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VOLITION

Metacognition of agency: proximal action and distal outcome

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Abstract The cues contributing to people's metacognitions of agency were investigated in two experiments in which people played a computer game that involved trying to "touch", via a mouse moving a cursor, downward scrolling X's (Experiment 1), or trying to "explode" the downward scrolling X's (Experiment 2). Both experiments varied (a) proximal action-related information by either introducing or not introducing Turbulence into the mouse controls and (b) distal outcome-related information such that touched X's "exploded" either 100 or 75 % of the time. Both variables affected people's judgments of agency (JOAs), but the effect was different. First, the decrement in feelings of agency was greater with the proximal variable than with distal variable. Second, while the proximal variable always had a large direct effect on JOAs, even taking judgments of performance (JOPs) into account, JOPs completely accounted for the effect of the distal variable in Experiment 1, where the instructions were just to touch the X's. And even in Experiment 2, in which the instructions were to explode the X's, the direct effect of the distal variable on JOAs was small. These data indicate that these two cues exhibit different psychological profiles. The proximal action-related information is a diagnostic cue to agency indicating the match between one's own intentions and actions. Internal monitoring of intentions is necessary and so the self is implicated. However, distal outcome can be largely monitored using information external to the agent, and so—while it is used by people to make agency judgments—it is a non-diagnostic cue.

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Introduction

While there is considerable agreement about the importance of the construct of metacognition of agency, there is much dispute about what it means. As Gallagher (2007) pointed out upon reviewing both theories and brain-imaging experiments: "There is no consensus about how to define the sense of agency" (p. 1). Some sources define agency as the "capacity of a person or entity to act in the world" or the "capacity, condition, or state of acting or of exerting power" (Wikipedia and Merriam Webster, respectively). These views put forth that it is the proximal, action-related information alone that contributes to our sense of agency, with no mention of the consequences of the action. Other views would have the distal outcome also be part of the definition (Anscombe 2000; Van der Wel and Knoblich in press). For example, Pacherie (in press) says that agency is "the sense that we are in control of our actions *and their effects*, that we are the doers of our deeds" (emphasis added).

Danto (1965) distinguished between a basic act and the effect of that act. As an illustration of this distinction, Joseph (2004) asks the reader to consider whether Booth's act was squeezing the trigger or killing Lincoln—events that happened at different times. A more benign example would be a person moving his or her finger to press a button that turns on a light. Is the action over which the person is the agent the pressing or the illumination? Given that there can be a distinction between the movement of the finger to press the button (a proximal action) and the light turning on (a distal outcome)—the question we address here is: to what extent do each of these contribute to the person's sense of agency?

Metacognition of agency resulting from proximal action monitoring

Strawson (2003), quoting Davidson concerning large-scale bodily action, says: ‘We never do more than move our bodies; the rest is up to nature.’ Although Davidson (2001) notes that acts are often retrospectively identified by their consequents, each such act can also be described as the more basic action involved in moving our bodies. What the outcome is, then, according to this view, is *up to nature,* not the mover. Although the outcome may be intrinsic to the reason for the action in the first place, the person has agentic control over the movement alone, and not the outcome. If this argument is correct and applies to people’s actual feelings of agency rather than only to what they ‘should’ feel, then people’s sense of agency should depend only on their control of their proximal actions (i.e., their motor movements), with distal outcome variables (i.e. consequences of their actions) being irrelevant except insofar as they are directly related to monitoring movement.

There is little debate that our volitional motor actions are the result of motor intentions and plans that exert control over our muscles. This movement system appears to be strongly related to people’s feelings of agency. There is a considerable literature investigating situations in which the doer’s apparent movements fail to correspond with what was intended. In these studies, healthy participants generally experience a lack of agency and may attribute control to either random circumstance or to another agent (e.g., Chaminade and Decety 2002; Farrer and Frith 2002; Farrer et al. 2003; Leube et al. 2003; Wegner et al. 2004; Balslev et al. 2006; Decety and Lamm 2007; David et al. 2008; Farrer et al. 2008; Haggard 2008; Haggard and Tsakiris 2009; Spengler et al. 2009).

Formal models of motor control have had success in accounting for people’s feelings of agency in relation to motor movement. Wolpert and colleagues (Wolpert 1997; Miall and Wolpert 1996; Wolpert et al. 1995), for example, have proposed a brain-based framework for motor control that relates in a natural way to people’s metacognitions of agency. This ‘comparator’ framework was originally devised to explain how people make fine-grained corrections of motor movements. According to the framework, when people have a goal (such as moving their finger to a particular spatial location), they generate motor plans based on their intentions using an inverse model. They also generate expected consequences of the intended action based on a copy of these motor plans using a forward model. Once the motors plans are executed, a comparator mechanism evaluates the correspondence between the actual and predicted consequences of the action. If there is a match, no motor adjustment is needed (and temporal binding occurs, see, Haggard et al. 2002, as well as signal attenuation, see, Blakemore et al. 2000). If there is a discrepancy, a signal is sent to the motor system indicating that the movement needs to be adjusted. Note that this model depends upon the person having a goal, but the goal is conceptualized in terms of the proximal action not the distal outcome.

The comparison signal which flags whether there was or was not a discrepancy can be used to inform metacognitive judgments of agency (JOAs) (Blakemore et al. 1999; Blakemore and Decety 2001). The discrepancy is used as a cue indicating that something was interfering with the intended action: the person was not in complete control. For example, if an earthquake occurred just as the person was trying to press the light switch, then the person’s expectation for his or her own motor actions and the resultant movement that occurred could fail to match. The discrepancy detected by the comparator could be fed into a conscious assessment process, leading to the person consciously perceiving a lack of smooth agency.

