experience of agency and will inspire further research to scrutinize contributors of the sense of agency.

APPENDICES

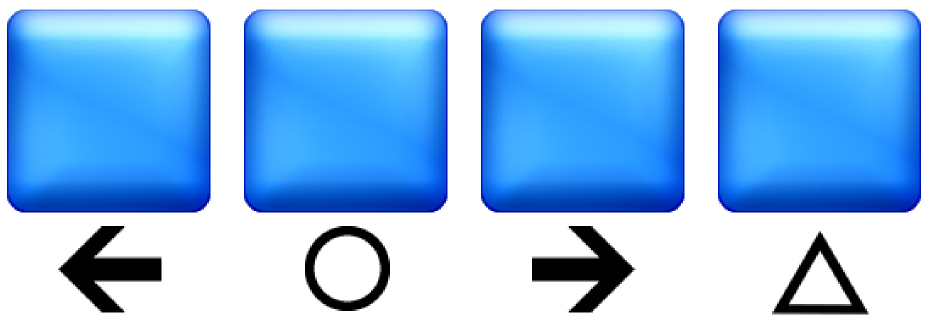
Appendix A: Original instructions given in Experiment 1

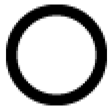
- Bu araştırmanın amacı eylemlilik hissinin zaman algısı(örtük, dolaylı) ve subjektif yargı(açık, direkt) ölçümlerine etki eden faktörleri incelemektir. Katılacağınız deneyin tamamı 3 aşamadan oluşmakta ve bu aşamaların tamamlanması için 2 gün arda arda labaratuvara gelmeniz gerekmektedir. İlk gün öğrenme aşaması yapılacak ve ikinci gün test ve deneysel aşamalar tamamlanacaktır.

Öğrenme Aşaması

- Bu aşamada amaç, klavye üzerinde aşağıdaki gibi gördüğünüz tuşları kullanarak ekrandaki mavi karenin hareketini nasil kontrol edebileceğinizi öğrenmenizdir. Aşağıdaki tuşlar ile mavi karenin sağ ya da sol hareketi arasındaki ilişkiyi öğrenmeniz yarın katılacağınız test ve deneysel aşamalar için önemlidir.

- Her bir denemede ekranda aşağıdaki gibi mavi kareyi altında basmanız gereken tuşu ya da hareket yönünü belirten bir işaret (üçgen, daire, sağa ya da sola yönelmiş ok) ile birlikte göreceksiniz.



- Kareyi SAĞA taşımak için  tuşuna,

- SOLA taşımak içinse  tuşuna basınız.

- Karenin altında belirtilen işarete göre doğru tuşa max. 2 saniye içinde basmaya çalışınız. Hatalı tuşa bastığınızda "Hatalı Yanıt", yanıt verme süreniz 2 saniyeyi geçtiğinde ise "Geç Yanıt" mesajlarını göreceksiniz.

<u>Süre Tahmini Eğitimi</u>

Bu aşamada iki olay arasında geçen süreyi tahmin edebilmeniz için alıştırmalar yapacaksınız.

- Her bir deneme, ekranın ortasına odaklanmanızı sağlayan "+" işareti ile başlayacaktır. "+" işaretini görünce yanıt vermek için hazır olunuz.

"+" işaretinden sonra ekranın ortasında mavi bir kare göreceksiniz. Mavi kareyi İSTEĞİNİZE GÖRE sağa hareket ettirmek için DAİRE tuşuna, sola hareket ettirmek için ÜÇGEN tuşuna basınız.

- Mümkün olduğunca hızlı yanıt veriniz.

- Tuşa basmanız ile mavi karenin hareketi arasında geçen süre her bir denemede 50 ms ile 1000 ms (1s) arasında değişecektir.

- Her bir deneme sonunda bu süreyi tahmin etmeniz istenecektir. Ölçek üzerinde süreyi belirtirken sağ elinizle fareyi kullanınız.

- Tahmin ettiğiniz sürenin doğru ya da yanlış olduğu sonraki ekranda belirtilecektir.

<u>Test Aşaması</u>

- Bu aşamada mavi kareyi hareket ettirirken hızlı ve doğru yanıt vermeniz beklenmektedir.

