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A Simple Task Uncovers a Postdictive Illusion of Choice

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Abstract
Do people know when, or whether, they have made a conscious choice? Here, we explore the possibility that choices can seem to occur before they are actually made. In two studies, participants were asked to quickly choose from a set of options before a randomly selected option was made salient. Even when they believed that they had made their decision prior to this event, participants were significantly more likely than chance to report choosing the salient option when this option was made salient soon after the perceived time of choice. Thus, without participants' awareness, a seemingly later event influenced choices that were experienced as occurring at an earlier time. These findings suggest that, like certain low-level perceptual experiences, the experience of choice is susceptible to "postdictive" influence and that people may systematically overestimate the role that consciousness plays in their chosen behavior.

Keywords
consciousness, perception

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A large literature in psychology suggests that people are powerfully influenced by the situations in which they find themselves (Milgram, 1963; Zimbardo, Haney, Banks, & Jaffe, 1973), that they confabulate reasons for why they perform certain actions (Gazzaniga & Sperry, 1967; Nisbett & Wilson, 1977), and that they even sometimes fail to notice what choices they made mere seconds in the past (Hall, Johansson, Tarning, Sikstrom, & Deutgen, 2010; Johansson, Hall, Sikstrom, & Olsson, 2005). People can also be mistaken about the causal relationship between their choices and their actions, believing that they are causally responsible for actions that are actually out of their conscious control (Libet, Gleason, Wright, & Pearl, 1983; Soon, Brass, Heinze, & Haynes, 2008; Wegner, 2002; Wegner & Wheatley, 1999). Here, we explore what might be regarded as an even more surprising property of choice: that people can feel as if they make a choice *before* the time at which this choice is actually made.

This proposal is rooted in research suggesting that people become conscious of an event a short time after it actually occurs; hence, their conscious experience of an event can be influenced by experiences that seem to follow that event in time, but have already been processed unconsciously (Choi & Scholl, 2006; Dennett, 1991; Phillips, 2011). "Postdictive" effects of this sort have been observed for low-level vision (Eagleman & Sejnowski, 2000; Enns & Di Lollo, 2000; Kolers & von Grünau, 1976; Sergent et al., 2013), somatosensory experience (Geldard & Sherrick, 1972; Libet, Wright, Feinstein, & Pearl, 1979), and the perception of causality (Choi & Scholl, 2006). One well-known example involves the perception of apparent motion: If a shape is briefly flashed in one position, and then another shape is flashed at a second position after a short time delay, people report seeing a single shape moving from the first to the second position (Kolers & von Grünau, 1976). For this to happen, the flash of the second shape on the screen must influence the perception of motion that seems to come before it. We explore here whether the experience of choice can be postdicted in a similar manner.

Experiment 1

Participants viewed five white circles that appeared in random positions on a computer screen and were asked to try to quickly choose one of these circles "in their

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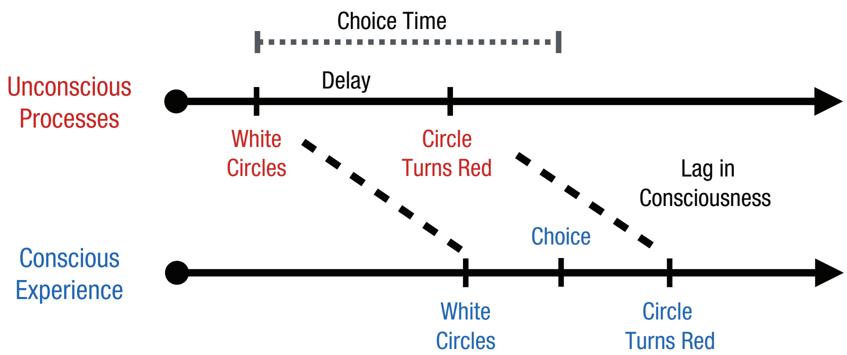

Fig. 1. A model of postdictive choice in Experiment 1. Although choice of a circle is not actually completed until after a circle has turned red (choice time > delay), the choice may seem to have occurred before that event because the participant has not yet become conscious of the circle's turning red (choice time < delay + lag in consciousness). The circle's turning red can therefore unconsciously bias a participant's choice when the delay is sufficiently short.

head" before one of the circles turned red. After a circle turned red, participants indicated whether they had chosen the red circle, had chosen a circle that did not turn red, or had not had enough time to choose a circle before one of them turned red.