Similarly, Wegner (2002) argues that people experience agency when a thought, which is consistent with an action, appears in consciousness prior to the action and is not accompanied by other conspicuous causes. This view is compatible with results showing that priming of the proximal goal can enhance people’s feelings of agency (see, e.g., Wegner and Wheatley 1999; Sato 2009; Wenke et al. 2010; Gentsch and Schutz-Bosbach 2011; Chambon et al. 2012). Experiments that have investigated this idea have focused on proximal action rather than distal outcomes.

Results of several lines of investigation indicate that the conscious judgment of agency is retrospective to the action (see, e.g., Synofzik et al. 2008). Fourneret and Jeannerod (1998) showed that people can correct their actions without explicit knowledge of how they did so—suggesting a dissociation between the motor correction and the conscious knowledge. Knoblich et al. (2004), too, showed a dissociation between the motor correction process and conscious awareness of that process. Miele et al. (2011) showed that while the online brain correlates of movement discrepancy were observed in the right temporal parietal junction, there was a separate retrospective anterior frontal correlate that occurred when people were making conscious JOAs. Lau et al. (2007) showed that the judgment of intention can be interfered with by the application of TMS *after* the motor movement is complete—a finding that is difficult to explain unless the judgment process was retrospective. These results all point to the separation of the online processing of the discrepancy and its use in making the retrospective JOA. But given that JOAs *are* retrospective, it is possible that cues other than proximal action-related information affect them.

Metacognition of agency resulting from distal outcome monitoring

In the real world, actions have consequences. The light goes on when the switch is pressed. Lincoln died as a result of the trigger having been squeezed. Theorists interested in self-efficacy, self-fulfillment, and well-being allude to such distal outcomes in relation to agency. This kind of agency is thought to be central to effective functioning and mental health (Seligman 1975; Bandura 1989, 1996, 2001; Deci and Ryan 2000). By these views, responsibility for and feeling of agency over consequences is essential. But while people are able to perceive differences in outcome contingencies (Alloy and Abramson 1979; Jenkins and Ward 1965), it is not clear whether distal outcome variables have the same effect on people's feelings of agency as do factors affecting their proximal control of actions.

The first question investigated here is whether distal outcomes figure at all into people's JOAs: Can they be ignored? And, if not, how much unique variance in JOAs do they account for when controlling for judgments of performance (JOPs) and proximal actions? Rather than attempting to define people's metacognition of agency in an a priori manner, this question is addressed empirically by manipulating the probability of an action having a particular effect and also by manipulating (across separate experiments) the goal of the participants with respect to that effect. Perhaps people assess their own agency in terms of their control over proximal actions alone, and distal outcomes do not matter. As noted above, one can make a compelling argument that outcomes should not matter, since they proceed 'by nature' and not by the person's own direct efforts. But that does not tell us whether outcomes contribute or do not contribute to the individual's *perception* of his or her own agency. If they do affect people's JOAs, then it may be asked whether proximal action variables and distal outcome variables make the same contribution to JOAs—with the effect of perceived performance factored out—or whether one is more dominant than the other. Finally, we may ask whether these two potential cues to agency have the same or different psychological signatures?

A procedure was used whereby participants moved a mouse to touch downward falling X's and avoid downward falling O's, as in past research (e.g., Metcalfe and Greene 2007). Within this paradigm, a number of proximal variables, such as the introduction of turbulence into the mouse controls, have been studied (e.g., Metcalfe et al. 2010). The new variable introduced here was a distal variable—the probability (75 vs. 100 %) of the X's exploding when touched. In the 75 % condition, when the X's failed to explode, they just continued on their trajectory as if nothing had happened (though, of course, the participant could see that the cursor had touched the target). The 75 % outcome condition was designed to decrease the probability of the target exploding to the same level that the introduction of the particular amount of turbulence in our experiment decreased performance. The manipulation of outcome allowed investigation of the impact of the distal variable on people's feelings of agency, while, so far as possible, holding their behavior constant by making it impossible for them to know in advance whether the particular X they were about to touch would explode or not, and also by equating as closely as possible the distal effect (of explosion of the X's) to the effect of the proximal variable (turbulence) on performance.

The proximal variable (which was crossed with the distal variable as part of a factorial design) was the presence or absence of turbulence in the control of the mouse. We have tested the effect of this manipulation on people's JOAs extensively in previous experiments. Adding turbulence results in decrements in people's JOAs—a consistent finding in all experiments and populations tested (Metcalfe and Greene 2007; Metcalfe et al. 2010; Miele et al. 2011), except patients with schizophrenia (Metcalfe et al. 2012).

Experiment 1 and 2 varied only in the instructions given to participants. In Experiment 1, participants were instructed to focus on the proximal action of touching the X's and were also told that the distal outcome did not matter. This first experiment allowed investigation of whether people can ignore the (highly salient) distal outcome if it is not part of their explicit goal. In Experiment 2, participants were told to explode the X's, and so both the action and the outcome were relevant. The contrast of the two experiments—which were otherwise alike—allows investigation of whether an explicit focus on the distal goal changes its influence on people's assessments of their own agency.

Experiment 1

Experiment 1 was designed to examine whether people could ignore the distal outcome if they were given a specific goal indicating that it was the motor movement that was crucial, not the outcome of that movement. Accordingly, participants were explicitly instructed that they should be concerned only with touching the X's, and not with making them explode. If people could discount the distal outcome in making JOAs, then the expectation was that JOAs would be affected only by the proximal action (Turbulence) manipulation and that the outcome variable would have no effect.

Methods

Participants

The participants were 21 Columbia University and Barnard College students who either received course credit or pay for participating. Data from 4 participants were eliminated from the analyses. Three were non-native speakers, and the fourth was a native English speaker who misunderstood (or did not read) the instructions. Over these 4 participants, O's were touched an average of 11.14, 8.81, 9.33, and 9.90 times per trial, and X's were touched only 2.38, 2.33, 1.48, and 2.05 times. None of the other 17 participants (7 M, 10 F between the ages of 18 and 28, mean age: 20.12) reversed the X's (the hits) and O's (the false alarms). The procedures described here conformed to the guidelines of the APA concerning the protection of human subjects and were approved by the Columbia Internal Review Board.

