Research Article

Psychological Science
2017, Vol. 28(9) 1240–1258

DOI: 10.1177/0956797617705386
www.psychologicalscience.org/PS
SAGE

Resisting Temptation: Tracking How Self-Control Conflicts Are Successfully Resolved in Real Time

Paul E. Stillman[1], Danila Medvedev[2], and Melissa J. Ferguson[2]
[1]Department of Psychology, Ohio State University, and [2]Department of Psychology, Cornell University

Abstract

Across four studies, we used mouse tracking to identify the dynamic, on-line cognitive processes that underlie successful self-control decisions. First, we showed that individuals display real-time conflict when choosing options consistent with their long-term goal over short-term temptations. Second, we found that individuals who are more successful at self-control—whether measured or manipulated—show significantly less real-time conflict in only self-control-relevant choices. Third, we demonstrated that successful individuals who choose a long-term goal over a short-term temptation display movements that are smooth rather than abrupt, which suggests dynamic rather than stage-based resolution of self-control conflicts. These findings have important implications for contemporary theories of self-control.

Keywords

self-control, social cognition, goals, cognitive processes, open data, open materials

Received 9/20/16; Revision accepted 3/28/17

People find it difficult to regulate their behavior according to long-term goals rather than short-term temptations—in other words, exert *self-control* (Mischel, 2014). For instance, health-minded people may find themselves reaching for chocolate instead of an apple. Although researchers have identified personality and situational factors that predict successful self-control decisions, much less is known about how cognitive processes unfold in real time to enable such decisions. An in-depth, micro-examination of how conflict is resolved when one resists temptation could reveal valuable information about successful versus unsuccessful choices and have important implications for self-control processes more broadly.

Traditional measures of conflict, however, largely rely on self-report data and are not able to quantify conflict over mere seconds. Furthermore, self-reports depend on respondents being able and willing to report their conflicts (Kleiman & Hassin, 2011). Implicit reaction-time measures similarly provide off-line assessments and do not reveal the ongoing changes in cognitive processes as someone progresses through a decision. And although measures that capture neural activity do provide on-line assessments, they typically lack either spatial (electroencephalogram) or temporal (functional MRI) precision.

In the present research, we used mouse tracking to measure real-time conflict resolution during successful self-control choices. Continuous motor output of the hand within a choice paradigm captures dynamic conflict between competing options (Freeman & Ambady, 2009; McKinstry, Dale, & Spivey, 2008; Wojnowicz, Ferguson, Dale, & Spivey, 2009). This method captures, in a nonobvious and unobtrusive manner, the real-time temporal profile of conflict during a successful self-control choice. As someone chooses an apple instead of chocolate, for instance, one can measure the person's mouse movements and assess whether, to what extent, and how the movement veers toward the chocolate.

We addressed three questions about real-time conflict resolution during successful self-control decisions.

Corresponding Author:
Paul E. Stillman, The Ohio State University, Department of Psychology, 1835 Neil Ave., Columbus, OH 43210
E-mail: paul.e.stillman@gmail.com

First, we established that hand movements during a mouse-tracking task reflect self-control conflict in real time. Second, we investigated whether conflict during successful self-control choices depends on self-control ability. Third, we examined how conflict is resolved—is it resolved as a function of sequential processes (i.e., abrupt, discrete) or more dynamic, iterative processes (i.e., smooth, gradual)?

Does Conflict Emerge in Real Time During Successful Self-Control Choices?

Traditional models of cognition assumed that decisions precede motor movements, so that when one selects an apple instead of chocolate, motor output is not influenced by the unchosen option (for a review, see Spivey, 2008). Recent evidence, however, shows that as one is moving a computer mouse toward one of two response options on a computer screen, hand movement varies according to the ongoing decision-making processes (Freeman & Ambady, 2011; Gold & Shadlen, 2001; Spivey, 2008). When choices are in conflict, trajectories reveal an early bias for one option that is then corrected (Dale, Kehoe, & Spivey, 2007; McKinstry et al., 2008). For example, Dale and colleagues (2007) showed that during the categorization of the atypical exemplar "whale" as "mammal" (vs. the tempting yet incorrect option, "fish"), participants' movements veered closer to "fish" than when the target was a typical mammal.