- Her bir deneme, ekranın ortasında "+" işaretinin belirmesiyle ile başlayacaktır.

- Ardından mavi kareyi altında 4 farklı işaretten (üçgen, daire, sağ ok, sol ok) biri ile göreceksiniz. Bu işaretler hangi tuşa basacağınızı ya da kareyi hangi yöne hareket ettirmeniz gerektiğini belirtmektedir.

- İşarete göre yanlış tuşa basmanız durumunda ya da yanıt vermenizin 1.5 saniyeden uzun sürmesi halinde kare hareket etmeyecek; onun yerine ekranda uyarı mesajı göreceksiniz (Hatalı yanıt! ya da Geç Yanıt!).

<u>Deneysel Aşama</u>

- Her bir deneme, ekranın ortasına odaklanmanızı sağlayan "+" işareti ile başlayacaktır. "+" işaretini görünce yanıt vermek için hazır olunuz.

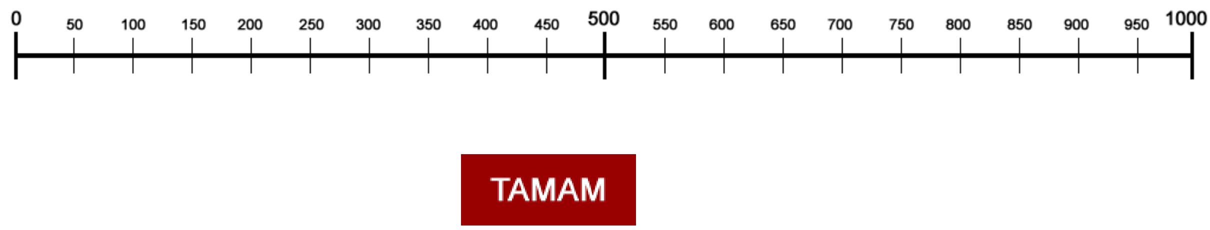
- "+" işaretinden sonra ekranda sadece mavi bir kare göreceksiniz. İsteğinize göre kareyi sağa taşımak için DAİRE tuşuna, sola taşımak içinse ÜÇGEN tuşuna basınız.

- Mümkün olduğunca hızlıı yanıt veriniz.

- Tuşa basmanız ile mavi karenin hareketi arasında geçen süre her bir denemede 50 ms ile 1000 ms (1s) arasında değişecektir.

- Her bir deneme sonunda bu süreyi tahmin etmeniz istenecektir (Aşağıdaki gibi). Ölçek üzerinde süreyi belirtirken sağ elinizle fareyi kullanınız.

"Lütfen fareyi kullanarak tuşa basmanız ile karenin hareketi arasinda gecen zamanı tahmin ediniz."



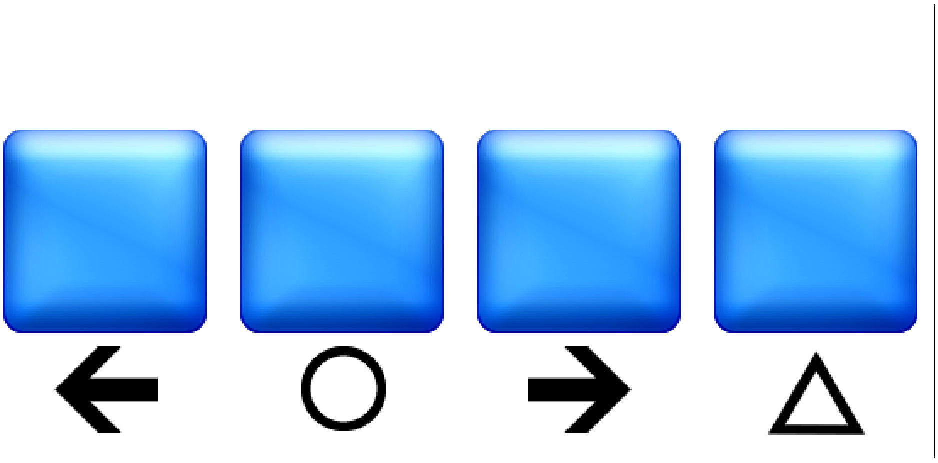
Appendix B: Original instructions given in Experiment 2

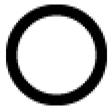
- Bu araştırmanın amacı eylemlilik hissinin zaman algısı(örtük, dolaylı) ve subjektif yargı(açık, direkt) ölçümlerine etki eden faktörleri incelemektir. Katılacağınız deneyin tamamı 3 aşamadan oluşmakta ve bu aşamaların tamamlanması için 2 gün arda arda labaratuvara gelmeniz gerekmektedir. İlk gün öğrenme aşaması yapılacak ve ikinci gün test ve deneysel aşamalar tamamlanacaktır.

