FREE WILL:
PHILOSOPHERS AND NEUROSCIENTISTS IN CONVERSATION

edited by Uri Maoz (Chapman University)
and Walter Sinnott-Armstrong (Duke University)

Question 12 – Do conscious decisions cause physical actions?

Answer by Ned Block

1. What is a conscious decision?

A decision in one sense of the term is the formation of an intention. A phenomenally conscious decision in one sense of the term is then a phenomenally conscious formation of an intention. To say that forming the intention is phenomenally conscious in this sense is to say that there is something it is like to form the intention, that the formation of the intention has a phenomenal "feel". That phenomenal feel can take the form of an awareness of making a choice. Or it can be a matter of being phenomenally conscious of the decision *as a decision*, in which case the subject must possess the concept of a decision. It seems though that there are plenty of conscious decisions that don't feel like anything at all. We make many minor choices every day. Does it always feel like something to make them? Perhaps there is only a feeling of choice when there is some kind of deliberation about the choice. Still, our mundane everyday choices are conscious in the sense of "access-consciousness".

Access-consciousness is immediate global availability to cognitive processing whether that cognitive processing is or is not itself phenomenally conscious (Block, 2002). An access-conscious state is immediately available to reasoning, planning, evaluating, problem-solving, reporting, memory and other cognitive processes. If there are Freudian repressed states, they are unconscious in the access sense whether or not they have any phenomenal feel.

I just introduced three senses of 'conscious decision', (1) a phenomenally conscious decision, (2) a decision that is phenomenally conscious as a decision, (3) an access-conscious decision. Of these three senses, the first two involve a phenomenal feel. And it is the presence of the phenomenal feel involved in such conscious decisions that give rise to the problem to be discussed here. That problem is this: There is experimental evidence that has been taken to support the claim that phenomenally conscious decisions are "epiphenomenal" in the sense that they have no causal effects on bodily movements (Libet, Gleason, Wright, & Pearl, 1983; Passingham & Lau, 2006). In these experiments, unconscious neural events leading up to the decision and consciousness of it are alleged to

be found *prior* to consciousness of the decision; indeed, some experiments suggest that the consciousness of the decision can occur at least in part *after* the action (Lau, Rogers, & Passingham, 2006). (Whether or not these experiments really do establish the conclusions they are taken to establish is not my concern here; my concern is what follows from these claims if they are true.) Some commentators conclude from this sort of evidence that the conscious decision to act is not causally efficacious in producing the action, because the unconscious neural events are sufficient to cause the action. This reasoning is my target.

I will explain why this reasoning is mistaken in terms that apply to *all mental events.* I will begin with the example of conscious vision, because we understand the psychology and neuroscience of vision much better than we understand any other aspect of the mind. In particular, there are dramatic cases in which unconscious and conscious states have *conflicting* contents. The lessons from such examples will then be applied to the case of conscious decisions.

2. Are conscious perceptions epiphenomenal?

All conscious mental events, including conscious perceptions, involve unconscious processing. Visual perception conscious and unconscious, is typically processed by the lateral geniculate nucleus and the first cortical visual area, V1, on the way to conscious processing in higher visual cortex. (For some kinds of unconscious perception, the pathways involve the superior colliculus and the pulvinar, bypassing the lateral geniculate nucleus-to-V1 route.) There is good reason to believe that representations at the level of the lateral geniculate nucleus and V1 are not part of the neural basis of consciousness. (Some of this evidence is summarized in (Koch, 2004; Koch, Massimini, Boly, & Tononi, 2016).)

The major theories of consciousness that are relevant to this issue agree that processing in the lateral geniculate nucleus and V1 *precedes* conscious processing. I will explain with respect to three of the major theories of consciousness.

(1) The global workspace theory dictates that conscious processing of a stimulus begins—at the earliest—270 ms after the stimulus, long after the stimulus is extensively processed in the lateral geniculate nucleus and V1 (Dehaene, Changeux, Nacchache, Sackur, & Sergent, 2006). (2) Higher-order thought takes somewhat *more* time than global broadcasting so theories of consciousness based on higher-order thought (Brown, Lau, & LeDoux, 2019; Rosenthal, 1986) also allow for substantial unconscious processing prior to conscious processing. (3) The recurrent processing approach to consciousness also dictates that conscious processing occurs well after stimuli are extensively processed in the lateral geniculate nucleus and V1 (Lamme, 2003; Pitts, Metzler, & Hillyard, 2014). According to Victor Lamme's version of the recurrent processing account, conscious perception requires processing in the lateral geniculate nucleus and V1, then processing in higher visual areas and then, finally, feedback to V1 (or V2). And there is independent evidence for the need

for the feedback to V1 (Block, 2007; Silvanto, Cowey, Lavie, & Walsh, 2005). So on this account, conscious perception requires first unconscious activations in V1 and then a second round of activations in V1.