If the cognitive processes underlying self-control decisions and the motor movements involved in enacting those decisions unfold in tandem, one would expect that when choosing an apple, one is drawn toward the chocolate. This would align with other recent findings showing that hand movement is tightly linked to underlying conflict-resolution processes (Freeman, Dale, & Farmer, 2011). We predicted that even though individuals know that they should eat an apple instead of chocolate in order to be healthy, interference from the temptation (i.e., conflict) should nevertheless occur when choosing the apple. This would be consistent with research showing the automatic influence of temptations on attention, cognition, and affect (e.g., Fishbach, Friedman, & Kruglanski, 2003).

Recent work suggests that mouse tracking can capture components relevant to self-control. However, whereas this work focused on the timing of incorporation of attributes into choices (Sullivan, Hutcherson, Harris, & Rangel, 2014), ambivalence while evaluating foods (Gillebaart, Schneider, & De Ridder, 2016), or distinguishing and validating different metrics of mouse tracking in an intertemporal choice context (Cheng & González-Vallejo, 2015), the present study focused on the nature of conflict between two options and how it is resolved within self-control decisions.

Do Successful Self-Regulators Show Less Real-Time Decisional Conflict Than Unsuccessful Self-Regulators?

If real-time conflict in the mouse-tracking task reflects self-control processes, it should be influenced by factors theorized to influence self-control (e.g., ability, importance). For example, among people skilled at self-control, nonconscious processes are assumed to reduce the degree to which a "temptation" is tempting, which minimizes conflict between two options (Fishbach, Zhang, & Trope, 2010; Fujita, 2011). To the skilled dieter, a piece of cake might not even activate conflict. However, such hypotheses are rarely tested with a direct measure of conflict, much less a real-time measure of conflict between the goal and the temptation. Our second aim, therefore, was to show that self-control ability (measured and manipulated) leads to less conflict during successful self-control decisions. We further demonstrated that self-control ability would not influence real-time conflict in self-control-irrelevant decisions.

How Is Real-Time Conflict Resolved?

If mouse-tracking conflict reflects self-control processes, then one can investigate how conflict is resolved in real time. The most widely endorsed theoretical models for self-control are dual-process approaches (Hofmann, Friese, & Strack, 2009; Kahneman, 2011). These perspectives assume that successful self-control requires inhibiting impulses toward temptations—that is, System 2 (controlled) processes effortfully inhibit System 1 (automatic) processes. For example, Kahneman (2011) argues that "one of the tasks of System 2 is to overcome the impulses of System 1. In other words, System 2 is in charge of self-control" (p. 26).

These two systems are generally assumed to operate sequentially, as System 2 takes more processing time relative to System 1 to exert influence (Shiv & Fedorikhin, 1999). The positivity (reward) associated with temptations is first activated automatically, whereas the rejection of that temptation requires (temporally delayed) effortful inhibition by more deliberative processes (i.e., System 2). Although these models do not specify exactly how the transition between System 1 and System 2 occurs, it is generally described as sequential. That is, temptations are activated automatically (via System 1) and have sole influence initially in self-control decisions. If the decision is successful, the long-term goal eventually effortfully inhibits those temptations (via System 2;

