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Illusory Feeling of Knowing in Self-Action Perception

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ILLUSORY FELING OF KNOWING IN SELF-ACTION PERCEPTION

by

Jonathan Brent Fonville

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Dedication

I would like to dedicate this thesis to my parents, Ray and Debbie Fonville, for always supporting me in all my ventures. Even if it didn't make complete sense, they stood behind my decisions and showed me love and care, never hindering my goals. They instilled in me a sense of integrity, character, perseverance, optimism and faith in myself. I owe them more than I could ever repay, and I will strive to do my best to make them proud of the man I will one day become.

Acknowledgement

I would like to thank and acknowledge my graduate advisor, Dr. Rick Dale. He has been encouraging, reassuring, and patient with me over these last two years. Without his guidance and mentorship I would not have achieved the experience and knowledge that has culminated in this thesis. Any graduate student would be lucky to be able to call Rick his/her graduate advisor and I'm incredibly grateful that I had the opportunity to work with him. To him I am indebted.

Abstract

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The perceptual illusion known as “The Illusion of Authorship” has received much attention in recent years. It reflects a false belief that one has willed or authored an event to occur, when in actuality it was simply coincidence or chance. Previous research has focused on motor movements and the participant’s perception of their movement. Researchers have failed to expand on this illusion and apply it to other cognitive processes, such as knowledge, metacognition, memory, etc. Two experiments were conducted using an action dynamics approach, by collecting arm movement trajectories with the Nintendo Wii remote. It was predicted that (1) arm movements will serve as signatures for metacognition (Experiment 1) and (2) that perception of arm movements should influence that metacognition (Experiment 2). A relationship was discovered between arm movements and metacognition. In the second experiment, the effect of self-action perception had no significant effect on feeling of knowing.

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Introduction

We gaze in amazement as a magician pulls a rabbit out of a hat, which was empty only a moment ago. Or as he levitates his assistant, we are compelled by what seems an impossible feat. We all know that magic is just an illusion, yet we still are dumbfounded by the magician's execution. A wooden dummy begins to take on its own life and personality as a ventriloquist manipulates the way we perceive the actions of a piece of carved wood. These are prime examples of the gullibility of our perceptual and cognitive systems. Along with believing that others are doing incredible feats, we also sometimes believe we have caused an incredible occurrence. We can easily trick our cognitive system into thinking we have done things in which we had no part. Imagine that you are sitting under a tree and you look up at a particular branch. You began to imagine that tree limb moving and then suddenly it moves. You look away and try your "mental experiment" again, achieving the same results. Suddenly, you begin to experience a feeling of authorship, as if you have performed a real-life Jedi mind trick and have caused the branch to move. This type of thinking has been referred to as "magical thinking" (Eckblad & Chapman, 1983; Nemeroff & Rozin, 2000; Pronin, Wegner, McCarthy, & Rodriguez, 2006; Woolley, 1997; Zusne & Jones, 1989).

Throughout any day we may find ourselves imagining a variety of events, and finding validation as we watch the event unfold, all the while taking full credit for the occurrence. My goal for this research is to show that the perception of one's own knowledge can be "tricked." I do this by exposing participants to feedback, in the form of arm trajectories, on their performance in a general knowledge "test." Metacognition and feeling of knowing (FOK) judgments are incorporated in the form of retrospective confidence ratings regarding their answers to trivia questions. By warping the feedback of the arm trajectories, it may be possible to instill a false sense of knowledge and authorship, essentially leading participants to believing they have acted in a particular way and know a particular piece of information. Such a finding suggests that our very sense of self-knowledge is subject to how we perceive ourselves moving in the world. When that movement is warped or changed in some way, our cognitive system may induce illusory interpretations of the dynamic, constructed "self."

Perceptual Adaptability

Potential illusions do not reveal that the human perceptual and cognitive systems are overwhelmingly inadequate, but instead reveal the dynamic adaptability of these systems. Research on perceptual-motor alignment has found that our cognitive systems can quickly adapt to distortions in perception. An example of this comes from prism adaptation studies that have been used to study the adaptability of the perceptual system with visual distortions and hand-eye coordination. Participants are either given prism glasses, or are asked to sit behind a prism and look through it. These prisms are used to either invert the vision, the world appearing upside down, or to skew the visual system on an angle, moving things to the left or right by 10 or more degrees. The researchers then have the participants do specific arm movements, involving extending their arms, touching their noses, and grasping nearby objects. Subjects are quick to adjust their movements to successfully perform these tasks with their "new" visual input. A striking finding from these studies is that not only do subjects easily adapt to their visual input, but also do not lose a sense of self during the visual distortion. They still see the arm as their own and the sense of ownership for the arm is not lost (Redding & Wallace, 1992).