Apparatus

All experiments were conducted on iMac computers, each of which included a mouse and mouse pad. Participants were tested individually.

Instructions

The instructions given to participants were:

"Throughout this experiment you are going to play a game in which you will use a mouse to move a box left or right. Your job is to touch all of the X's as they come into range and to avoid touching any of the O's.

On half of the trials, every X you touch will pop and make a sound. On the other half of the trials, the X's will pop and make the sound only 75 % of the time. 25 % of the time nothing will happen even if you touched the X.

The computer knows, and is keeping track of, whether you have touched each X, regardless of whether it produces a popping response to the touch or not. Whether you actually touched or not is what the computer will compute as your performance. We are interested in whether you, also, know whether you touched the X's or not, regardless of whether it popped.

You will be asked to make a judgment of performance after each trial, as well as a judgment of control. Please make your judgment of control based on how much control you felt you had. But when you make the judgment of performance, please make it based on how many X's you actually touched (trying to approximate what the computer will say is your performance) and disregard whether the X's popped or not.

Here is a practice trial."

Program

The reader needs to imagine a 4.5-inch vertical lane on the computer screen containing randomly scattered white X's and O's scrolling vertically downward at a constant rate, and the participant using the mouse to move a gray box (or cursor) horizontally along a track that spans the width of the lane toward the bottom of the screen. Touching an X with the gray box usually resulted in the X flashing red and then disappearing. The flash was accompanied by a sharp, but not unpleasant, sound similar to that of a crystal wine glass being struck. However, 25 % of the time in the 75 % outcome condition, a touched X would simply pass through the bar as if it had not been touched. Whenever a false alarm was committed (i.e., an O was touched), a boop sound occurred. Past experiments with a similar program (Metcalfe and Greene 2007) showed that it made no difference whether the X's or O's were designated as hits, and so in this version X's were always the designated target. When either an X or an O got to the bottom edge of the lane, or when a disappeared target virtually got to the bottom, the program redrew it at the top of the screen, but in a random position (horizontally) rather than in the same position it had previously occupied. Once redrawn at the top, it fell downward at the same rate as the other scrolling X's and O's. The program also recorded the movement of the mouse and the position of the onscreen cursor about every 34–58 ms (51 ms on average).

In the No Turbulence conditions, there was no discrepancy between the cursor position and the mouse position. In the Turbulence conditions, pseudo random noise (−50 to 50 pixels) was added to the position of the cursor each time the computer program updated the game's graphical display (about every 34–58 ms; 51 ms on average). A smoothing function was employed so that the movement of the cursor did not appear too jerky.

In the 100 % condition, the X's exploded when touched 100 % of the time. In the 75 % condition, the X's did not explode when touched for a randomly determined 25 % of the cases. All trials were either in the 100 and 75 % condition, so that on all trials the X's exploded most of the time.

Procedure

Participants practiced both playing the game and making judgments. During the practice trial of the game, which lasted for 15 s, the X's turned red upon being contacted 100 % of the time and seemed to 'explode' and then disappear as soon as participants touched them. The explosion was accompanied by a pleasant sound, much like a crystal wine glass being struck. If participants did not touch an X's, it simply continued to scroll downward past the cursor track. If an O was touched (a false alarm), a soft bonk sound occurred. On each trial, there were 15 O's and 20 X's.

After the practice trial, participants made a JOA (i.e., a judgment of how in control they felt), followed by a JOP (i.e., a judgment of how well they thought they had done on the trial). These judgments were made by moving a brightly colored indicator bar to the desired point along a clearly marked visual analog scale. The scale was continuous and the participants could move the indicator to any point along it. This indicator bar was blue for the performance judgments and red for the agency judgments. The far left of the bar was coded in our data as 0; the far right was coded as 100, with values in between being assigned a proportional value on a linear scale. The experimenter checked to be sure that the participants understood how the scales worked by having them report what each judgment meant, both during the practice trial and at the end of the experiment. After the practice trial, the experimenter asked if there were any questions, and if there were, answered them. Once the participants affirmed that they were ready to begin, they hit the continue button and went through 20 trials of the game (15 s each), while making JOAs and JOPs after each trial. At the end of the experiment, participants were questioned about what they had done, debriefed, given credit or pay, and thanked.

Design

The experiment was a 2 × 2 factorial within-participants design. The proximal variable was called Turbulence. In the Turbulence conditions, a random discrepancy (described in more detail below) was introduced between the participants' mouse movements and the movement of the cursor on the screen. In the No Turbulence conditions, no discrepancy was introduced. The distal variable was called Outcome (either 100 or 75 %). In the 100 % conditions, touching an X produced an 'explosion' 100 % of the time. In the 75 % conditions, touching an X produced an 'explosion' only 75 % of the time. There were 5 trials in each of the 4 conditions. These trials were blocked in a quasi-random manner, such that all 4 conditions occurred before the next block began. For most analyses, data from the 5 trials in each of the 4 conditions were collapsed. The condition in which there was No Turbulence and the X's exploded 100 % of the time served as a control condition (because participants were expected to report maximal agency under these circumstances). It was the same as a condition used to assess the effects of agency manipulations in past experiments.

The most important dependent variable was judgment of agency (JOA): How in control did people think they were? People's judgments of performance (JOPs) were also analyzed: How well did they think they performed on the task? We also computed hit rate (as a measure of actual performance) and 'explode' rate (which, in the two 75 % conditions, differed from hit rate). Since past research has shown that false alarm rate has little effect on either judgments of agency or performance in this paradigm (see Metcalfe and Greene 2007), it is not reported. Finally, the amount of mouse motion on each trial was recorded, as was the position of the cursor at each ~34–58 ms interval (51 ms on average) during all trials. These variables are not reported here in detail, though horizontal mouse motion is included in the regression analyses described below.