Because the red circle is selected randomly on all trials, people performing this task should choose the red circle on approximately 20% of the trials in which they claim to have had time to make a choice if they are, in fact, making their choices before a circle turns red (and they are not biased to report choosing the red circle for some other reason). In contrast, a postdictive model predicts that people could consciously experience having made a choice before a circle turned red even though this choice did, in fact, occur after a circle turned red and was influenced by that event. Specifically, this could happen if a circle turns red soon enough to bias a person's choice *unconsciously* (e.g., by subliminally capturing visual attention—Yantis & Jonides, 1990), but this person completes the choice before becoming *conscious* of the circle's turning red (Fig. 1). On the other hand, if there is a relatively long delay until a circle turns red, a person would be more likely to have finished making a choice before even unconsciously processing a circle's turning red; hence, this event would be less likely to bias the choice.

Method

Twenty-five participants from Yale University and the greater New Haven, Connecticut, area (mean age = 24.0 years) were recruited to take part in a 30-min study for course credit or $5 compensation. We selected this number of participants to be slightly larger than that used in typical perception studies (which often have fewer than 20 participants) because our effect size was unknown and we wanted to be conservative in order to ensure reasonable statistical power.

Stimuli were presented on an Acer monitor with a 60-Hz refresh rate, using custom software written in Python with the PsychoPy libraries (Peirce, 2007). Participants first read the following instructions:

> This experiment is going to look at how people choose shapes on a screen. Here is what is going to happen. First, a plus sign (+) is going to flash in the middle of the screen. And then five circles will suddenly show up on the screen. You will not know where these circles are going to show up. As quickly as you can, you will have to choose one of these circles in your head and remember the circle you chose. You can choose a circle in whatever way you want; there is no right choice.
>
> At some point after the five circles show up on the screen, one of the circles will turn red. If this was the circle you remember choosing, indicate yes by pressing Y on your keyboard. If it was not the circle you remember choosing, press N, indicating no.
>
> A circle will sometimes turn red really fast, so it is important that you try to choose a circle in your head as fast as you can. But, if you tried your hardest and you still could not choose a circle before one of them turned red, indicate that you did not have time to choose a circle, by pressing the D key on your keyboard.

Each trial began with the presentation of five white circles on a black background in random (nonoverlapping) positions in a 300- × 300-pixel square window centered in the middle of the screen. After a variable time