I conclude that with perception, as with decision, there is reason to accept that some *unconscious visual processing precedes all conscious visual processing in the same stream*. Nonetheless, we can agree that conscious perceptions are involved in the production of actions. Consciously seeing the red light is *often* part of the cause of stepping on the brake.

There is a complication however. When one event causes another, some of the properties of the cause may be causally efficacious in producing the effect and others not. When the brick flying through the air breaks the window, it is in virtue of its mass and velocity that the window breaks, not in virtue of its color: the color is causally inefficacious in breaking the window. The soprano's high C "Help!" may shatter the glass but the meaning of the word "help" is not causally efficacious in shattering the glass (Dretske, 1988).

In terms of this distinction then, how do we know whether it is in virtue of the *conscious aspect* of seeing the red light that I stepped on the brake? That is, how do we know whether the conscious aspect of seeing the red light is causally efficacious in producing the action of stepping on the brake?

A conscious perception has conscious and unconscious aspects, and when a conscious perception causes something, it will not always make sense to ask which aspects are causally efficacious. An iceberg displaces an amount of water equal to the weight of the whole iceberg so it is the whole iceberg that is causally efficacious in that respect, not just the part below water. If the above-water part of an iceberg hits a ship, we cannot conclude that the below-water part was not causally efficacious, since without the below-water part there would be no above-water part to hit the ship. The same point applies to conscious mental events—without their unconscious part there would be no conscious part.

Still, in many cases we can ask whether the conscious part is causally efficacious, that is, whether it was at least partly in virtue of the conscious part that the effect happened. In some cases the answer is demonstrably yes.

In the light of controversies over whether to use the "objective threshold" (better than chance responding) or the subjective threshold (the subjects' belief that they see something), I will use the following methodology: If a perception is above both the objective and the subjective threshold, then the perception is conscious. The principle that if a perception is below both the objective and subjective threshold, it is not conscious is also very plausible but not very useable since in many cases, subjects are sure they did not see the stimulus but can still answer questions at better than chance accuracy. A more useful principle for classifying unconscious perception is: if the subject is sure that they are unaware of the stimulus (or its properties) and if the putative unconscious content is

incompatible with a conscious content, then the content is unconscious. Examples will be given below.

It is well known that unconscious perception can influence behavior. In one experiment (Debner & Jacoby, 1994), subjects were presented with a masked word and then asked to complete a word stem, but not with the word they saw if they saw a word. (Masking—the presentation of pattern before or after the original stimulus—can make the stimulus hard to consciously see if the timing is right.) If the word 'reason' is presented consciously (lightly masked), then the subject can succeed in avoiding the presented word in completing the stem, for example, by completing 'rea___' with 'reader'. But if 'reason' is presented unconsciously (heavily masked), then the subject is more likely than baseline to complete the stem 'rea___' with 'reason'. (There is an issue of whether the perception of 'reason' that I described as unconscious is really unconscious as opposed to weakly conscious, but I cannot take up that issue here.)

Similar "opposite" effects of conscious and unconscious processing occur in other kinds of visual perception. For example, V1 can register black stripes on a white background that are too narrowly spaced to see consciously. If the density of such stripes is greater than 50 cycles per degree of visual angle, the stimulus looks to be a uniform gray field—as far as conscious vision is concerned, but stimuli that are substantially higher than 50 cycles per degree are registered by V1 as stripes (He & MacLeod, 2001). Similarly, if two colors (e.g. red and green) alternate at frequencies above 10 Hz, viewers consciously see a single fused color (in this case, yellow) rather than flickering different colors. But V1 and the lateral geniculate nucleus respond to flickering colors at frequencies up to 30 Hz. (Gur & Snodderly, 1997).