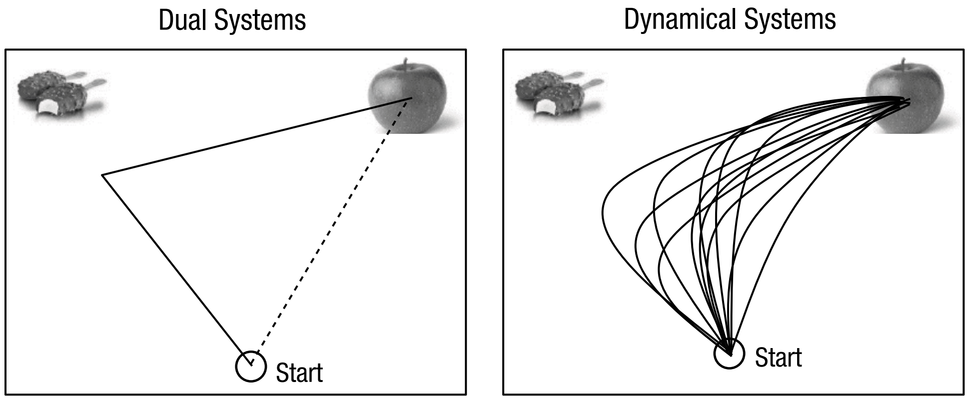

Fig. 1. Predictions of dual-systems and dynamical-systems models within a successfully resolved self-control conflict. Given the choice between two options, dual-systems models predict either direct trajectories toward the tempting object followed by abrupt midflight corrections toward the healthy option when the controlled and automatic systems compete (solid line) or direct trajectories toward the healthy object when the two systems agree (dashed line). Dynamical-systems models, in contrast, predict smooth trajectories that cover the spectrum of possible curvature amounts.

Hofmann et al., 2009). This perspective predicts that mouse movements during successful self-control decisions will initially veer toward the temptation and then abruptly reverse toward the goal-consistent option once System 2 comes on-line. Thus, this perspective predicts abrupt movements in such decisions. This approach also allows, however, that the supposed "temptation" may not always be tempting (e.g., a hamburger for a vegetarian). In these nonconflict cases, hand movements would proceed directly to the goal (i.e., Systems 1 and 2 are predisposed toward the same option). Over the course of many decisions, this dual-mode perspective thus predicts a combination of indirect and abrupt trajectories (i.e., high-conflict decisions) and direct and straight trajectories (i.e., no-conflict decisions)—in other words, a bimodal distribution of conflict (see Fig. 1).

In contrast to dual-system approaches, dynamical-systems models of decision making (outside of the self-control literature) contradict the idea that decisions unfold sequentially with input from two (computationally) distinct systems or processes. Instead, dynamical models suggest that information from both choice options would be activated from the beginning and interact over time dynamically until a final response emerges (Freeman & Ambady, 2011; Gold & Shadlen, 2001; Spivey, 2008). This perspective aligns with certain findings in self-control research. For example, information about goals and temptations can be activated automatically and rapidly from the earliest onset of the decision and subsequently predict decisions (Critcher & Ferguson, 2016; Ferguson, 2007; Fishbach et al., 2003). This perspective predicts that goal and temptation information should be activated simultaneously from the beginning and compete against each other dynamically over time until a response emerges. This suggests that mouse-tracking movements during successful self-control decisions should appear smooth.

Overview of the Present Studies

We tested these questions using mouse tracking in the domains of healthy eating (Studies 1 and 2) and intertemporal choice (Studies 3a and 3b). Study 1 demonstrated that the mere presence of temptations leads to real-time conflict during successful decision making and that conflict during self-control decisions predicts a real self-control decision. The remaining studies showed that conflict is reduced for people with enhanced self-control, whether measured (Study 2) or manipulated (Studies 3a and 3b). Further, these effects emerged only during self-control choices (Study 2) and only when participants chose the goal over the temptation (Studies 3a and 3b). Across all studies, we examined the nature of conflict resolution—whether trajectories appear smooth or abrupt—and thus provide novel evidence about how individuals successfully resolve self-control conflicts in real time.

For all studies, we report how we determined our sample size, all data exclusions, all manipulations, and all measures used (Simmons, Nelson, & Simonsohn, 2012). Further, across all studies, data were collected in a single wave and then analyzed (no participants were added following the first analyses).