Öğrenme Aşaması

- Bu aşamada amaç, klavye üzerinde aşağıdaki gibi gördüğünüz tuşları kullanarak ekrandaki mavi karenin hareketini nasil kontrol edebileceğinizi öğrenmenizdir. Aşağıdaki tuşlar ile mavi karenin sağ ya da sol hareketi arasındaki ilişkiyi öğrenmeniz yarın katılacağınız test ve deneysel aşamalar için önemlidir.

- Her bir denemede ekranda aşağıdaki gibi mavi kareyi altında basmanız gereken tuşu ya da hareket yönünü belirten bir işaret (üçgen, daire, sağa ya da sola yönelmiş ok) ile birlikte göreceksiniz.



- Kareyi SAĞA taşımak için  tuşuna,

- SOLA taşımak içinse  tuşuna basınız.

- Karenin altında belirtilen işarete göre doğru tuşa max. 2 saniye içinde basmaya çalışınız. Hatalı tuşa bastığınızda "Hatalı Yanıt", yanıt verme süreniz 2 saniyeyi geçtiğinde ise "Geç Yanıt" mesajlarını göreceksiniz.

<u>Test Aşaması</u>

- Bu aşamada mavi kareyi hareket ettirirken hızlı ve doğru yanıt vermeniz beklenmektedir.

- Her bir deneme, ekranın ortasında "+" işaretinin belirmesiyle ile başlayacaktır.

- Ardından mavi kareyi altında 4 farklı işaretten (üçgen, daire, sağ ok, sol ok) biri ile göreceksiniz. Bu işaretler hangi tuşa basacağınızı ya da kareyi hangi yöne hareket ettirmeniz gerektiğini belirtmektedir.

- İşarete göre yanlış tuşa basmanız durumunda ya da yanıt vermenizin 1.5 saniyeden uzun sürmesi halinde kare hareket etmeyecek; onun yerine ekranda uyarı mesajı göreceksiniz (Hatalı yanıt! ya da Geç Yanıt!).

Deneysel Aşama

- Bu aşamada her bir tuşa basma işinden sonra ekrandaki mavi kare sağa ya da sola hareket edecektir. Ancak siz tuşa bastıktan sonra karenin bu hareketinin kaynağı SİZ (sizin tuşa basmanız) ya da BİLGİSAYAR olabilir. Siz tuşa bastıktan sonra bilgisayar mavi kareyi rastgele ve herhangi bir zamanda hareket ettirmek isteyeceğinden, sonuçta karenin hareketi sizin yapmak istediğinizle aynı ya da zıt yönde olabilir.
- Her bir deneme, ekranın ortasına odaklanmanızı sağlayan "+" işareti ile başlayacaktır. "+" işaretini görünce yanıt vermek için hazır olunuz.
- "+" işaretinden sonra ekranda sadece mavi bir kare göreceksiniz. İsteğinize göre kareyi sağa taşımak için DAİRE tuşuna, sola taşımak içinse ÜÇGEN tuşuna basınız.
- Mümkün olduğunca hızlı yanıt veriniz.
- Her bir deneme sonunda mavi karenin hareketine sizin mi yoksa bilgisayarın mı neden olduğunu 0 (Kesinlikle Bilgisayar) ile 10 (Kesinlikle Ben) arasinda değerleri içeren bir ölçek üzerinde (aşağıdaki gibi) belirtmeniz istenecektir. Ölçeklendirmeyi yaparken sağ elinizle fareyi kullanınız ve sezgilerinize dayanarak ilk aklınıza gelen değeri işaretleyiniz.