The unconscious perception of stripes at higher than 50 cycles per degree—say 60 cycles per degree-- and unconscious perception of red and green flickering fit the principle mentioned above: if the subject is sure that they are unaware of the stimulus (or its properties) and if the putative unconscious content is incompatible with a conscious content, then the content is unconscious. The content of stripes at 60 cycles per degree is one that the subject denies and is incompatible with the subjects' certainty that they are seeing a uniform grey field. Similarly, the content red and green flickering is incompatible with the subjects' certainty that they are seeing a uniform unflickering yellow.

Suppose a subject has the task of pressing the button marked "yellow" if the stimulus is yellow and a button marked "red & green" if the stimulus is flickering red & green. If the stimulus is a red/green flickering stimulus at 12 Hz, the subject will consciously see yellow (since the flicker rate is above 10 Hz) and so can be expected to press the "yellow" button.

But if the stimulus had been sufficiently degraded or masked to be entirely unconscious, the stimulus would have registered in unconscious processing as red and green flickering (since unconscious processing in the lateral geniculate nucleus and V1 registers flicker up

to 30 Hz), so the yellow color would not have been perceptually registered and if the resulting unconscious perception had an effect on behavior, it would incline the subject towards the "red & green" rather than the "yellow" button (Gur & Snodderly, 1997).

When the colored stimulus flickers at 12 Hz, resulting in the subject pressing the "yellow" button, we can conclude that the conscious aspect of the processing was causally efficacious, since the earlier unconscious part by itself would not have influenced the subject's behavior in the direction of the "yellow" button. Similarly, if the stripe density of a stimulus is 60 cycles per degree, a subject will classify it as uniform gray on the basis of conscious perception. But if the perception had had no conscious part, the visual system would have registered it as striped rather than uniform, so it would have inclined the subject towards the striped response—to the extent that the unconscious perception would have causally influenced a response. So, in the conscious case, we can conclude that the conscious aspect was causally efficacious.

The counterfactual test I am using has to be applied carefully. If the exposed part of an iceberg caused damage to a ship sufficient to sink it, we can ask what would have happened had the top part of the iceberg not been there so that the iceberg was entirely below water. The ship might have been sunk anyway though through a different causal path. Still, if the result goes the other way—if the iceberg would not have sunk the ship had it not had the above-water part—then we can reasonably conclude in normal circumstances that the above-water part was causally efficacious.

The resulting picture of the relation between conscious and unconscious mental events is that when a conscious mental event is causally efficacious, we can sometimes ask whether it is causally efficacious in virtue of its conscious aspect. I have just given examples that show that *the conscious and unconscious aspects can have different and opposed effects on behavior* in at least some cases. In these cases, it is particularly obvious that the conscious aspect of the mental event is causally efficacious. But even in the case where the influence of the conscious and unconscious aspects of the mental events point in the same direction, they may make somewhat independent contributions to the behavioral effect.

There is reason to believe that in vision, conscious and unconscious representations may have different contents. Representations in the lateral geniculate nucleus and V1 are always unconscious. They have "low level" contents, zero-crossings, edges, orientations, contrast, textures. "High level" contents such as representations of faces, emotional expressions, causation and numerosity can be either conscious or unconscious, but to make some of these contents unconscious requires very brief presentations, highly degraded stimuli or one or another kind of masking. Thus while representations of low level properties will typically have a substantial unconscious component, representations of high level properties will typically be conscious.

3. <u>Back to phenomenally conscious decisions</u>

Conscious decisions (I'm talking about phenomenally conscious decisions here) are conscious mental events and so the points just made about *all conscious mental events* apply to them. If the subject is choosing between salad and chocolate cake, the unconscious aspect of the decision might incline the subject towards the chocolate cake whereas the conscious aspect might incline the subject towards the salad. If the subject chooses the salad, then the conscious aspect was causally efficacious. However, if the conscious and unconscious aspects inclined the subject towards the same decision, *both* may be causally efficacious. With decision as with perception, the unconscious and conscious aspects of the decision can point in the same direction but make somewhat independent contributions, in which case again the conscious aspects are causally efficacious. An unconscious part of a mental event always precedes conscious aspects, but the conscious aspects may nonetheless be causally efficacious.