Results

Effect sizes are given as partial eta squared, which will be designated E, in the results that follow. All effects that reached $p < .05$ are reported. ANOVAs are based on means that were computed by averaging across all five trials in each of the four conditions, for each participant.

Hit rate

The main effect of Turbulence was significant, $F(1,16) = 131.53$, $\mathrm{MSE} = 55.19$, $p < .001$, $E = .89$, such that hit rate was higher with no turbulence than with turbulence. Neither the effect of Outcome, nor the interaction between Outcome and Turbulence was significant. These results are presented in the left panel of Fig. 1.

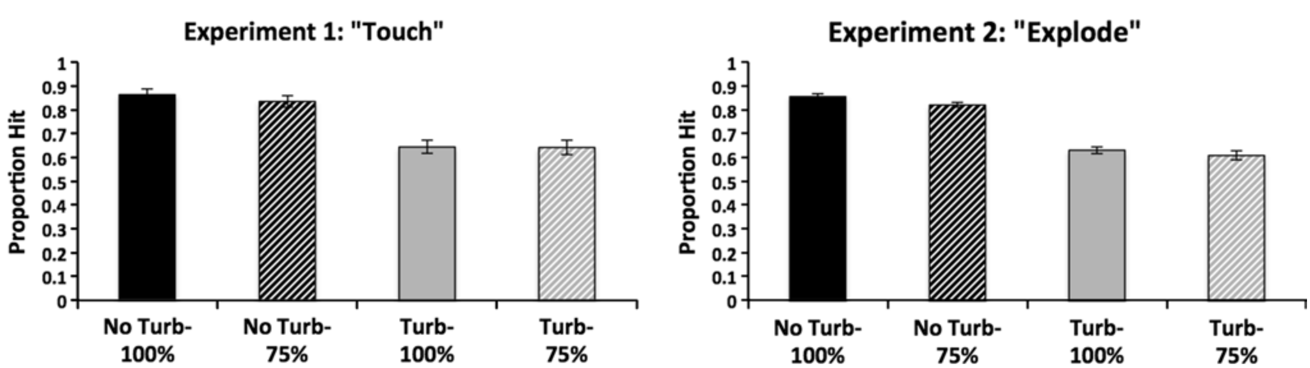

Fig. 1 Hit rate for Experiment 1 and 2. A hit was credited if the participant touched the X, regardless of whether it exploded or not. Note that the only difference between the experiments was that in Experiment 1: "Touch", participants were told that their goal was to touch the X's and avoid the O's, and that it did not matter whether the X's exploded or not, whereas in Experiment 2: "Explode", participants were told that they should explode the X's. In the 75 % outcome condition, the X's exploded only 75 % of the time, whereas in the 100 % outcome conditions, they always exploded when touched

Explode rate

Figure 2, left panel, shows the rates at which the X's exploded. There was a main effect of Turbulence, such that the explode rate was higher in the conditions with No Turbulence than Turbulence, $F(1,16) = 102.99$, MSE = 52.01, $p < .0001$, $E = .87$. There was also, of course, a main effect of Outcome such that the explode rate was higher in the 100 % as compared to the 75 % conditions, $F(1,16) = 292.18$, MSE = 24.07, $p < .0001$, $E = .95$. There was an interaction between Turbulence and Outcome, $F(1,16) = 6.35$, MSE = 48.99, $p = .023$, $E = .28$. The two conditions in which performance was decremented by different means—Turbulence 100 % and No Turbulence 75 %—were compared. There was no difference in explode rate between these two conditions, $t(16) = 1.35$, $p = .19$, n.s.

Judgments of agency

As is shown in Fig. 3, left panel, there was a main effect of Turbulence, $F(1, 16) = 114.39$, MSE = 213.19, $p < .0001$, $E = .88$, on people's JOAs. The effect of this proximal variable on JOAs has been found many times before and was unsurprising. More importantly in the present context, even though people were told to ignore the consequences of their actions, there was also a significant main effect of the distal variable, Outcome, $F(1,16) = 19.51$, MSE = 36.29, $p < .0001$, $E = .55$. People felt more agentic in the 100 % than the 75 % conditions. There was no interaction between Turbulence and Outcome. The fact that there was a main effect of Outcome indicates that despite the elaborate instructions telling people that only *touching* the X's mattered and that it did not matter whether they exploded or not, people were unable to ignore the distal variable.

JOAs were compared in the No Turbulence-75 % condition and the Turbulence-100 % condition—conditions with equivalent performance. The JOAs were much higher in the No Turbulence-75 % condition (69.74) than in the Turbulence-100 % condition (38.32), $t(16) = 8.48$, $p < .0001$.

Judgments of performance

JOPs are shown in the left panel of Fig. 4. Unlike the pattern shown in Fig. 1 for the hit rate, the JOPs took into account whether or not the X exploded—the distal variable. In addition to a main effect of Turbulence, $F(1,16) = 94.81$, MSE = 125.58, $p < .0001$, $E = .86$, there was also a main effect of Outcome, $F(1,16) = 21.75$, MSE = 49.67,