One of the reasons the human cognitive system is so adaptable is because it can readily recognize one's own movements amongst the movements of others. In a task that required participants to make drawings and then recognize their own movements retrospectively, participants were able to easily distinguish their own movements against simulated movements that they believed to be the movements of others. This ability to distinguish and perceive one's own movements and body is one that develops as early as 5 months of age (Bahrick & Watson, 1985). An ability to recognize one's movements is important because it is an essential part in the sense of agency and its role in the self-attribution of actions. The self-attribution of action is permitted due to a strong correlation between the expected results of our actions and those resulting outcomes (van den Bos & Jeannerod, 2002). Yet there is an important aspect, that when removed can make recognition of movements more difficult: velocity. The velocity of movements seemed to be the basis for this recognition. When drawing, artists sketch different parts of the picture at different speeds. The arm does not move in a constant motion at a constant speed, but instead varies in velocity. When the velocity was slowed to a consistent pace rather than the original variations of speeds that one would notice when drawing, the ability to distinguish self-made movements diminished (Knoblich & Prinz, 2001; Knoblich, Seigerschmidt, Flach, & Prinz, 2002).

It would appear that our cognitive systems are strong-guarded against perception failures, with its pre-installed adaptive features; however, failures can occur. While our cognitive systems can easily and quickly adapt to changes, false feelings of ownership, will and authorship can sometimes occur. We often believe that experiences and situations occur solely as a result of our actions. We may falsely assume that the lights come on because “I flipped the switch,” yet a number of other possibilities could have occurred, causing the lights to illuminate (e.g., a short in the wiring). On a daily basis, we consistently credit ourselves to a number of environmental events as the cause for those particular outcomes. These misattributions of cause and will create an illusion just as the magician has done with his tricks: an illusion of authorship.

Three Principles for Illusions of Authorship

Prior research has found that three particular ingredients are included when an illusion of authorship is experienced: priority, consistency, and exclusivity (Alloy & Tabachnik, 1984; Einhorn & Hogarth, 1986; Michotte, 1946/1963; Wegner & Wheatley, 1999). Priority is indicative of the timing and contemplation of the event. The action or event must be preceded by the thought in a proper interval. In experiments of perception, people perceive a causal event when one object hits another, causing the second object to move (such as in billiards). However, if the objects collide and the second object makes no movement or moves before the first even touches it then the causal event has diminished and the cause of the event is no longer attributed to the first object (Michotte, 1963). Thoughts occurring more than a few seconds before an action will lose causality because the thought and action are not together in the mind. There is only a small window of time prior to an action for relevant thoughts to be viewed as willed and/or authored (Heider, 1958; Wegner & Wheatley, 1999).

The second principle is consistency, which refers to the compatibility of the thought with the action. When people think of an action and then perform that action, the experience of will is enhanced. When people have a high frequency of predicting a chance event, they are likely to perceive a feeling of control over that event (Langer &

Roth, 1975). Likewise, inconsistency of thought and action can cause perceptions of involuntariness. When dowsing with a Y-shaped rod people generally report that the stick moves on its own with no help from the stick holder. Vogt and Hyman (1959) found that when using these rods, people typically make movements in their wrists, which puts pressure on the rod and causes it to move "on its own." The movements caused by this pressure are unpredictable and the relationship between the rod's movements and the rod holder's wrists is readily forgettable, causing a sense of involuntariness in the rod itself. This inconsistency of movements causes a loss in the experience of will.

The third principle in the experience of will is exclusivity, which refers to the potential causes of an action. We must have no reason to believe that the action has occurred by any means other than our actions, or that our actions are more salient and have more impact on the event than other causes. If the other possible causes are less salient, then the experience of will is greater. On the other hand, if other possible variables could be causing the action, then the sense of will and authorship diminishes. In billiards, the player feels a sense of will when hitting the pool balls either with the pool cue or with other balls. Someone bumping into the table at the moment the player hits a ball may cause a decrease the sense of will because of the saliency of the bumping. Both internal causes (such as thoughts and beliefs) and external causes (e.g., other people) can decrease the sense of will (Wegner & Wheatley, 1999).