Study 1: Healthy Versus Unhealthy Food Choices

On each of 200 trials, we presented participants in Study 1 with a choice between two food options and asked them to select the food that they should eat on average to be healthy, thus limiting responses to a "correct" answer. The trials either posed a self-control dilemma (unhealthy vs. healthy foods) or did not (healthy foods vs. inedible objects). We predicted (a) greater conflict on trials that involved self-control than on those that did not (expecting mouse movements to veer more toward temptations than nonfood items), (b) that average conflict during self-control trials would predict participants' real-life choice between an apple and chocolate, and (c) that trajectories would be smooth versus abrupt.

Method

Participants. Eighty-one undergraduate students at Cornell University participated for partial completion of course requirements. We based our sample size on past work using within-subjects designs and a mouse-tracking task (Sullivan et al., 2014). However, choice data were unavailable for 6 participants, and so we extended our data collection by approximately 1 week.

Procedure and stimuli. Participants completed 200 trials of decisions in which we used MouseTracker software (Freeman & Ambady, 2010; www.mousetracker.org) to record participants' x- and y-coordinate mouse movements as they made their decisions (approximate sampling rate = 70 Hz). On each trial, participants first clicked a small rectangle labeled "Start" at the bottom center of the screen. Once this was clicked, two images appeared, one in the upper-left and one in the upper-right corner of the screen (see Fig. 2), along with a caption that read "Choose." On half of the trials, participants saw pairings of one healthy food and one unhealthy food. We labeled these trials the *self-control* trials because they pitted taste goals against health goals, invoking a classic self-control dilemma (e.g., Sullivan et al., 2014). On the other half of trials, participants saw pairings of a healthy food and an inedible object, which we label the *comparison* trials. Thus, half of trials constituted a self-control dilemma (i.e., selecting the healthy nontasty food instead of the unhealthy tasty food) and half constituted a decision not obviously related to self-control. Participants were instructed to choose as quickly as possible which of the two foods would most help them meet their health and fitness goals. This allowed us to restrict participants' responses to a single correct response (Freeman & Ambady, 2010), which allowed for better comparison of trajectories from one trial to the next.[1]

To ensure that participants' decisions were ecologically relevant, we instructed them that they would be given one of the foods that they chose in the experiment. However, at the conclusion of the study, we told participants that they could choose between an apple and a candy bar, regardless of the kinds of choices they made in the task itself. We subsequently recorded whether participants chose the healthy or unhealthy food (choice data from 6 participants were unavailable, and these participants were dropped from analyses involving choice behavior).

To create maximal conflict on our self-control trials, we selected 10 foods that were rated in a pilot study as being healthy but not tasty (e.g., Brussels sprouts) and 10 that were rated as tasty but not healthy (e.g., brownies) for use in the self-control trials (see the Supplemental Material available online for pilot-testing details). For the comparison trials, in order to present a low-conflict choice unrelated to self-control, we pitted healthy objects against 10 inedible objects (e.g., a printer, a box). Participants saw all 200 possible pairings between the 10 healthy and 10 unhealthy foods, as well as the 10 healthy foods and 10 inedible objects. All trials were presented randomly, as was the left-right position of each food on screen. After completing all trials, participants were asked whether they were currently on a diet (see Appendix SA in the Supplemental Material). However, because our sample contained a relatively small number of dieters, and because we