“Lütfen fareyi kullanarak ekrandaki mavi karenin hareketine SİZin mi yok BİLGİSAYARın mı neden olduğunu belirtiniz.”

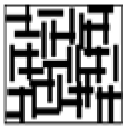
Kesinlikle Bilgisayar | Kesinlikle Ben

Appendix C: Prime and Mask Images Used in the Experiments

Action Primes

Effect Primes

Mask Image



REFERENCES

Aarts, H., Custers, R., & Wegner, D. M. (2005). On the inference of personal authorship: Enhancing experienced agency by priming effect information. *Consciousness and Cognition*, *14*(3), 439–458.

Aarts, H., Custers, R., & Marien, H. (2009). Priming and authorship ascription: when nonconscious goals turn into conscious experiences of self-agency. *Journal of personality and social psychology*, *96*(5), 967-79.

Balslev, D., Cole, J., & Miall, R. C. (2007). Proprioception contributes to the sense of agency during visual observation of hand movements: Evidence from temporal judgments of action. *Journal of Cognitive Neuroscience, 19*(9), 1535–1541.

Bayne, T., & Levy, N. (2006). The Feeling of Doing: Deconstructing the Phenomenology of Agency. In N. Sebanz &W. Prinz (Eds.), *Disorders of volition*. Cambridge, MA: MIT Press.

Bayne, T., & Pacherie, E. (2007). Narrators and comparators: The architecture of agentive self-awareness. *Synthese, 159*, 475–491.

Bayne, T. Forthcoming. Agency as a Marker of Consciousness. In T. Vierkant, J.Kiverstein and A. Clark (Eds.) *Decomposing the Will*. Oxford: Oxford University Press.

Blakemore, S. J., Wolpert, D. M., & Frith, C. D. (2002). Abnormalities in the awareness of action. *Trends in Cognitive Sciences*, *6*(6), 237–242.

de Vignemont, F., & Fourneret, P. (2004). The sense of agency: A philosophical and empirical review of the ‘‘who’’ system. *Consciousness and Cognition*, *13*(1), 1–19.

Desantis, A., Roussel, C., & Waszak, F. (2011). On the influence of causal beliefs on the feeling of agency. *Consciousness and cognition*, *33*, 1-10

Dijksterhuis, A., Preston, J., Wegner, D. M., & Aarts, H. (2008). Effects of subliminal priming of self and God on self-attribution of authorship for events. *Journal of Experimental Social Psychology, 44*, 2-9.

Ebert, J. P., & Wegner, D. M. (2010). Time warp: Authorship shapes the perceived timing of actions and events. *Consciousness and Cognition, 19*, 481-489.

Elsner, B., & Hommel, B. (2001). Effect Anticipation and Action Control. *Perception*, *27*(1), 229-240.

Frith, C. (2005). The self in action: Lessons from delusions of control. *Conscious Cognition, 14*(4), 752–770.

Frith, C.D., Blakemore, S.J., &Wolpert, D.M. (2000). Abnormalities in the awareness and control of action. *Philosophical Transactions of the Royal Society of London – B: Biological Sciences, 355*, 1771–1788.

Georgieff, N., & Jeannerod, M. (1998). Beyond consciousness of external reality: A ‘‘Who’’ system for consciousness of action and self-consciousness. *Consciousness and Cognition, 7*, 465–477.

Gallagher, S. (2000) Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Science, 4*, 14–21

Gallagher, S. (2007). The natural philosophy of agency. *Philosophy Compass, 2*(2), 347-357.

Gallagher, S. (2010). Multiple aspects in the sense of agency1. *New Ideas in Psychology*, 1-13.

Haggard, P., & Clark, S. (2003). Intentional action: Conscious experience and neural prediction. *Consciousness and Cognition, 12*, 695–707.

Haggard, P., Clark, S., & Kalogeras, J. (2002). Voluntary action and conscious awareness. *Nature Neuroscience, 5*, 382–385.

Haggard, P., Poonian, S., Walsh, E. (2009). Representing the consequences of intentionally inhibited actions. *Brain Research, 1286*, 106-113

Haggard, P., & Tsakiris, M. (2009). The Experience of Agency: Feelings, Judgments, and Responsibility. *Current Directions in Psychological Science, 18*(4), 242-246.