With decision, as with perception, we can expect that there will be differences between the kinds of contents that will typically be unconscious and those that will typically be conscious. An unfortunate legacy of the Libet style experiments is a focus in the neuroscience of decision on very simple contents that can be either conscious or unconscious, basically go/no go contents. The field would be better off with an increased emphasis on the contents of decision and on which ones can be expected to be conscious and which unconscious.[1]

[1] Thanks to Amber Hopkins, Uri Maoz, Claire Simmons and Walter Sinnott-Armstrong for comments on an earlier version.

FOLLOW-UP QUESTIONS

1. **Mark Hallett and Liad Mudrik**:
   As pointed out, unconscious events can cause physical actions, but in some circumstances it appears that the action seems to have depended on a conscious event. However, a conscious event is likely complex. Is the consciousness aspect of the event the critical part? Could the consciousness part be the red of the brick and an unconscious part be the mass of the brick?

2. **Amber Hopkins**:
   In their chapter in this volume, Jake Gavenas, Mark Hallett, and Uri Maoz describe two possible roles for consciousness in action generation: generative or modulatory. Would you agree more with the suggestion that consciousness is a generative source of action or that consciousness has a modulatory impact on action outcomes? You save a causally relevant place for unconscious aspects of conscious percepts in behavior. Would the conscious aspects have an impact on the unconscious aspects? Would this align more with the idea of consciousness as having a modulatory role in behavior?

3. **David Silverstein and Hans Liljenström**:
   Can unconscious decisions cause physical actions? For example, consider rapid and perhaps unconscious reactions by fear, such as a surprise encounter with a spider or snake (or something that appeared like one). Some hypotheses assert that signaling from threat-relevant stimuli can traverse a rapid and subcortical low road that activates the amygdala prior to conscious access and that amygdala efferents can trigger a response. Given this, can conscious awareness of an action and perhaps the awareness of fear emerge after the physical action?

4. **Walter Sinnott-Armstrong**:
   You argue forcefully that "the conscious aspect was causally efficacious" in your commonsense example of choosing a salad. However, it is still not clear *how* this causation works. In their chapter in this volume, Gavenas, Hallett, and Maoz conclude, "further advances in the conscious control of movement are required to understand how those [conscious, subjective] experiences lead to action." Do you agree with them that we do not yet know how any of this works? Can we be justified in believing that the conscious aspect of our mental states do cause us to eat the salad when we do not know how one causes the other?

REPLIES TO FOLLOW-UP QUESTIONS
by Ned Block

Color or mass?

When the heavy red brick breaks the window, the mass is causally efficacious but the color is not. Mark Hallett and Liad Mudrik want to know whether the conscious part of a mental event that causes a behavioral response is like the redness of the brick or like the mass of the brick.

The issue my essay was concerned with was the allegation that because an unconscious part of a decision inevitably precedes all conscious aspects, it follows that the conscious aspects are like the redness of the brick rather than the mass of the brick. That is, the allegation is that the conscious aspects of the decision *never* are causally efficacious.

My response was to note that *every* phenomenally conscious mental event has an unconscious part that precedes all conscious parts. In conscious visual perceptions, unconscious activations of V1 precede the conscious aspects of the perception. But that does not show that the conscious aspect is like the redness of the brick. The way I argued for that was by pointing to the fact that in some cases, the conscious part and the unconscious part influence action in opposite ways. When red and green lights flicker at frequencies above 10 Hz, the subject sees yellow but the unconscious processing activations in V1 and the lateral geniculate nucleus that precede the conscious experience of yellow register red and green. This opposition can give rise to contrary tendencies in behavior. If the subject presses the button for yellow, we know that the conscious aspect of the perception was causally efficacious, that is, like the mass of the brick rather than the redness of the brick. If the subject presses the button for red or green, we know that the unconscious aspect has dominated the response.

For all we know, cases in which conscious and unconscious aspects of a mental event push in opposite directions are a rare exception. Still, the existence of these cases is enough to show that the fact that an unconscious part of a mental event inevitably precedes all conscious aspects leaves it open whether consciousness is causally efficacious. At least sometimes, consciousness is like the mass of the brick, not its color.

Generation or modulation?