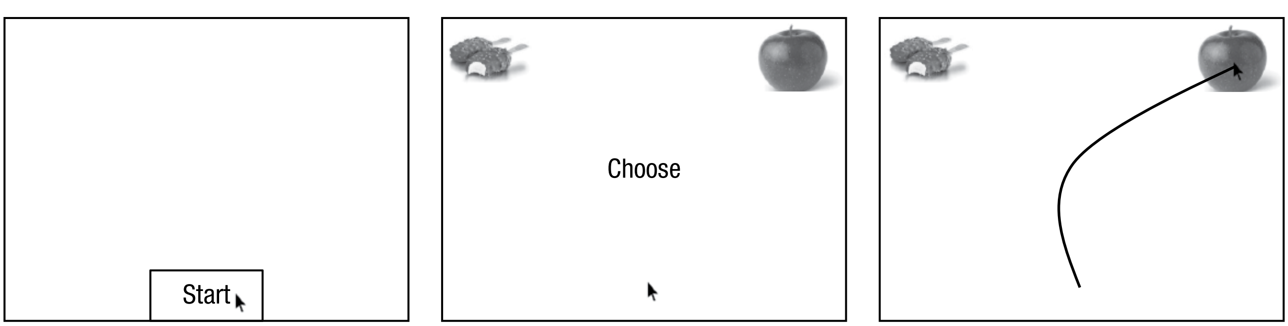

Fig. 2. Screen shots from an example self-control trial in Studies 1 and 2. After participants pressed the start button, two options appeared (one healthier and one tastier), along with the instruction to choose one. Participants used the mouse to indicate which option they should eat in order to promote their health goals.

made our strongest predictions for dieters with good self-control, we did not have strong a priori hypotheses for these data.[2]

Results

Mouse-tracking data preparation. We prepared our data in line with standard practices (Freeman & Ambady, 2010). Specifically, we time-normalized the trajectories into 101 time bins and rescaled every response such that each trajectory terminated at the top-right response location. We then removed trajectories that were ±3 standard deviations from the mean on reaction time, area under the curve (AUC), and time until initial mouse movement. We then omitted trials in which participants made the "incorrect" choice (i.e., did not choose the healthy food). All totaled, this excluded 7% of trials. An additional method of data cleaning removes trajectories with AUCs greater than 3, as values in this range suggest that trajectories loop or double back on themselves. As this consisted of a large amount of our sample (up to 16%), we opted to keep these trajectories.

In order for mouse trajectories to reflect real-time decisions, participants must be moving their mouse from the onset of the choices, rather than waiting until relatively late in their processing stream to begin moving the mouse. Mean initialization time after removing outliers was 130.41 ms (SD = 98.85).[3]

Real-time conflict. To investigate conflict, we analyzed the AUC. This metric reflects the area between the actual trajectory and an ideal (i.e., straight) trajectory. This metric has been validated as a measure of relative competition between two options—the more the two response options compete, the less direct the mouse trajectory will be, which results in a greater AUC (Freeman & Ambady, 2010). This metric thus captures information about the temporal dynamics of conflict between two choice outcomes from the very beginning of a decision. Unless otherwise noted, we predicted conflict on a trial-by-trial basis using mixed-effects modeling with the lme4 package in R. In these analyses, we analyzed trials nested within participants, which allowed us to estimate the conflict of each individual trial trajectory instead of aggregating across trajectories. All analyses used fixed slope and variable intercept models.

Using the AUC metric of conflict, we first investigated whether self-control trials produced significantly greater conflict than comparison trials. Consistent with our hypotheses, results showed significantly greater conflict in the self-control trials (mean AUC = 0.96, SD = 1.29) relative to the comparison trials (mean AUC = 0.67, SD = 1.08), b = 0.29, 95% confidence interval (CI) = [0.26, 0.33], SE = 0.01, $t(15001.09) = 15.75$, $p < .001$. This supports our first main hypothesis that conflict should be greater when the choice is a self-control choice (that thus involves a tempting alternative) than when the choice is self-control irrelevant (food vs. an inedible object). We note that this effect was (unexpectedly) moderated by dieting status (p = .02), such that in comparison (but not self-control) trials, being on a diet corresponded to nonsignificantly more direct trajectories (p = .16).

We next tested our second hypothesis—that participants' average conflict in the self-control trials should predict their eventual choice of an apple versus a chocolate bar after the mouse-tracking task. If conflict during a self-control dilemma is indeed reflective of self-control processes more generally, we would expect fewer apple (healthy) choices as conflict increases. This should still be true even when controlling for average curvature in the comparison trials (though we did not make strong predictions as to how curvature in comparison trials predicted choice). Consistent with our predictions, results revealed that greater average conflict in self-control trials was marginally related to reduced likelihood of choosing the healthy option (apple), b = −1.06, 95% CI = [−2.24, 0.03], SE = 0.57, Z = −1.86, p = .06. This was true even when we controlled for average curvature in the comparison trials, b = −1.22, 95% CI = [−2.86, 0.17], SE = 0.75, Z = −1.63, p = .10 (curvature on the comparison trials was not significantly related to choice, $p > .7$, though the difference between comparison and self-control trials was not significant, p = .30).[4]