These three principles combine together to form a false sense of will and authorship in random events. However, it is not only events that can be misattributed to oneself. People also have a tendency to misattribute thoughts and ideas of others as their own. Studies have been implemented in which participants falsely recalled ideas as their own, when they were actually thoughts of their experimental partner (Preston & Wegner, 2007). It would seem as though that our perception of will and authorship is quite susceptible to false attributions. During facilitated communication, false attributions run rampant when helpers falsely attribute their own typed messages to the autistic children they are helping (Jacobson, 1995). This causes a false sense of accomplishment for both the children and the helper, though no progress is being made.

The Role of Feedback

An important aspect of this illusion of authorship is the role of feedback from the body, such as visual and proprioceptive feedback. When we think of an action and then perform it, we usually see it happening. We think about moving our hand to grab a glass of water and then our hand moves and we grasp the glass. The visual and proprioceptive feedback validates our sense of authorship. The visual feedback seems to be so powerful that it can even cause false physiological sensations. Botvinick and Cohen (1998) poked a rubber arm that participants believed to be their own. Patients reported feeling sensations in their actual arm (which was hidden from their view) and some reported experiencing a sense of ownership to the arm. The researchers emphasized that visual and tactile feedback is sufficient for self-attribution to occur. In another study subjects were asked to move their hand in a particular manner while looking at a screen that would show them their hand. However, the experimenter's hand would be shown randomly instead of the subject's hand. The hand would either mimic the subject's movements, or make different movements. Subjects misattributed the hand as their own 30% of the time when the movements were similar to those of their own (Daprati et al., 2002). When participants were asked to draw straight lines, while simultaneously viewing their "drawings" on a screen, participants made slight deviations when the screen made it seem as if he/she were deviating from the straight line. When asked about the deviations, participants did not recognize or remember making the movements to counteract the small deviations they saw on the screen, but did remember when the deviations were larger. Proprioceptive feedback is important and is perceived, but only when deviations are 15° or more does the perceiver notice a change is being made. These findings suggest that initial movements and intentions are remembered, but the corrections made along the way go unnoticed (Fourneret & Jeannerod, 1998; Frith, 2005).

Feedback need not always come in a visual form. Physiological states have been used to "trick" patients into falsely believing psychological changes. Valins and Ray (1967) had participants with a snake phobia view a snake while listening to a calm heartbeat, which they were led to believe was his/her own heart, but actually was not. These participants were able to get physically closer to a live snake than the ones in the control condition. The participants were misattributing this physiological state (heartbeat) to themselves and this impacted the way they interacted with the snake. Similarly, Valins (1966) used the heartbeat of subjects to skew the attractiveness that subjects reported of various pictures of men and women.

Even though we do not always consciously will an action, it seems there are times when we feel we need to reason that we *did* consciously will the action, even if the reasoning is falsely self-attributed. In studies involving patients with alien hand syndrome, it becomes apparent that we do not always consciously will the actions of our bodies. Gazzaniga (1995) found that split-brain patients would create "left brain interpretations" about right hemisphere actions to which the left hemisphere had no awareness of the cause. Other research has argued that actions are not always willed because we are not consciously aware of the action until our brains are beginning to make electrical signals to make the movements. Libet, Gleason, Wright, and Pearl (1983) found that the brain begins to generate signals before patients are aware of their will to make a movement. They stated that actions are being unconsciously initiated and therefore cannot be "willed." It is important to note that recent research has found that this unconscious willing of action is false and that previous research did not provide evidence for unconscious decision (Trevena & Miller, 2010). As a result, the theories of the unconscious and conscious initiation of action are still open to debate.

Though the three principles (priority, consistency, and exclusivity) are generally viewed as being the necessary ingredients for illusions of authorship to occur, I respectfully disagree that the presence of all three must be present for the illusion to occur. Earlier studies found that when priority is no longer factored in (Knoblich & Prinz, 2001; Knoblich et al., 2002) that participants can still feel authorship retrospectively, without priority occurring during the authorship process. This finding leads me to believe that presenting visual feedback retrospectively to a participant will present a similar finding when velocity variations are removed to keep the movements constant. It should become difficult for a participant to distinguish his/her movements between accurate or warped depictions of a previous action.

In sum, I have reviewed the research as it relates to the "illusion of authorship" and false attributions of causation and will. Based on this research, I examine to the illusion of authorship and its applicability to the ownership of knowledge. Though Knoblich and his colleagues (2001/2002) had participants judge their drawings two weeks after the initial actions, I contend that only moments after the action has occurred, participants falsely attribute manipulated movements to themselves in the same manner as participants whose movements have not been manipulated. The movements made between the starting point and their answer will be forgotten, while only their answer and intention will be remembered, thus allowing the experimenter to manipulate the participant's sense of confidence and knowledge.