Amber Hopkins asks whether consciousness has a generative or modulatory effect on action. Let us ask this question with regard to the example of the perception of flicker that I mentioned earlier. We could say that the unconscious representations of red and green in

the lateral geniculate nucleus and V1 have a generative effect but that (when the flicker rate is above 10 Hz) the conscious representation modulates that effect by turning the representation of red and green into a representation of yellow. But we could equally well say that the conscious representation of yellow has a generative effect on the percept since there is no unconscious representation of yellow. Or we could say that the unconscious processing generates the perception itself whereas the conscious processing generates the content of the perception. These alternative ways of talking suggest that the generative/modulatory distinction is not as useful a distinction as one might have thought. If we are going to use the generative/modulatory distinction, we should take care to say whether we are talking about the mental event itself or its content. What generates the mental event might not be what generates its content.

Unconscious decisions?

David Silverstein and Hans Liljenström ask whether an unconscious decision can cause an action. What I would like to have available for an answer is a decision case that is parallel to the flicker and spatial frequency cases for perception, but there are two problems in finding such cases. The problems are illustrated by the example given by Silverstein and Liljenström in which exposure to a threatening stimulus might activate the amygdala via a fast, subcortical pathway, triggering a response prior to conscious perception of the threat. What they are considering is an *entirely* unconscious decision. The first problem is that the existence of entirely unconscious mental events is less certain than mental events that are partly conscious and partly unconscious. My perception examples were of the partially conscious/partially unconscious sort. When a perceiver sees red and green lights that flicker at 12 Hz, the resulting perception is partly conscious and partly unconscious. The conscious aspect registers yellow, whereas the unconscious part registers red and green. The reality of unconscious mental effects on action should not be taken to depend on whether the conscious part of a mental event can be "shaved off" to yield an entirely unconscious mental event. See my contribution to (Peters, Kentridge, Phillips, & Block, 2017) for more on this point.

The second problem is that in the case of a putatively entirely unconscious decision, there is always an issue as to whether it is a decision at all as opposed to a sub-personal event—something more like a reflex. When the subcortical "low road" activates the amygdala, leading to the triggering of a fear response, is the triggering or some other part of this process really a decision at all?

Despite these problems, there are decision cases that share some important properties with the perception examples I described earlier and I will now describe one. My example will not be totally parallel to the perception examples, since conscious and unconscious

aspects of the decision process are woven together. What is parallel about the case, though, is that both conscious and unconscious aspects contribute to causing an action. Marc Jeannerod did an experiment involving three dowels that could be illuminated by computer controlled diodes at their bases (Castiello, Paulignan, & Jeannerod, 1991). Subjects were asked to quickly grasp a dowel when it lit up and lift the dowel up. In separate trials, subjects were asked to vocalize "Tah" when they saw the illumination and to grasp the lighted dowel. The start of reaching took 330 ms on average whereas the start of the "Tah" sound took 380 ms on average. Unsurprisingly, when they did both tasks together, the hand movement started 50 ms before the vocalization.

20% of the time the illumination would shift between one dowel and another just as the reach started. Subjects were asked to say "Tah" again when they detected a change in illumination. In the 20% of cases, where the light shifted, subjects started reaching towards one dowel and then in 100 ms course-corrected, grasping the second dowel. The experimenters also ran trials with the vocalization but no motor task and with the motor task but no vocalization. The main result is that the vocalizations occurred 315 ms after the subjects started to correct the trajectories of their motor movements despite the fact that control of the speech system is faster than control of the motor system. The time taken to produce a vocalization did not depend on whether or not there was also a motor movement and conversely, so it seems as if the two processes were substantially independent. Jeannerod argues from plausible assumptions about both motor processing and language processing that the course correction preceded awareness of the changing illumination and so must have been unconsciously generated. As Jeannerod notes (1997, p. 85), subjects "reported that they saw the light jumping from the first to the second object near the end of their movement, just at the time they were about to take the object (sometimes even after they took it!)". Jeannerod told me that subjects reacted by saying their hand movement seemed to precede their awareness.

This case is not exactly parallel to the perception cases I mentioned. Both the original decision and the decision to course-correct occur in a conscious envelope, since subjects must have decided in advance to course-correct on the condition of seeing the light change. Still, the implementation of the original conditional decision is unconsciously generated, whereas the decision to grasp the original lighted dowel is conscious. So we do see both conscious and unconscious effects pointing in different directions in this example.

Whether or how?