Nature of trajectories. Mouse-tracking metrics allow one to detect whether the temporal evolution of trajectories follows an abrupt, impulse-inhibition profile or a smooth, dynamic competition profile. We used two existing methods of quantifying the nature of trajectories: the maximum deviation of trajectories—which quantifies individual trajectories as abrupt versus smooth—as well as a metric to quantify the bimodality of the distribution of conflict.

Maximum deviation. One way of investigating whether an individual appeared to use impulse inhibition on a given trial was to examine whether the maximum deviation of the trial exceeded a certain amount. Maximum deviation is obtained by taking the maximal distance between the actual trajectory and an ideal (i.e., straight) trajectory. Past research has shown that trajectories for which the maximum deviation is greater than .9 demonstrate the dramatic midflight corrections that abrupt, impulse-inhibition accounts predict (Freeman, 2014).[5]

Using the maximum-deviation measure allowed us to test both the prevalence of impulse inhibition in self-control decisions, as well as predict who will rely

Table 1. Distribution of Trials in Which Mouse Trajectories Were Abrupt or Smooth in Studies 1 and 2

	Study 1		Study 2	
Trajectory	Self-control trials	Comparison trials	Self-control trials	Comparison trials
Abrupt (*n*)	1,870	1,337	5,773	7,371
Smooth (*n*)	5,406	6,456	16,505	16,990
Smooth (%)	74	83	74	70

Note: Trials were labeled as *abrupt* if they had a maximum deviation greater than .9.

on impulse inhibition and when they will do so. It is possible that individuals who need to frequently engage in impulse inhibition may be those whose first lines of defense are failing and are thus producing initially indulgent responses, which must then be corrected. Supporting a smooth, dynamic evolution of choice, analyses revealed that only 26% of total self-control trials appeared to show the large midflight correction (see Table 1).

Beyond overall descriptive statistics, however, we also tested whether individuals relying on a seemingly abrupt, impulse-inhibition approach tend to be more or less successful. Some theorists have argued that impulse-inhibition processes may constitute only a small minority of successful self-control decisions (Galla & Duckworth, 2015; Hofmann, Baumeister, Förster, & Vohs, 2012) and may instead serve as a last line of defense when other processes have failed (Fishbach & Trope, 2005; Fujita, 2011). Although effortful inhibition of impulses may occur occasionally, perhaps especially in poor self-regulators, they are supplemented by automatic processes that promote the goal over the temptation. For example, effective self-regulators automatically activate the goal when presented with the temptation, but do not activate the temptation when presented with the goal (Fishbach et al., 2003). Supporting the claim that individuals with worse self-control are the ones relying on impulse inhibition, results showed that participants with a higher overall proportion of self-control trajectories with maximum deviation greater than .9 were marginally less likely to select the apple than the chocolate bar, $b = -3.13$, 95% CI = [−6.69, 0.19], $SE = 1.74$, $Z = -1.80$, $p = .07$.

Bimodality. A second way of quantifying the nature of mouse trajectories is to test the bimodality of the distributions of conflict across all mouse-tracking trials (Freeman & Dale, 2012). As mentioned earlier, the logic is that if trajectories are indeed the function of an abrupt, stage-based process, then one would expect to overwhelmingly see two different trajectory profiles. In a stage-based cognitive system, the fast system automatically activates desire toward a certain response (often the temptation but sometimes the goal), after which the slow system comes on-line and either (a) inhibits the initial decision (i.e., standard impulse inhibition)—which results in a pronounced midflight correction that corresponds to a high amount of conflict—or (b) affirms it—which results in a direct trajectory with minimal conflict. If trajectories are following a stage-based process, then one would expect conflict to show a bimodal distribution because trajectories are likely to have either minimal conflict or a large degree of conflict (see Fig. 1). On the other hand, smooth, dynamical processes suggest dynamic competition of both responses from an early time point and thus predict unimodal distributions of conflict that are graded to the level of competition on a given trial. Therefore, if our distributions are bimodal, that is evidence of abrupt, stage-based processing, whereas if they are unimodal, that is evidence of smooth, dynamical processing.