Metacognition

Metacognition, specifically metacognitive judgments, has been found to be of importance in guiding behavior (Nelson, 1996). By using metacognitive judgments of confidence in accuracy, we are able to assume that the judgments form a strong relationship with behavior and action. Koriat (1998) found that people blindly follow their own metacognitive judgments regardless of their accuracy on the questions. This sightless pursuit provides evidence that metacognitive judgments are an excellent predictor of one's behaviors. Based on this, one can be confident that the actions performed by participants accurately reflect their metacognitive states and a confidence judgment would not even be necessary if a relationship is found between arm movements and confidence ratings. The relationship will provide evidence to create a new metacognitive measurement using the Wiimote technology that will allow for an explicit measurement of the cognitive processes taking place during action and decision-making.

Experiment 1

An initial experiment was run to test the materials and to search for any trends that may be occurring. Reaction times, confidence ratings, x-flips (e.g., an "S"–shaped trajectory would contain 2 or more x-flips), and the ease of the questions were used to test the effectiveness of the chosen methods and materials. It was hypothesized that "easier" questions will have faster reaction times, higher confidence ratings, and fewer x-flips than the "harder" questions.

Participants. Participants included 10 undergraduate students from the University of Memphis who signed up using the psychology subject pool. Each received extra credit towards their introductory psychology course and each reported normal or corrected vision.

Interface display and device. The experiment took place in an oblong laboratory room (3.8 m x 1.8 m). An Epson LCD projector and Apple Mac mini were placed on a small 76 cm high table that stood approximately 2.7 m away from the long wall of the room. The Mac mini's display was projected onto the wall at the end of the room creating a display approximately 1.4 m in width (29.1° visual angle). Participants interacted with the experimental program by using the Nintendo Wii remote. Standing behind the table, participants held the Wii remote in their right hand that was approximately lined up with the projector's lens. The Wii remote interfaces with the Apple mini computer via a Bluetooth transfer protocol called DarwiinRemote (2006, Hiroaki Kimura). A Nyko infrared emitter at the base of the projected screen provided the remote with a frame of reference so that arm movements could be mapped isomorphically onto x,y pixel-coordinate movements (see Figure 1). MATLAB Psychophysics Toolbox (Brainard, 1997) was used to develop the experimental program and sample the Wii remote-controlled cursor movements as streaming x-y coordinates at approximately 80-90 Hz.

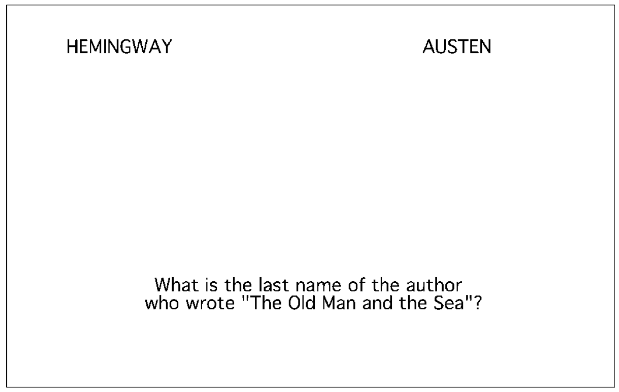

Figure 1. General Knowledge Example Question

Stimuli. This experiment used a trivia-style design. General knowledge trivia questions normed by Nelson and Narens (1980) were used to elicit arm movement trajectories. Ninety questions were chosen from the list of 300. These questions were then changed from open-ended questions to multiple-choice questions. Because the original norming of these questions may not hold for the present, due to the subject matter, we pursued a new norming. To achieve this, the questions were uploaded onto Amazon's Mechanical Turk. Twenty-five participants were paid $0.25 to answer the 90 questions and rate them on difficulty (easy or hard). After compiling the results, 30 "easy" questions and 30 "hard" questions were chosen for these experiments. The questions and answer choices were pseudo-randomized to eliminate any potential effects of order or pattern in the response options. A confidence scale was also created on MATLAB. Participants were then asked to rate their confidence of their performance on a Likert scale numbered -7 to +7.