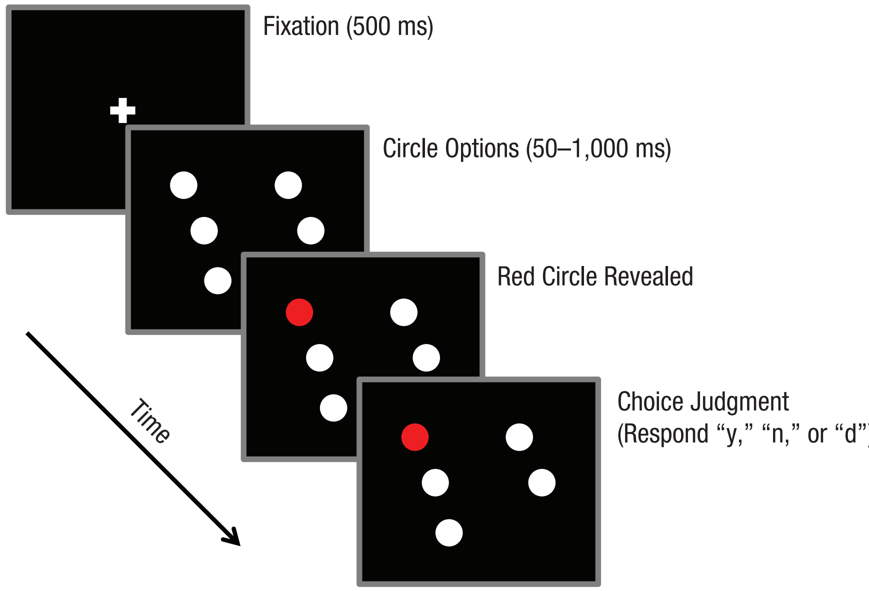

Fig. 2. Experimental procedure in Experiment 1. Five white circles appeared in random positions on the screen for a variable amount of time, and participants were asked to choose one of the circles mentally. One circle was then randomly selected to turn red. While these circles remained on the screen, participants pressed a key on the keyboard to indicate whether they had chosen the circle that turned red ("y"), had chosen a different circle ("n"), or had not had enough time to reach a decision before a circle turned red ("d").

delay of 50.00, 83.33, 166.67, 250.00, 333.33, 500.00, or 1,000.00 ms (corresponding, respectively, to 3, 5, 10, 15, 20, 30, or 60 frames on the 60-Hz monitor), one of these circles, randomly selected, turned red (Fig. 2).

Participants first completed 7 practice trials, 1 trial in each of the seven delay conditions, presented in random order. They then completed 280 experimental trials, which consisted of 40 trials of each of the delay conditions, intermixed in random order. (Because of a coding error, 1 subject completed only 30 trials of each delay condition, for a total of 210 trials.) This number of trials was selected in order to fit within the 30-min time window that participants had agreed to for our experiment.

After completing these trials, participants were asked questions about their experience in the experiment and their beliefs about the nature of the experiment before being debriefed about its purpose.

Results

Table 1 presents the distribution of "yes," "no," and "didn't have time" responses in each delay condition. Figure 3 depicts the relationship between time delay and probability of choosing the red circle among trials in which participants claimed (by pressing "y" or "n") to have had enough time to make a choice before a circle turned red. The 95% confidence intervals denoted by the error bands were computed hierarchically, using robust standard errors of the log odds of choosing the red circle for each time delay. Standard errors were clustered on the participant variable to account for the nonindependence of repeated observations from the same participant, and log-odds estimates were then converted to probability values. Thus, probability values with error bands that do not overlap with .20 are values that differ significantly from chance, $p < .05$, according to a z test. As shown, for most delays, participants claimed to have chosen the red circle significantly more often than would be predicted by chance.

Critically, if participants' choices were postdictively biased, this bias to choose the red circle should have been largest for the shortest delays (when these choices were still made within the window of time in which unconscious processing could manipulate the choice) and decrease as this delay lengthened (when these choices were mostly outside of this window of unconscious processing). In contrast, other sources of bias, such as a simple response bias to lie about one's choice or consciously revise one's choice after the red circle appeared, would not result in this time dependence: The incentives to lie or make weak commitments to one's choices were the same for all delay conditions in the experiment.

To examine whether participants' probability of choosing the red circle varied as a function of time delay (and, therefore, showed evidence of postdictive influence), we fit responses to a logistic regression in which the log odds of choosing the red circle (among "y" and "n"

Table 1. Distribution of Responses by Delay Condition in Experiments 1 and 2

Experiment and delay	Response: "Yes"	"No"	"Didn't have time"	Total
Experiment 1				
50.00-ms delay	222	501	267	990
83.33-ms delay	237	522	231	990
166.67-ms delay	242	620	128	990
250.00-ms delay	220	687	83	990
333.33-ms delay	196	735	59	990
500.00-ms delay	212	734	44	990
1,000.00-ms delay	233	744	13	990
Experiment 2				
50.00-ms delay	299	180	221	700
83.33-ms delay	306	251	143	700
166.67-ms delay	338	274	88	700
250.00-ms delay	344	285	71	700
333.33-ms delay	329	316	55	700
500.00-ms delay	360	293	47	700
1,000.00-ms delay	330	344	26	700

responses) was modeled as a function of the reciprocal of time delay (measured in milliseconds):

$$\text{logit(choose red)} = b(1/\text{delay}) + \text{constant}.$$

Standard errors were, again, robustly clustered at the participant level to account for the nonindependence of repeated observations from the same participant.