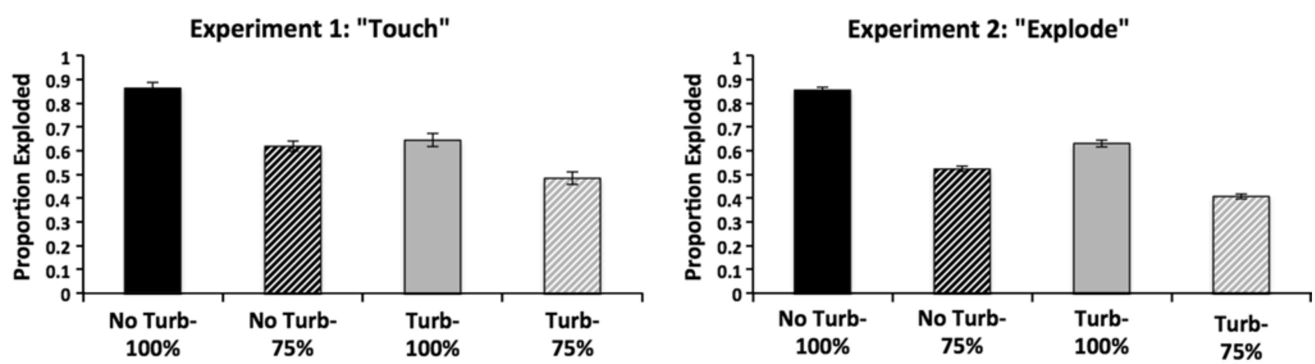

Fig. 2 Explode rate was credited only if the touched X exploded, for Experiments 1 and 2

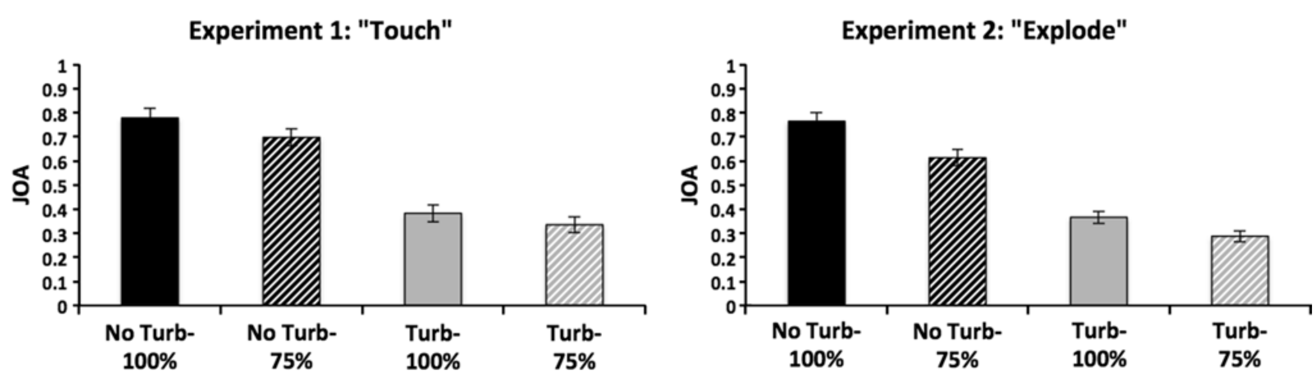

Fig. 3 Judgment of agency (JOA) for Experiment 1 and Experiment 2 given as a proportion from 0 to 1

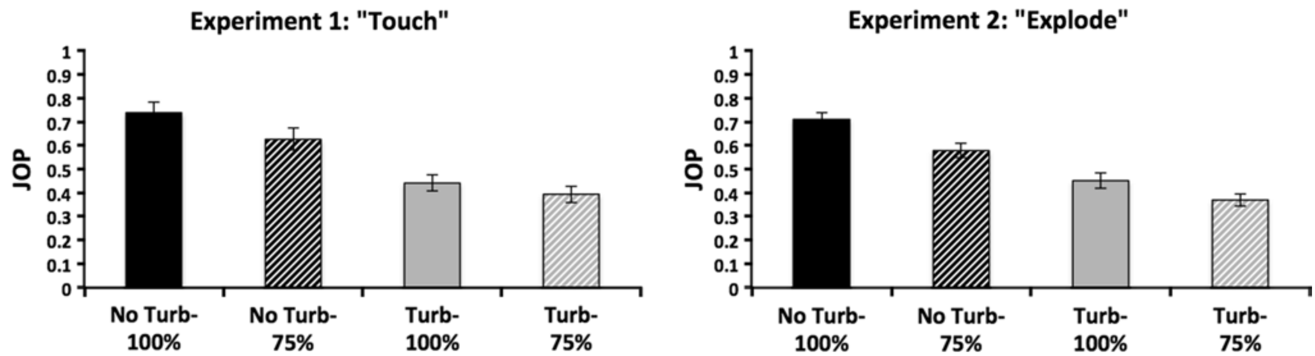

Fig. 4 Judgment of performance (JOP) for Experiment 1 and Experiment 2 given as a proportion from 0 to 1

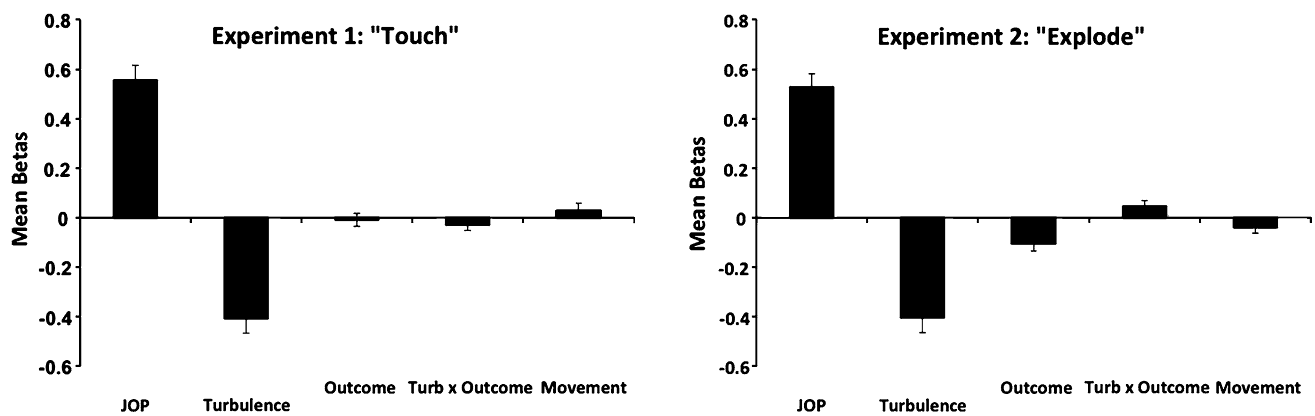

Fig. 5 Mean betas for each predictor included in the within-participant regression analyses for Experiment 1 and Experiment 2

$p < .0001$, $E = .58$, and an interaction between Turbulence and Outcome, $F(1,16) = 5.29$, $\mathrm{MSE} = 34.53$, $p = .035$, $E = .25$.