To quantify bimodality, we used Hartigan's dip statistic (HDS; Freeman & Dale, 2012; Hartigan & Hartigan, 1985), which gives a statistic and a p value for a test against the null hypothesis of unimodality—if the test is significant, one can reject the hypothesis that the distribution is unimodal. Using this test, we found no evidence for bimodality in either self-control trials, $d = .002$, $p = .99$, or comparison trials, $d = .002$, $p = .99$ (see Fig. 3). This is thus preliminary evidence that, overall, self-control decisions appear to unfold in a smooth, rather than abrupt, manner.

Reaction times. One potential criticism of using mouse trajectories is that they offer no new data beyond those already available using decision reaction times (but see Wojnowicz et al., 2009). Although conflict and reaction time were correlated ($r = .4$), unless otherwise noted,[6] our results remain unchanged when controlling for reaction time. Further, conducting the same analyses with reaction time as the dependent variable or predictor of interest generally did not yield the same conclusions as with spatial conflict (for instance, reaction times did not predict participants' choice at the end of the study, $p = .7$). Together, these data suggest that although reaction time

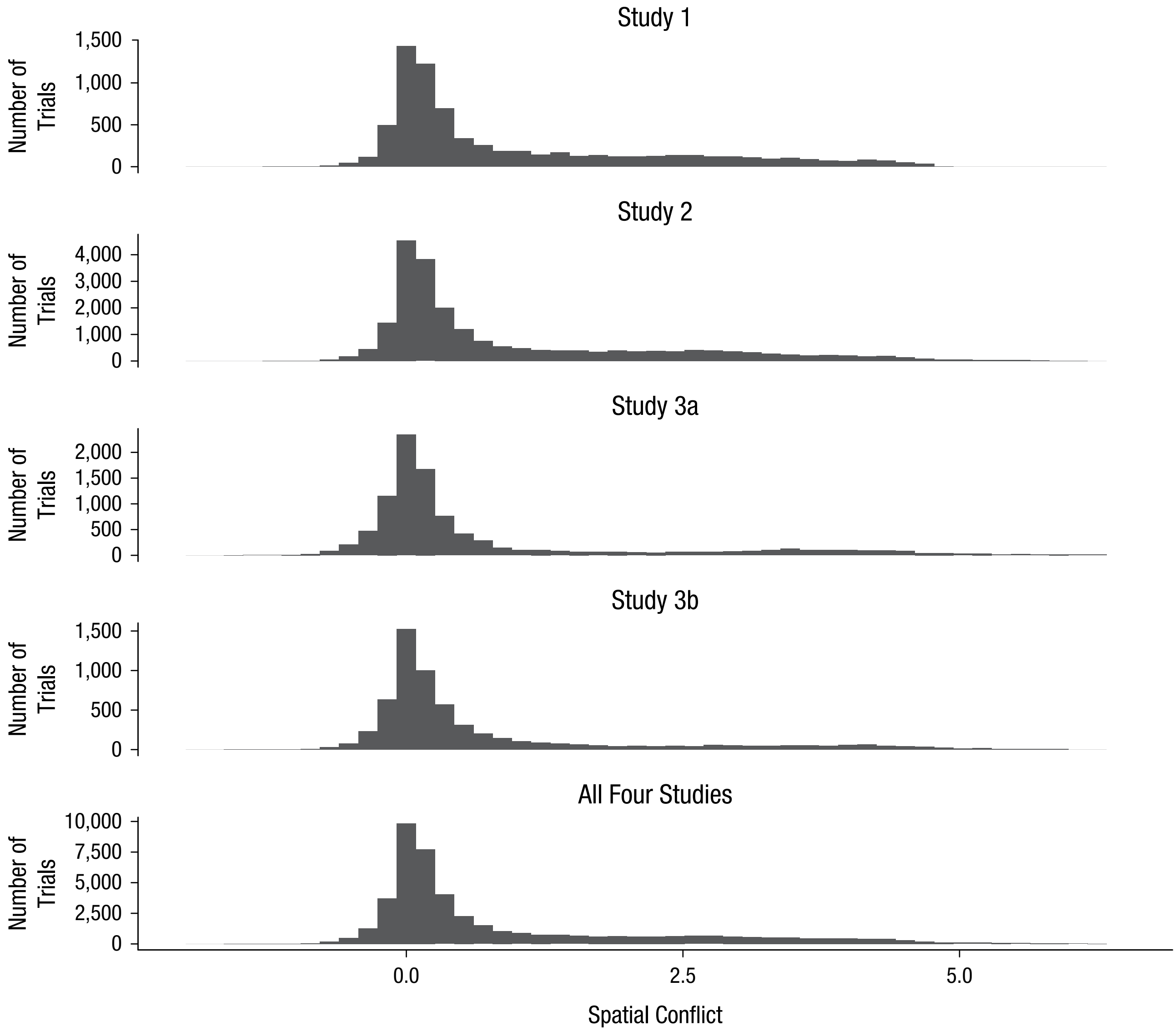

Fig. 3. Distribution of spatial conflict for Studies 1 through 3b, and for all studies combined. Only results for trajectories in the primary conditions of interest (Studies 1 and 2: self-control trials, Studies 3a and 3b: participants with high manipulated self-control and trials in which they chose the larger-later option) are shown.

may often be an important and potentially illuminating component of a decision, mouse tracking captures variance that is distinct from that revealed by reaction time. Finally, real-time conflict further appears to be distinct from other mouse-tracking metrics (e.g., Sullivan et al., 2014), which we describe in the Supplemental Material.

Study 2: Healthy Versus Unhealthy Food Choices