Measures. The Wii remote is not fixed on a surface, as in computer-mouse studies, (Dale, Kehoe, & Spivey, 2007; Spivey, Grosjean, & Knoblich, 2005), but instead allows for free movement of the extended arm in which the remote is being held. This causes constant subtle fluctuations in the extended arm and hand. To account for these fluctuations, a small region around the starting point for each question was defined and the recording of arm movements began once the cursor left this "escape" region. Previously, Dale, Roche, Snyder, and McCall (2008) used a 100-pixel escape region and the same region was used for these studies. The movement of each participant's arm was tracked and recorded using the Wiimote. This not only allows for analysis of the actual movements, but is also the method by which the feedback can be collected and presented to each participant. The reaction time (the time from when the participant leaves the "escape region" and when he/she answers the question) was collected for analysis, as well as the ratings given by participants on each of question blocks.

Task. For experiment 1, participants were asked to answer a set of 60 trivia questions. The questions were displayed on the screen as described above with the question at the bottom of the screen and each answer option in the top two corners (see Figure 1). Participants clicked the "Start" button, initiating the first question. After the question had been answered the participants were told to click the "Rate" button, initiating the Likert screen. The screen displayed the question "How confident do you feel about your previous answer?" and below the question a Likert scaled numbered -7 to +7 was displayed (see Figure 2). Participants would simply click the number on the Likert scale that best reflected his/her level of confidence. After the confidence had been rated, a "Next" button was displayed that would initiate the subsequent question. When all 60 questions had been answered and the confidence ratings were fulfilled, the experiment was complete. Participants were then debriefed and given a copy of the informed consent.

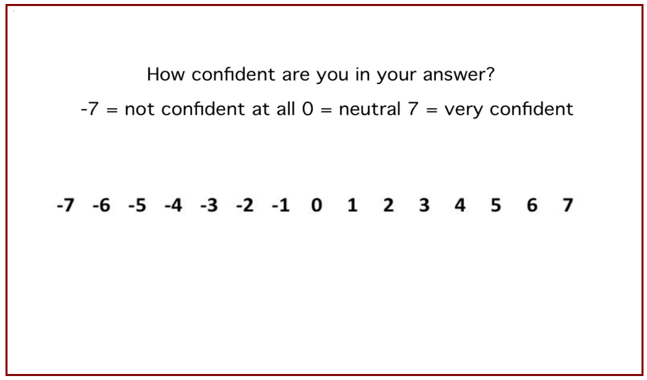

Figure 2. Likert Scale for Confidence Rating

Results

A linear mixed-effects regression was run using confidence ratings at the outcome variable and question ease as the predictor variable. There was a significant effect of question ease (i.e., whether the question was categorized as "easier" or "harder") on the confidence ratings reported by the participants, $F(1,598) = 72.44$, $p < 0.001$. The "easy" questions had higher confidence ratings (for means see Table 1).

A second test was run in order to examine other relationships among the variables. A linear mixed-effects regression was run using reaction time (i.e., the total time from when the question presented until an answer was chosen) and question ease. There was a significant effect with easier questions having shorter reaction times, $F(1,598) = 15.43$, $p < 0.001$.

A final test was run to test any relationship between trajectories (x-flips) and question ease. Previous research has found a link between number of x-flips and complexity of cognitive process (Dale & Duran, 2010; Dale et al., 2008; Duran, Dale, & McNamara, 2010). A linear mixed-effects regression was run using x-flips (i.e., when the direction of the trajectory shifts across the x axis) and question ease. There was a significant effect with easier questions having fewer x-flips, $F(1,598) = 17.82$, $p < 0.001$.

Discussion

The results from experiment 1 support the methods used. The results are indicative of the relationship between metacognitive judgments and action. As predicted, the "easy" questions had faster reaction times, higher confidence ratings, and fewer x-flips. One can be confident that the chosen methods allow the metacognitive states of participants to be analyzed without an explicit questioning of such. It also allows for an accurate analysis of the cognitive processes taking place during the decision-making and actions being made. The patterns found in this experiment serve as an index of metacognition by using arm movements. With no trepidation regarding the trajectories' reflections of confidence and self-action, the chosen methods can now be applied to the illusion of authorship and knowledge.