Walter Sinnott-Armstrong suggests—and I agree—that we do not know how the conscious control of action works. But, then, he asks, how can we be justified in supposing that there is any conscious control of action at all? A first level of reply would be to note that in the

Jeannerod experiment, features of the course correction are unconsciously controlled, whereas the initial reach is consciously controlled. But how do we answer a sceptic who says the initial reach is really unconsciously controlled, too—given that we don't know how conscious control works? Such skepticism is undermined by the perception examples. We know that when the subject perceives the flickering red and green lights as yellow and presses the button for yellow, that there is conscious causation. But once we have allowed some conscious causation, why should we think that it never happens in the case of decision?

REFERENCES

Block, N. (2002). Concepts of Consciousness. In D. Chalmers (Ed.), *Philosophy of Mind: Classical and Contemporary Readings* (pp. 206-218). New York: Oxford University Press.

Block, N. (2007). Consciousness, accessibility, and the mesh between psychology and neuroscience. *Behavioral and Brain Sciences, 30*, 481-548.

Brown, R., Lau, H., & LeDoux, J. (2019). Understanding the Higher-Order Approach to Consciousness. *Trends in Cognitive Sciences, xx*(xx). doi:https://doi.org/10.1016/j.tics.2019.06.009

Castiello, U., Paulignan, Y., & Jeannerod, M. (1991). Temporal dissociation of motor responses and subjective awareness. A study in normal subjects. *Brain, 114 (Pt 6)*, 2639-2655. doi:10.1093/brain/114.6.2639

Debner, J. A., & Jacoby, L. L. (1994). Unconscious perception: Attention, awareness and control. *Journal of Experimental Psychology: Learning, Memory and Cognition, 20*, 304-317.

Dehaene, S., Changeux, J.-P., Nacchache, L., Sackur, J., & Sergent, C. (2006). Conscious, preconscious, and subliminal processing: a testable taxonomy. *Trends in Cognitive Sciences, 10*, 204-211.

Dretske, F. (1988). *Explaining Behavior: Reasons in a World of Causes*: MIT Press.

Gur, M., & Snodderly, D. M. (1997). A dissociation between brain activity and perception: chromatically opponent cortical neurons signal chromatic flicker that is not perceived. *Vision Research, 37*(4), 377-382.

He, S., & MacLeod, D. I. A. (2001). Orientation-selective adaptation and tilt after-effect from invisible patterns. *Nature, 411*, 473-476.

Jeannerod, M. (1997). *The Cognitive Neuroscience of Action*. Oxford: Blackwell.

Koch, C. (2004). *The Quest for Consciousness: A Neurobiological Approach*. Englewood, Colorado: Roberts and Company.

Koch, C., Massimini, M., Boly, M., & Tononi, G. (2016). Neural correlates of consciousness: progress and problems. *Nature Reviews Neuroscience, 17*(5), 307-321. doi:10.1038/nrn.2016.22

Lamme, V. (2003). Why visual attention and awareness are different. *Trends in Cognitive Sciences, 7*, 12-18.

Lau, H., Rogers, R., & Passingham, R. (2006). Manipulating the Experienced Onset of Intention after Action Execution. *Journal of Cognitive Neuroscience*.

Libet, B., Gleason, C. A., Wright, E. W., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). The unconscious initiation of a freely voluntary act. *Brain, 106*(0006-8950 (Print)), 623-642.

Passingham, R., & Lau, H. (2006). Free Choice and the Human Brain. In S. Pockett, W. Banks, & S. Gallagher (Eds.), *Does Consciousness Cause Behavior?* Cambridge MA: MIT Press.

Peters, M. A. K., Kentridge, R. W., Phillips, I., & Block, N. (2017). Does unconscious perception really exist? Continuing the ASSC20 debate. *Neuroscience of Consciousness, 2017*(1). doi:10.1093/nc/nix015

Pitts, M., Metzler, S., & Hillyard, S. (2014). Isolating neural correlates of conscious perception from neural correlates of reporting one's perception. *Frontiers in Psychology, 5*(1078), 1-16.

Rosenthal, D. (1986). Two concepts of consciousness. *Philosophical Studies, 49*(3), 329-359.

Silvanto, J., Cowey, A., Lavie, N., & Walsh, V. (2005). Striate cortex (V1) activity gates awareness of motion. *Nature Neuroscience, 8*(2), 143-144.