Regression analysis

Finally, to examine the potential factors that impacted JOAs, we submitted each participant's judgments to a separate within-participant regression analysis in which JOPs, Turbulence, Outcome, the Turbulence × Outcome interaction, and total Movement (i.e., the number of pixels that the participant moved the mouse to the left or to the right on each trial) served as simultaneous predictors. JOPs and Movement were included so that we could estimate effects of Turbulence and Outcome that could not be explained in terms of perceived performance or mouse motion. Turbulence and Outcome were contrast-coded, with −.5 indicating full agency (i.e., an absence of turbulence or a 100 % explosion rate) and .5 indicating deficits in agency (i.e., the presence of turbulence or a 75 % explosion rate). After conducting the within-participant regression analyses, we submitted the resulting beta coefficients to a series of one-sample *t*-tests (see Lorch and Myers 1990). As shown in Fig. 5, left panel, the effects of JOP, $b^*_{\mathrm{mean}} = .58$, $t(16) = 10.58$, $p < .001$, and Turbulence, $b^*_{\mathrm{mean}} = -.41$, $t(16) = 7.23$, $p < .001$, were significantly different from zero, whereas the effects of Outcome, $b^*_{\mathrm{mean}} = -.01$, $t(16) = .43$, $p = .67$, the Turbulence × Outcome interaction, $b^*_{\mathrm{mean}} = -.03$, $t(16) = 1.36$, $p = .19$, and Movement, $b^*_{\mathrm{mean}} = .02$, $t(16) = .61$, $p = .55$, were not different from zero.

Discussion

Experiment 1 indicated that people could not ignore the distal variable in making their JOAs, even when the stated instructions indicated that explosion outcomes were irrelevant. However, the effect of the distal variable on JOAs was small, and it appeared to be mediated entirely by the effect that it had on people's JOPs. The regression analyses indicated that the change in JOAs associated with the Outcome variable was likely due to change in JOPs. JOPs themselves have been shown here, and in past research (Metcalfe et al. 2012) to influence JOAs directly. Although the direction of causality cannot be definitively inferred from this analyses, it is plausible that the highly salient explosion of the X's resulted in perceived performance differences between the 100 and 75 % conditions. People may have thought, at least some of the time, that they had not touched the X's that fell through without exploding. It is likely that it was these perceived performance differences, in the outcome conditions, that affected participants' JOAs, rather than the distal variable having a direct effect on JOAs.

Experiment 2

Although the computer program in Experiment 2 was identical to the program in Experiment 1, the objective given to the participant was not just to touch the target X's, but rather, to explode them. Because the instructions should have made the distal outcome manipulation more salient to participants, we expected a more direct effect of distal outcome on JOAs. Insofar as the effect of the 75 % condition on explode rate was of about the same magnitude as that of the Turbulence condition on explode rate, in Experiment 1, we were in position to evaluate their relative contribution.

Methods

Participants

The participants were 23 Columbia University or Barnard College undergraduates, all of whom were native English speakers, who participated either for pay or for course credit. Two participants were run but eliminated, as recommended by the experimenter who ran them, before looking at their data. One was eliminated because he told the experimenter that he had automatically and intentionally used the identical rating for the JOA and JOP on each trial. The second was eliminated because she said she had missed a complete trial because she had been distracted. The mean age of the remaining 21 participants was 22.93, and 6 were male, 10 female, and 5 did not answer the gender question.

Apparatus, program, procedure, and design

These were identical to Experiment 1.

Instructions

Participants, at the outset of the experiment, read the following instructions: "Throughout this experiment, you are going to play a game in which you will use the computer mouse to move a box left or right. Your job is to touch the X's to explode them as they come in range and to avoid touching any of the O's. At the end of each 15 s of playing this game, you'll be asked to make a judgment of how in control you felt during the past 15 s of play, and a second judgment of how good your performance was. Then, you'll go on to the next trial."

Results

Hit rate

As is shown in Fig. 1, right panel, there was a main effect of Turbulence such that hit rate was higher in the No Turbulence conditions than in the Turbulence conditions, $F(1, 20) = 207.92$, MSE = 48.49, $p < .0001$, $E = .912$. The probability of touching an X was slightly, but significantly, better in the 100 % conditions than in the 75 % conditions, $F(1, 20) = 5.88$, MSE = 32.12, $p = .025$, $E = .23$. This effect, while small, was unexpected because the participants could not have known in advance whether any particular X would explode or not.

Explode rate

As can be seen from Fig. 2, right panel, the explode rate was greater in the No Turbulence as compared to the Turbulence conditions, $F(1, 20) = 160.72$, MSE = 38.29, $p < .0001$, $E = .89$. It was also greater in the 100 % conditions than in the 75 % conditions, $F(1, 20) = 543.55$, MSE = 30.08, $p < .0001$, $E = .97$. There was also an interaction between Turbulence and Outcome, $F(1, 20) = 31.29$, MSE = 20.68, $p < .0001$, $E = .61$. An attempt had been made to equate the explode rate in the No Turbulence-75 %, and the Turbulence-100 % conditions, that is to equate the performance decrements with these different ways of impairing performance. There was a difference between these two, however. The explode rate was higher in the Turbulence-100 % condition (.63) than in the No Turbulence-75 % condition (.52), $t(20) = 5.72$, $p < .0001$.