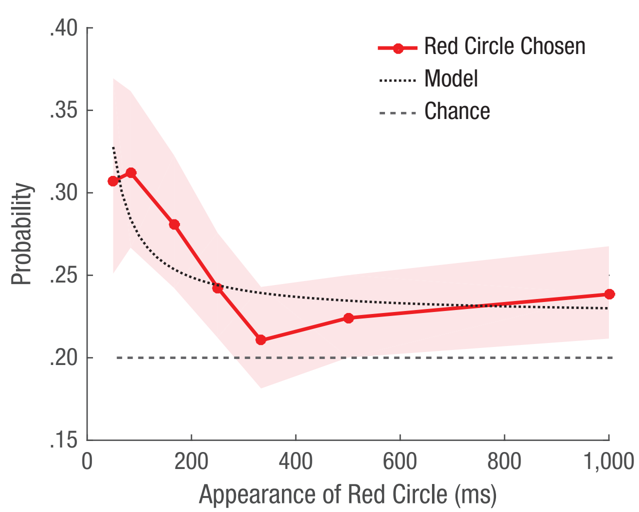

Fig. 3. Results from Experiment 1: probability that participants chose the red circle on trials in which they claimed to have had time to make a choice. The error bands denote 95% confidence intervals. Also shown are the results of the best-fitting logistic model of responses as a function of the reciprocal of time delay.

For reasons explained earlier, a postdictive account predicts that participants should be most likely to report choosing the red circle when the reciprocal of delay is large (i.e., delay is small), and then the likelihood of choosing the red circle should reach an asymptote at chance (.20 in this experiment) as the reciprocal approaches 0 (i.e., as delay gets large). In other words, in the equation, b should be significantly greater than 0, which would indicate that the likelihood of choosing the red circle increases as time delay gets shorter, and the constant should hover around the .20 chance responding that would be expected when there is no postdiction.

The results of this regression were significant, $\chi^2(1) = 13.37$, $p < .001$, and support a postdictive interpretation. The probability of choosing the red circle increased greatly as time delay got shorter (and the reciprocal of delay got larger), $b = 25.79$, $z = 3.66$, $p < .001$.[1] Moreover, a model comparison using Akaike's information criterion (AIC) suggested that this model, which included a term for delay, was preferable (AIC = 6,918) to an intercept-only model, which did not include this delay term (AIC = 6,946).

This model also estimated that as delay got longer, the probability of choosing the red circle approached .2255, which is significantly greater than the .20 chance level, $z = 2.95$, $p = .003$. Thus, participants in this study were slightly biased to choose the red circle even on longer trials, in which postdiction was unlikely to take place. This bias might be explained by a minority of choices being made late enough in time that they were still susceptible to a postdictive bias, or participants may have had a simple response bias to sometimes say they had chosen the red circle even when they had not (e.g., because they were lying or had made weak commitments to their original choices). Critically, though, because their likelihood of reporting that they had chosen the red circle increased significantly as the time delay shortened, the experiment provides strong evidence that postdiction took place during these shorter delays, having an effect over and above any response bias that may have existed at baseline.

During debriefing, 5 of the 25 participants guessed the basic purpose of the experiment, and 2 participants (1 of whom was also one of the 5 from the previous category) suspected that they had chosen the red circle more often on faster trials than on slower trials. Excluding these 6 participants, however, did not qualitatively change our findings: The reciprocal of delay remained a highly significant predictor of choice, $p < .001$, and the constant term was still significantly greater than .20, $p = .027$. Thus, the observed effects did not depend on conscious theorizing about the experiment and obtained even when participants were not aware of showing a time-dependent bias.