Hume, D. (1888). *A treatise of human nature*. In L. A. Selby-Bigge (Ed.), Hume’s Treatise of human nature. Oxford: Clarendon Press. Original work published 1739.

Jaśkowski, P. & Przekoracka-Krawczyk, A. (2005). On the role of mask structure in subliminal priming. *Acta Neurobiologiae Experimentalis, 65*, 409-417.

Libet, B., Gleason, C.A.,Wright, E.W. and Pearl, D.K. (1983), Time of conscious intention to act in relation to onset of cerebral activity (readiness potential): The unconscious initiation of a freely voluntary act, *Brain, 102*, 623–42.

Linser, K., & Goschke, T. (2007). Unconscious modulation of the conscious experience of voluntary control. *Cognition, 104*, 459-475.

Metcalfe, J., & Greene, M.J. (2007). Metacognition of agency. *Journal of Experimental Psychology – General, 136*, 184–199.

Moore, J. W., & Haggard, P. (2008). Awareness of action: Inference and prediction. *Consciousness and Cognition, 17*(1), 136–144.

Moore, J. W., & Haggard, P. (2010). Intentional binding and higher order agency experience. *Consciousness and cognition*, *19*(1), 490-1.

Moore, J.W., Wegner, D.M. & Haggard, P. (2009). Modulating the sense of agency with external cues. *Consciousness and Cognition, 18*, 1056–1064.

Moore, J. W., & Obhi, S. S. (2012). Intentional binding and the sense of agency: A review. *Consciousness and cognition*, *21*(1), 546-61.

Obhi, S. S., & Hall, P. (2011). Sense of agency and intentional binding in joint action. *Experimental brain research. 211*(3-4), 655-62.

Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition, 107*, 179–217.

Sato, A. & Yasuda, A. (2005). Illusion of self-agency: Discrepancy between predicted and actual sensory consequences of actions modulates the sense of self-agency, but not the sense of self-ownership. *Cognition, 94*, 241–255.

Sebanz, N., & Lackner, U. (2007). Who's calling the shots? Intentional content and feelings of control. *Consciousness and Cognition*, *16*(4), 859–876.

Spengler, S., Cramon, D. Y. von, & Brass, M. (2009). Was it me or was it you? How the sense of agency originates from ideomotor learning revealed by fMRI. *NeuroImage*, *46*(1), 290-8.

Synofzik, M., Vosgerau, G. & Newen, A. (2008a). Beyond the comparator model: A multifactorial two-step account of agency. *Consciousness and Cognition*, *17,* 219-239.

Synofzik, M., Vosgerau, G., Newen, A. (2008b). I move, therefore I am: a new theoretical framework to investigate agency and ownership. *Consciousness and Cognition, 17*, 411-424.

Tsakiris, M., & Haggard, P. (2003). Awareness of somatic events associated with a voluntary action. Experimental Brain Research, *149*(4), 439–446.

Wegner, D. M. (2002). *The Illusion of Conscious Will*. Cambridge, MA: MIT Press.

Wegner, D. M. (2003). The mind's best trick: How we experience conscious will. *Trends in Cognitive Sciences*, *7*(2), 65–69.

Wenke, D., Fleming, S., & Haggard, P. (2010). Subliminal priming of actions influences sense of control over effects of action. *Cognition, 115,* 26-38.

Wenke, D., & Haggard, P. (2009). How voluntary actions modulate time perception. *Experimental brain research*, *196*(3), 311–318.

Wegner, D. M., & Sparrow, B. (2004). Authorship processing. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences (3rd ed.*). Cambridge, MA, USA: MIT Press.

Wegner, D. M., Sparrow, B., & Winerman, L. (2004). Vicarious agency: Experiencing control over the movements of others. *Journal of Personality and Social Psychology, 86,* 838–848.

Wegner, D. M., & Wheatley, T. (1999). Apparent mental causation: Sources of the experience of will. *American Psychologist, 54*(7), 481–492.

Wolpert, D. M. (1997). Computational approaches to motor control. *Trends in Cognitive Sciences, 1*, 209-216.

Wolpert, D. M., Ghahramani, Z., & Jordan, M. I. (1995). An internal model for sensorimotor integration. *Science, 269*, 1880–1882.