Table 1

Group means for X-Flips, Reaction Time (in seconds) and Confidence Ratings (in pixels)

	Experiment 1		Experiment 2	
	Easy	Hard	Easy	Hard
X-Flips	10.05	12.80	13.66	16.32
Reaction Time	5.05	6.10	5.38	6.30
Conf. Ratings	226.57	60.13	255.20	21.20

Experiment 2

A second experiment was run in order to test the theory of illusions of authorship and its application to an illusion of knowledge. The chosen methods were shown to successfully reflect participants' metacognitive states in answering general knowledge questions in relation to self-made actions in the form of arm trajectories. It was hypothesized that participants will report higher ratings of confidence in conditions in which their trajectories have been warped to reflect a higher level of confidence.

Participants. Participants included 30 undergraduate students from the University of Memphis who signed up using the psychology subject pool. Each received extra credit towards their psychology course, and each reported normal or corrected vision.

Interface display and device. The same display and devices used for experiment 1 were used for experiment 2.

Stimuli. The same pseudo-randomly ordered set of 60 questions and Likert scale from experiment 1 were used as the stimuli for experiment 2.

Task. Participants were informed that they would answer five blocks of 12 trivia questions with a total of 60 questions altogether. They were then told that after each of the 12-question blocks, they would receive feedback on their performance and were asked to rate their confidence on each question. Once participants were clear on the instructions, the experiment began. Trials began with a display containing the word "Start" and the participants pointed and clicked on "Start" using the Wiimote to initiate the experiment. Two answer choices (one correct and one incorrect) at the top left and right position of the screen appeared and a trivia question appeared at the bottom center of the screen. The participants then moved the Wii remote cursor to the answer they wished to choose for the question.

The questions were split into five blocks containing twelve questions. After completing each block, participants were presented with feedback regarding the previous 12 trials. Participants were presented with each question from the completed block. The question was presented on the screen and the participant's arm trajectory was "drawn" onto the screen to show the participant how he or she answered. A Likert scale (identical to the one used in the previous experiment, figure 2) was presented and participants clicked on the number that best represented their feeling of confidence in his or her answer. Once feedback had presented and the Likert scale had been answered for each question, the participants began the next block of questions.

Once all 60 questions were answered, a screen appeared displaying the words "Begin Part 2." New instructions were given to the participants regarding the second part of the experiment. Participants were told that they would now see four questions they answered correctly along with their trajectory on each question. After reviewing the question they were asked to pick which of the four possible answers best explained why they chose their answer. The four answer choices were then presented on the screen: "Learned in class," "I guessed," "Not Sure," and " Past Experience." Participants chose an option and the next question was then presented. Once all four questions were reviewed and answered, the experiment ended.[1]

Manipulation. Two conditions were used in this experiment: "Neutral" and "Confident." Throughout the experiment, one-third of the questions were randomly

[1] A short pilot study originally had this second part as an oral self-report. The answers were counted and these four answers occurred more often than any others.

chosen by MATLAB. These randomly chosen questions were part of the experimental condition. When the feedback was presented to the participants, the questions from this condition were “warped.” The trajectories were morphed by a set of algorithms to reflect a “confident” trajectory (straighter, and moving directly to the participant’s chosen answer). The mean of the x,y coordinates of the original trajectory was compared with the mean of a straight line, with the straight line being weighted more heavily. The correctness of the participants’ answers was kept the same, with only the trajectory being manipulated. The remaining two-thirds of the questions were part of the “neutral” condition. The trajectories for these questions consisted of the participants’ trajectories in their natural form, with no warping taking place. These questions served as our control trials.[2]

Knoblich et al. (2001) found velocity to be of great importance. To ensure that the participants were exposed to their own subtle trial-by-trial modulations of velocity, the warping was applied to the participants’ actual trajectories, and not simulated trajectories. By having the questions randomly chosen and warped, each participant received an equal opportunity to be presented with both types of trajectory confidence levels (confident and neutral). In order to look at the proportions of false attributions of knowledge, four additional questions were presented to participants in a second part of the experiment. These questions were randomly chosen from the questions that the participant answered correctly in the first part of the experiment. Two of the four questions had been previously warped in the confident condition and the other two were chosen from the

[2] The original design of this experiment contained three conditions: “neutral,” “confident,” and “unconfident.” The unconfident trajectories were to be warped to reflect an unconfident style trajectory (containing more x-flips, and a movement towards the opposite answer). However, due to a MATLAB programming error, this condition was inactive and never warped any of the randomly chosen questions, resulting in 2/3 of the questions being “neutral.”

neutral condition. By choosing only correct answers, we can more accurately assess to what extent the confident movements influence the participant's beliefs about what he/she "knew."