Experiment 2

In this experiment, we explored whether postdiction could occur in a slightly different paradigm, in which participants chose one of two different-colored circles. We used two, rather than five, choice options in this experiment to control for a worry that the time-dependent bias we observed in Experiment 1 could have been driven by low-confidence responding. If participants were less confident in choices they made more quickly, they might have been prone to choose relatively randomly between the "y" and "n" response options in short-delay trials. Such a random pattern of responding would have biased participants' reports of choosing the red circle toward .50 (because there were only two response options), and would have resulted in greater-than-chance reports of choosing the red circle for these shorter delays (because chance was .20 in Experiment 1). By making chance .50 in this experiment, we eliminated any concern that random responding could yield the time-dependent pattern of bias that we observed in Experiment 1. We additionally collected confidence judgments to more directly rule out the possibility that participants were more likely to show a bias to report choosing the red circle when they were less confident.

Method

Twenty-five non-color-blind participants (mean age = 19.2 years) were provided with the following instructions:

> This experiment is going to look at how people choose objects on a screen. Here is what is going to happen. First, a plus sign (+) is going to flash in the middle of the screen. And then 2 different colored circles will suddenly show up on the screen. You will not know where these circles are going to show up. As quickly as you can, you will have to choose one of these circles in your head and remember the circle you chose. You can choose a circle in whatever way you want; there is no right choice.
>
> At some point after the 2 circles show up on the screen, a new circle, which matches the color of one of the 2 circles you saw, will appear in the middle of the screen. If this new circle has the same color as the circle you remember choosing, indicate yes by pressing Y on your keyboard. If it does not have the same color as the circle you remember choosing, press N, indicating no.

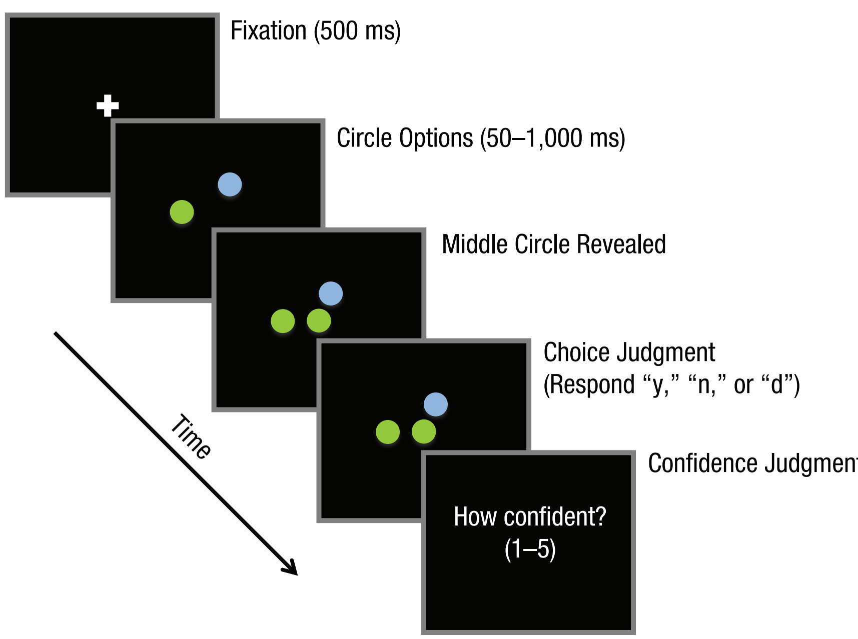

Fig. 4. Experimental procedure in Experiment 2. Two colored circles appeared in random positions a fixed distance away from the center of the screen, and participants were asked to choose one of these circles mentally. After a variable delay, a new circle that matched the color of one of the two initial circles appeared directly in the center of the screen. While these circles remained on the screen, participants pressed a key on the keyboard to indicate whether they had chosen the circle that matched this middle circle's color ("y"), had chosen the other circle ("n"), or had not had enough time to complete their choice before the middle circle appeared ("d"). On some trials in which participants answered with "y" or "n," they were also asked to rate how confident they were in their choice judgment.