Judgments of agency

As is shown in Fig. 3, right panel, there was a main effect of Turbulence, $F(1, 20) = 128.56$, MSE = 214.19, $p < .0001$, $E = .87$, such that JOAs were higher in the No Turbulence than the Turbulence conditions. There was a main effect of Outcome, $F(1, 20) = 38.18$, MSE = 73.77, $p < .001$, $E = .66$, such that JOAs were higher in the 100 % conditions than in the 75 % conditions. There was also an interaction between Turbulence and Outcome, $F(1,20) = 6.16$. MSE = 46.31, $p = .02$, $E = .24$, as shown in the figure.

To investigate whether Turbulence or Outcome impacted more on people's assessments of agency, JOAs in the No Turbulence-75 % condition were compared to those in the Turbulence-100 % condition. Although the explode rate was *higher* in the Turbulence-100 % condition (.63) than in the

No Turbulence-75 % condition (.52) (despite our efforts to equate them), people's JOAs were significantly *lower* in the Turbulence-100 % condition (36.66) than in the No Turbulence-75 % condition (61.29), $t(20) = 7.11$, $p < .0001$.

Judgments of performance

As is shown in Fig. 4, right panel, there was a main effect of Turbulence on JOPs, $F(1,20) = 114.48$, MSE = 101.03, $p < .001$, $E = .85$. There was also a main effect of Outcome, $F(1,20) = 50.96$, MSE = 47.82, $p < .0001$, $E = .72$, and no interaction.

Regression analysis

We again submitted each participant's judgments to a separate within-participant regression analysis. As shown in Fig. 5, right panel, the effects of JOP, $b^*_{\text{mean}} = .53$, $t(16) = 9.88$, $p < .001$, Turbulence, $b^*_{\text{mean}} = -.41$, $t(16) = 6.79$, $p < .001$, Outcome, $b^*_{\text{mean}} = -.11$, $t(16) = 4.05$, $p = .001$, the Turbulence × Outcome interaction, $b^*_{\text{mean}} = .05$, $t(16) = 2.12$, $p = .05$, and Movement, $b^*_{\text{mean}} = -.04$, $t(16) = 2.23$, $p = .04$, were all significantly different from zero. Thus, in contrast to the previous experiment, the Outcome manipulation had a small but significant effect on participants' JOAs. Importantly, though, this effect was substantially smaller (less negative) than the effect of Outcome, $t(16) = 4.16$, $p < .001$.

Discussion

The outcome variable had a significant effect on people's JOAs when they were assessed in the most straightforward way—by asking people how in control they felt. However, even with this simple evaluation of metacognition of agency, the distal variable had a smaller effect on people's JOAs than did the proximal variable. Furthermore, although simple JOAs were affected by the outcome variable, when a regression analysis was conducted, the direct effect of the Outcome variable was surprisingly small: Turbulence had a much larger effect than Outcome on JOAs.

Comparison of Experiment 1 and Experiment 2

Because the only difference between the two experiments was in the particular participants included (from the same student population) and the instructions given to them about whether their goal was to touch the X's or to explode them, it was decided to compare the two experiments directly. To this end, we conducted a new set of ANOVAs with participants from both studies that included Experiment (1 vs. 2) as an added factor. As such, we were interested in the two- and three-way interactions between the proximal factor, the distal factor, and the experiment version. The direct contrast between experiments allows us to investigate whether certain patterns were more pronounced when the objective was to explode the X's compared to when the objective was just to touch them. Because participants were not randomly assigned to one experiment versus the other, the results of these analyses should be tentatively interpreted.

Hit rate

Both the main effects of Turbulence and of Outcome that had been significant in the separate experiments were, of course, significant ($F(36) = 330.87$, MSE = 51.47, $p < .001$, $E = .90$ and $F(36) = 7.51$, MSE = 26.49, $p = .009$, $E = .17$, respectively). There was no main effect of Experiment on hit rate, nor were there any interactions involving Experiment (all Fs < 1).

Explode rate

The main effects of Turbulence and Outcome were significant in the joint data, as expected ($F(36) = 257.34$, MSE = 44.39, $p < .001$, $E = .88$ and $F(36) = 797.72$, MSE = 27.41, $p < .001$, $E = .96$, respectively). There was a main effect of Experiment, $F(1,36) = 5.97$, MSE = 147.13, $p = .02$, $E = .14$, that was qualified by an interaction between Experiment and Outcome, $F(1,36) = 19.61$, MSE = 27.41, $p < .0001$, $E = .35$. A difference in the Explode rate was found in both of the 75 % Outcome conditions (Turbulence and No Turbulence) that was slightly lower in Experiment 2 than in Experiment 1 ($t(36) = 2.78$, $p = .009$ and $t(36) = 4.33$, $p < .001$, respectively).

Judgments of agency

Again, as expected, the main effects of Turbulence, $F(1,36) = 241.25$, MSE = 213.75, $p < .0001$, $E = .87$, and Outcome, $F(1,36) = 53.50$, MSE = 57.11, $p < .0001$, $E = .59$, were significant in the combined analysis, as was the interaction between Turbulence and Outcome, $F(1,36) = 6.63$, MSE = 40.79, $p = .01$, $E = .16$). The main effect of Experiment was not significant, $F(1,36) = 1.25$, $p = .27$.

Outcome interacted with Experiment, such that there were larger decreases in JOAs in the 75 % conditions when the instructions had been to explode the X's (in Experiment 2) than when the instructions were to simply touch the X's (in Experiment 1), $F(1,36) = 4.33$, MSE = 57.11, $p = .045$, $E = .11$. Thus, the instructions to either just touch or to explode the X's mattered on exactly the manipulation (outcome) that was targeted by the instructions.