Analysis. In order to statistically analyze the variables and relationships, mixed-effects models were used. The manipulation and warping of arm trajectories were used as predictors in different analyses. The second part of the experiment was analyzed using a logistic regression to examine any potential relationship between the condition of the warping for each question and the answer chosen by participants (i.e., do the chosen answers predict which condition the feedback was from?).

Results

In hopes of obtaining similar patterns found in Experiment 1, the same analyses were run first using the same variables (number of x-flips, reaction times, and confidence ratings) before the new variables (conditions of arm trajectory warping) were analyzed. A linear mixed-effects model was used with confidence ratings as the outcome variable and question ease as the predictor variable, inputting subject as a random factor. There was a significant effect of question ease (i.e., whether the question was categorized as "easy" or "hard") on the confidence ratings reported by the participants, $F(1,1798) = 373.68$, $p < 0.001$.

Another linear mixed-effects model was run using x-flips (i.e. when the direction of the trajectory shifts across the x axis) and question ease. There was a significant effect with easier questions having fewer x-flips, $F(1,1798) = 30.07$, $p < 0.001$ (for means see Table 1).

An additional linear mixed-effects model was run using reaction time (i.e., the total time from when the question presented until an answer was chosen) and question ease. As in Experiment 1, there was a significant effect with easier questions having shorter reaction times, $F(1,1798) = 26.53$, $p < 0.001$.

With confidence that the initial relationships in Experiment 1 were consistent in Experiment 2, new analyses can be run to test the effects of Experiment 2's manipulation. A linear mixed-effects model was employed to test the effect of condition ("neutral," and "confident") on the confidence ratings of participants. There was a nonsignificant effect with condition as a predictor variable, ratings as the outcome variable and subject as a random factor, $F(1, 1798) < 1$, $p = 0.68$ (see Table 2 for means).

Though confidence ratings did not differ significantly across the conditions, a linear mixed-effects model was used to see if condition caused a great number of x-flips during the rating process. With subject as a random factor, rating x-flips was input as the outcome variable and condition as the predictor variable. The effect was nonsignificant $F(1, 1798) = 1.659$, $p = 0.20$ (see Table 2 for means).

For the second part of the experiment, a logistic regression was run with condition as the outcome variable and the four answer choices as the predictor variables to see if a particular response predicted which condition the feedback represented. The full model containing all predictors was not statistically significant, $\chi^2(3, N = 84) = 0.674$, $p = 0.879$. The answer chosen by participants had no relationship to the condition of the warping for that question.

Table 2.

Group means for Confidence Ratings (in pixels) and X-Flips during rating.

	Experiment 2	
	Neutral	Confident
Confidence Ratings	142.71	136.70
Rating X-Flips	2.76	2.94

Discussion

This experiment attempted to examine the ability to use self-action perception in the form of visual feedback to influence a sense of confidence in knowledge. In the second experiment, the same patterns were found as those in Experiment 1. The "easy" questions had fewer x-flips, shorter reaction times and higher confidence ratings. These findings replicate those obtained in Experiment 1. An important relationship was discovered between arm movements and metacognition. The arm movements accurately reflect metacognition in real-time. However, the new variable and manipulation added for Experiment 2 yielded no significant results. In the current design, manipulating the self-action feedback did not affect participants' sense of confidence in performance and knowledge.

In regards to the second part of the experiment, it was found that the warping had no relationship with the answers given by participants. Warping the trajectories did not alter the sense of knowledge (the participants' tendency to answer "learned in class" or "past experience" for a feeling of knowledge rather than answering "guessed" or "not sure" for no feelings of knowledge). As we discuss below, there may be reasons the experiment did not display self-action perception effects.

General Discussion

The main focus of these experiments was to examine the impact of self-action perception on the feeling of knowing and metacognition. Does the illusion of authorship hold when a feeling of priority is retroactively induced? This is an important psychological phenomenon to examine due to its applicability in education, particularly with intelligent tutoring systems. If providing feedback to students can affect their confidence and ideally increase their accuracy, then it could be easily incorporated into tutoring systems to improve learning.

By using a dynamic approach, the real-time unfolding of the cognitive system cannot only be tracked via the Wiimote, but then can also be used as feedback to give participants an accurate account of his/her performance. Feedback in various forms has been found to have an impact on perception, fear, metacognition and other psychological issues. Feedback from the environment plays a crucial role in the illusion of authorship, and it must be included in some way to give participants information regarding the actions and decisions they have just made. Manipulating this feedback was hypothesized to influence the sense of knowledge and confidence in participants. It was predicted that (1) arm movements will serve as signatures for metacognition (Experiment 1) and (2) that perception of arm movements should influence that metacognition (Experiment 2).