This process will sometimes occur very quickly, so it is important that you try to choose a circle in your head as fast as you can. But, if you tried your hardest and you still could not choose a circle before the new circle appeared in the middle, indicate that you did not have time to choose a circle, by pressing the D key on your keyboard.

On some trials, you will be asked how confident you were (on a 1-5 scale) in your judgment about whether or not you chose the circle with the same color as the center circle. You may find that you feel very confident on all or most trials, in which case it is perfectly acceptable to always answer 5. You may also find that you almost never feel confident about your choice, in which case it is perfectly acceptable to always answer 1 or 2. We simply want your honest judgments.

The circles' colors were randomly selected from a set of six colors from Python's color library (red, gold, lime, fuchsia, aqua, and coral). The centers of the two different-colored circles were always located in random (nonoverlapping) positions 150 pixels from the center of the screen, and a new circle matching the color of one of these two circles appeared directly in the center of the screen after a variable delay. This delay was chosen from the same set of delays used in Experiment 1. Figure 4 depicts this experimental procedure.

Participants completed 14 practice trials, followed by 196 experimental trials (28 of each time delay), presented in random order, as in Experiment 1. On approximately half of the trials, participants were asked how confident they were in their choice judgment, but confidence was never assessed when participants reported that they had not had enough time to make a choice (by responding with "d"). Confidence ratings were made on a scale from 1 (*not at all confident*) to 5 (*extremely confident*).

Results

Tables 1 and 2 present the distributions of responses for each delay condition and confidence level. The results from this experiment once again suggested that postdiction occurred (Fig. 5; the 95% confidence intervals were calculated in the same way as in Experiment 1). Using the same regression model from Experiment 1 (but changing the dependent variable to the probability of choosing the circle whose color matched the middle circle), we found that this model was significant overall, $\chi^2(1) = 10.03$, $p = .002$. Crucially, we also found that the reciprocal of delay predicted choice responding in the expected direction, $b = 21.38$, $z = 3.17$, $p = .002$. Moreover, unlike in Experiment 1, the constant term did not differ significantly from chance (.50 in this experiment), $z = 0.66$, $p > .250$, which suggests that participants showed no general response bias to choose the circle that matched the middle circle's color when the time delay was large. (These effects held when we excluded 2 participants who indicated in debriefing that they believed they had a greater bias to choose the circle matching the middle circle's color on trials with shorter delays: $p = .007$ for the reciprocal term and $p > .250$ for the constant term. No participant guessed the purpose of the experiment.) Finally, a model comparison suggested that this model, which included a delay term, was preferable (AIC = 5,847) to an intercept-only model, which did not include this term (AIC = 5,861).

Because chance was .50 in this experiment, we know that participants were not simply answering yes or no arbitrarily on trials with the shortest delay, as they showed a bias on these trials to choose the circle matching the

Table 2. Distribution of Responses by Confidence Level in Experiment 2

Confidence rating (1–5)	Response		
	"Yes"	"No"	Total
1	21	17	38
2	42	30	72
3	110	88	198
4	193	163	356
5	786	672	1,458