Judgments of performance

The main effects of Turbulence and of Outcome were significant in the joint analysis ($F(1,36) = 209.25$, MSE $= 111.94$, $p < .001$, $E = .85$ and $F(1,36) = 67.85$, MSE $= 48.64$, $p < .001$, $E = .65$ respectively), as was the interaction between Turbulence and Outcome, $F(1,36) = 322.42$, MSE $= 48.71$, $p = .01$, $E = .16$. There was no main effect of Experiment; however, unlike with JOAs, none of the interactions involving Experiment were significant (all Fs < 1). Thus, while the effect of Outcome on JOAs was greater in Experiment 2 (when the goal was to explode) than in Experiment 1 (when the goal was just to touch), Outcome had the same effect on JOPs in the two experiments.

Regression analysis

To determine whether the effects of JOPs, Turbulence, Outcome, the Turbulence × Outcome interaction, and Movement differed between experiments, we submitted the corresponding betas to a series of independent-samples t-tests. The results showed no difference in the effect of JOPs, $t(36) = .61$, $p = .54$, or Turbulence, $t(36) = .05$, $p = .96$, between experiments. However, there was significant difference for Outcome, $t(36) = 2.35$, $p = .03$, and the Turbulence × Outcome interaction, $t(36) = 2.43$, $p = .02$, as well as a marginal difference for Movement, $t(36) = 1.72$, $p = .10$.

Conclusion

The results of these experiments indicate that the outcome of an act has an impact on people's JOAs. In particular, when the ostensible goal was to explode the X's and sometimes those X's failed to explode (as in Experiment 2), people said that they felt less in control than when the X's always exploded. This decrement in feelings of agency was also observed when the objective was only to touch the X's (as in Experiment 1), though to a lesser extent. But although the distal outcome variable did affect JOAs, its effects were dissociable from those the proximal action variable influencing motor control. First, the distal variable had a much smaller effect on people's JOA than did the proximal variable. But, more importantly, when the effect of people's perceived performance was factored out, the proximal variable still had a large effect on people's metacognition of agency, while the distal variable had only a small effect, in Experiment 2, and no effect, in Experiment 1. Thus, although simple JOAs *were* affected by the distal outcome, this effect appears to have largely been mediated by decreases in perceived performance that resulted from the X's failing to explode when touched. When the distal outcome was not the goal, its effect on agency appeared to be entirely mediated through its effect on perceived performance. Presumably, the explosion of the Xs made it easier for the person to realize that they had touched the Xs—their proximal goal. Only when their goal was explicitly connected to the distal manipulation, that is, when the stated goal was to explode the X's, did the distal manipulation directly affect JOAs. And even then, the effect was small.

These results provide support for the idea that distinctively different cues contribute to people's JOAs. Some of these cues are diagnostic of people's real control over their movements and indicate in a veridical way that they are the doer of their deeds. Others are non-diagnostic of their own causal role as the actor (Metcalfe in press).

One of the diagnostic cues that has frequently been found to have an effect on agency is the discrepancy between the person's intended and actual motor movements. The use of this discrepancy has been described by the comparator model and has much support in the literature. The proximal variable in the present experiments (i.e., Turbulence) picked up on this cue. There is little to no discrepancy in the No Turbulence conditions, whereas there is presumably a large discrepancy in the Turbulence conditions—a discrepancy associated with right temporoparietal junction activation in an fMRI study conducted using this paradigm (Miele et al. 2011). Consistent with our past research, people used turbulence cues in the present experiment to make JOAs. Furthermore, turbulence cues are diagnostic because under normal circumstances the concordance between one's own internal intention and one's own monitored external acts is highly predictive of whether the self was the source of the action. Notably, too, patients with schizophrenia failed to use such proximal cues in a previous experiment using this paradigm (see Metcalfe et al. 2012, and see Synofzik et al. 2010 for a similar conclusion)—they showed almost no indication that turbulence disrupted their sense of agency (as evaluated by regressions similar to those reported here).

The patients, however, were not random in their JOAs. What they used was their perception of performance—the same variable that appears to underlie much of people's responses to the Outcome variable in the present experiments. Regression analyses of the potential cues that contribute to people's sense of agency in the schizophrenia study indicated that perception of performance was used both by people with schizophrenia and by healthy controls. It is just that schizophrenics used *only* this source of information, whereas healthy controls also used proximal action-relevant information.

Consistent with past results, the findings presented here also implicate JOPs as being central to people's JOAs. Although people undoubtedly feel out of control when an outcome is not as good as they expected or (as the second experiment presented here shows) when an outcome is not highly contingent on their behavior, performance is not a cue that uniquely specifies the individual as the source of the action. If the term agency is taken to indicate the extent to which the individual is responsible for what happened, or the extent to which the self was implicated, perceived performance is moot with respect to this responsibility. It is not necessary for the person to take any action at all to be able to assess performance. Indeed, someone else could have been playing the game and the performance assessment could still be accurate. Similarly, while it was necessary in the present experiments for the X's to be touched in order for explosions to occur, the person's successful action of touching did not ensure an explosion.

In conclusion, these results indicate that the change in JOAs due to outcome variables is psychologically dissociable from the change due to discrepancy detection. Proximal variables such as turbulence, that are associated with basic actions, appear to affect our metacognition of agency to a greater extent and in more direct ways than distal variables that are associated with the consequences of our action in the world, though we experience a loss of control in both cases. Given that a behavioral dissociation exists, it would be interesting to investigate neural differences in patients suspected of reacting differentially to these two components, and by investigating what should purportedly be different brain activation patterns (see, e.g., Tricomi et al. 2004) evoked by these distinct cues to agency.

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