In both experiments, a dynamic motor pattern was found that reflected metacognitive reports of confidence in performance. Trajectories that were faster and contained fewer x-flips were indicative of the participants' confidence. These trajectories correlated with higher ratings of confidence in both experiments. This finding supports the design of the study and the assumption that the pattern of arm trajectories reflects the cognitive processes in action. The pattern of an arm trajectory can accurately reflect the cognitive state of the individual in real-time and obtaining the individual's self report becomes unnecessary. To our knowledge, this is the first demonstration that collateral movement variables, like reaching behaviors, can serve as indices of metacognitive states.

Flaws in the experiment's design and execution can account for the Experiment 2's nonsignificant effect. When presenting the trajectories to the participants there was an inconsistency with the velocity and shaping. Though none of the participants reported "anything strange" about the trajectories in an informal post-experiment interview, the "confident" trajectories were easily distinguishable from the "neutral" trajectories and could have been indicative that the trajectories were unnatural. Attempting to straighten the trajectories for the "confident" condition was difficult due to the variability of participants' movements. Variations in x-coordinates caused a significant slowing of the trajectories' speed. This problem can be fixed for future experiments by altering the algorithms used for the warping and reducing the sampling rate of the trajectories. A procedure known as "down sampling" will reduce the number of x,y-coordinates to be drawn on the screen and will speed up the trajectories, making them comparable to the "neutral" trajectories. Down sampling does not alter the configuration of the confident trajectories, but instead alters the velocity.

Another error in this study is the uneven data. Only one-third of the data in Experiment 2 came from the experimental condition. Having a greater amount of the control condition (“neutral”) does result in less variance for that condition, but it does not maximize the benefit of the within-subjects power that was sought. By increasing the number of experimental trials, more data can be included into the analyses and more variance can be accounted for, perhaps leading to different outcomes in the results of the first part of the experiment. The second part of the experiment was unaffected and enough trials remained as they were originally designed; yet still no influence was found.

Though the purpose was to study the impact on an implicit level, participants could have been trained on trajectories. Rather than train participants on these patterns, these experiments were designed to examine the implicit nature of feedback without prior knowledge of a prototypical “confident” trajectory. If participants had been aware of the that arm trajectories were indicative of confidence and cognition, the results of this study may have been different, but would have reflected the participants’ perception of the feedback as they had been trained. The purpose of our design was to test the potential implicit influence of arm movements on metacognition. In an informal post-experiment interview, participants were asked if they were aware of what the trajectories indicated. Most reported accurately perceiving it as the “way I moved my arm” with only a small portion (5 participants) reporting paying no attention to the feedback or having no thought of the trajectories. These participants were still included into the analyses because of the study’s emphasis on implicit perceptions of the feedback.

Though Valins (1966) found significant results when using heart rates as feedback, heart rate is a more widely known indicator of physiological and psychological being. With the increasing popularity of the Nintendo Wii and its use of the motor movements and feedback, the population will become more experienced in perceiving self-made actions. With this new awareness of body and motion comes a greater awareness of the impact that actions have on the environment. Unfortunately, a lack of knowledge regarding significant patterns found in trajectories may also account for the nonsignificant effect impact of the feedback.

For future studies, the MATLAB scripts can be refined to more accurately account for variations in arm trajectories to obtain a more normalized and consistent manipulation. Standardizing the velocity across conditions is important for minimizing any cues that any one trajectory is different from another other than the path taken from question to answer. The inclusion of unconfident trajectories is a goal for future studies. Perhaps confident trajectories don't seem to differ from neutral trajectories due to the natural variations of arm trajectories, but they may differ from unconfident trajectories in which a prototypical pattern differentiates the two conditions. Currently, these modifications have been made and a new experiment is underway in hopes of correcting for the issues of Experiment 2. Once these adjustments have been made and data are collected, then a clearer picture can be painted about the induction of the illusion of authorship in a retroactive perceptual fashion.

It would seem that the illusion of authorship and magical thinking are more complex than originally believed. Much of magic and puppetry can be explained by perceptual trickery, which when revealed, seems so simple and logical. Yet, we still fall victim to this trickery. Though Wegner and Wheatley (1999) argue that an illusion of will or authorship can be created by a simple combination of specific elements, this research would point to a more intricate pathway from intent to a belief of authorship.

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