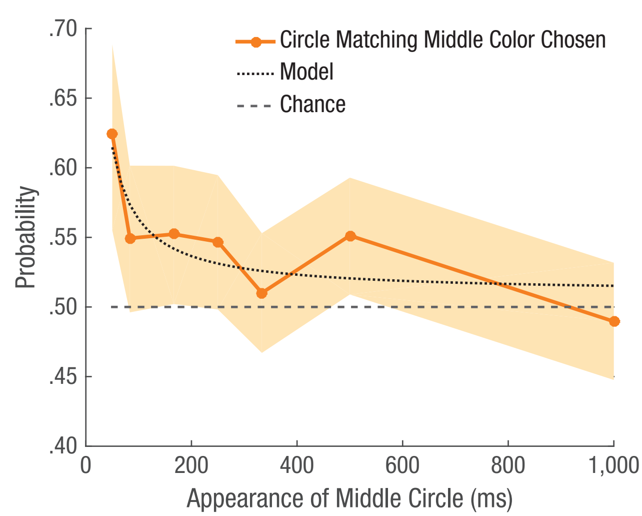

Fig. 5. Results from Experiment 2: probability that participants chose the circle that matched the color of the middle circle on trials in which they claimed to have had time to make a choice. The error bands denote 95% confidence intervals. Also shown are the results of the best-fitting logistic model of responses as a function of the reciprocal of time delay.

middle circle at a rate greater than .50. But were they more inclined to respond "y" when the delay was shorter simply because they were confused or unsure of their choices? A logistic regression examining the influence of self-reported confidence on choice judgments found no significant relationship between these two measures, $b = -0.03$, $z = -0.55$, $p > .250$, and confidence still did not influence choice when we controlled for the effect of (the reciprocal of) delay, $b = -0.002$, $z = -0.03$, $p > .250$. Moreover, the effect of time delay on choice remained significant even when the analysis was restricted to the much smaller subset of trials in which confidence judgments were collected and participants reported feeling maximally confident in their choice (i.e., rating of 5), $b = 24.67$, $z = 2.11$, $p = .035$. Hence, the observed results cannot be explained by low confidence: Even when participants strongly believed that they had completed a choice before the middle circle appeared, this middle circle biased their choice.

General Discussion

Our experiments suggest that people can have the subjective experience of having made a choice before their choice was actually made. When tasked with quickly choosing a circle among a set of circles, participants were biased by a crucial event (a circle turning red or a new circle appearing) even though their response ("y" or "n") indicated that they had experienced their choice as occurring before that event. Critically, this bias was largest when the delay for the occurrence of this crucial event was short, and bias steadily decreased as this delay increased. Our findings are inconsistent with participants' simply having a response bias to report choosing the red circle or the circle matching the color of the middle circle, because such biases would not result in this characteristic time dependence. Moreover, Experiment 2 demonstrates that low confidence or random responding cannot account for the bias we observed on short-delay trials.

We have assumed that our results are explained by participants' misperceiving the *time* of their choice. In particular, we have argued that a low-level visual change (e.g., a circle's turning red) can subliminally bias choice before one becomes consciously aware of this change, in the same way that a visual event can generate an illusory experience of apparent motion before one becomes aware of the event that generates this illusion. But it is also possible that participants in our experiments initially experienced their choices at the correct time, but immediately afterward encoded these experiences into memory incorrectly, which subsequently biased their reports of what they had chosen (see Dennett, 1991; Phillips, 2011). According to this explanation, a tendency to report choosing the red circle in the task in Experiment 1 should diminish when this circle turns red late enough that memory for the choice has been fully encoded and can no longer be covertly modified. Thus, as is true for the perceptual explanation we have emphasized, this memory-revision account must posit that there is only a small window of time in which the unconscious bias can occur. Further research is needed to distinguish between these two importantly different interpretations of our results.

The current findings build on past research suggesting that humans' phenomenology of agency can be misleading in surprising and interesting ways. For example, previous work suggests that although people experience themselves as consciously "willing" certain actions, this conscious experience can actually be the product of a post hoc inference that is causally independent from the true cognitive processes driving these actions (Wegner, 2002; Wegner & Wheatley, 1999). The present studies, too, suggest that the experience of choice may be an interpretive, post hoc construction that nevertheless seems to be causally antecedent to certain influencing events, such as a circle turning red.

Our results also relate to the phenomenon of *intentional binding*, whereby an intentional action and its associated consequences are consciously perceived (or remembered) to occur closer to each other in time than is actually the case (Haggard, Clark, & Kalogeras, 2002). In the study by Haggard et al., the perception of the timing of a person's intentional key press was postdictively influenced by whether or not a tone was subsequently played. Moreover, the magnitude of this effect has been shown to be postdictively modulated by information about whether the tone is associated with a rewarding or punishing outcome (Takahata et al., 2012). In conjunction with the present results, these findings suggest that apparently high-level processes involved in intention and choice may be more similar to low-level perceptual processes than previously thought.

Conversely, recent work suggests that the relatively low-level phenomenology that is involved in intentional binding may influence quite complex views that people have about the world. Specifically, the degree to which intentional binding is experienced has been found to correlate with people's high-level beliefs about free will (Aarts & van den Bos, 2011). Future work could explore whether postdictive effects of the sort we observed in our experiments might also influence people's high-level beliefs about agency and, if so, how this influence might relate to pathologies that involve delusions of control, such as schizophrenia (Daprati et al., 1997; Frith, Blakemore, & Wolpert, 2000).

The present results bear a particularly striking connection to work on *choice blindness* (e.g., Hall et al., 2010; Johansson et al., 2005). In such studies, people are found, remarkably, to forget choices they have made just seconds earlier about, for example, which of two individuals is more attractive (Johansson et al., 2005) and to confabulate reasons for choices they never made. Nevertheless, the cognitive processes that explain our effect likely differ from those that explain choice blindness. The latter effect is noteworthy because it happens so soon after the time of choice: People are, of course, likely to forget choices they made years ago, but it was surprising to find that they can also sometimes forget choices they have just made. In contrast, the effect we observed in our studies follows the opposite temporal pattern, with quicker choices being more susceptible to bias. Compared with choice blindness, therefore, our effect may be more akin to low-level perceptual illusions, such as the illusion of apparent motion, which happen on similar time scales (Phillips, 2011).

Our work is limited in several ways, which future work might address. First, our experiments lacked a measure of when, if ever, participants actually made their choices. Having such a measure (e.g., by using eye tracking) might help delineate between perception- and memory-based explanations of our results. Second, we have assumed that choice is completed at some discrete time point—either before or after the red or middle circle is revealed—but some work suggests that choice may be more of an evolving process that involves competing representations over time (Cisek, 2007). Thus, the story we have told about choice here may be oversimplified. Finally, the choices participants made in our studies were highly speeded and largely arbitrary (e.g., there were no costs or rewards associated with the options). Such choices may be more susceptible to postdictive influence than choices that are made more slowly or hold more value, which presumably are guided more by conscious reasoning.

Indeed, the kind of inconsequential choices that participants made in our studies bear little resemblance to the most important choices people make over the course of their lives. But everyday life is also made up of many less important decisions. When we lift our arms to grab objects, when we type with our fingers on a keyboard, when we switch from one activity to the next, we experience ourselves as agents consciously guiding our decisions moment by moment. Perhaps, in these cases, our sense that we make a choice well in advance of our actions is an illusion, making us feel more in control of ourselves than we actually are.

Action Editor

Hal Arkes served as action editor for this article.

Author Contributions

The two authors contributed equally to the study's design. A. Bear wrote the computer script for stimulus presentation, tested participants, and analyzed the data under the supervision of P. Bloom. A. Bear drafted the manuscript, and P. Bloom provided critical revisions. Both authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Note

1. This key time-dependence result was replicated in a sample of 25 additional participants who performed an almost identical version of the experiment in which the 50-ms delay condition was dropped and a very brief white flash occurred at some point during the presentation of the white circles. Once again, the probability of choosing the red circle increased significantly with the reciprocal of time delay, $b = 55.06$, $z = 4.99$, $p < .001$, although we did not find evidence for bias on trials with long delays (as measured by the constant term in the model), $z = 0.21$, $p > .250$.

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