Study 1 showed that conflict during self-control choices was greater than in comparison trials and predicted successful self-control when choosing between a healthy and an unhealthy food. Furthermore, participants' mouse trajectories were smooth rather than abrupt. Study 2 tested whether participants with higher self-reported self-control ability would show reduced conflict, specifically during self-control-relevant trials (long-term goal vs. temptation) but not in comparison trials. We also measured the importance of the goal (i.e., participants who were dieters would be more motivated to choose the healthy option than participants who were not on a diet). If self-control ability predicts self-control conflict, we would expect to see the strongest effects of ability among people who experienced the trials in which they had to choose between a healthy and an unhealthy item as a self-control dilemma. Finally, we expected successful trajectories to be smooth.

Method

Participants. A power analysis (using a moderate effect size of $\rho = .25$) suggested that we would need a total sample of approximately 200 individuals. We thus had a target of 100 dieters and 100 nondieters. In previous studies with this sample, approximately 35 to 40% of participants reported dieting. We thus set our target sample size at 250 analyzable participants in order to get an appropriate number of dieters. Overall, 264 undergraduate students at The Ohio State University participated for partial completion of course requirements. Seven participants had incomplete data and were not analyzed. Two participants were recorded as the same participant number, which made connecting their questionnaire and mouse-tracking data impossible, and therefore were excluded from analysis.

Materials and measures

Food stimuli and mouse tracking. The mouse-tracking component of the study was identical to that in Study 1, except that in Study 2 we replaced the comparison trials with decisions between two healthy foods. We did this in order to include control trials that were high conflict (difficult choices) but were not classic self-control choices. In this way, whereas in Study 1 we predicted that choosing a long-term goal option over a temptation would lead to more conflict compared with choosing a goal over an inedible item, in this study, we examined conflict during two types of trials that should be similarly difficult and thus produce possibly similar levels of conflict. We therefore did not examine the amount of conflict between the two types of trials but rather whether self-control ability predicted the amount of conflict during the self-control-relevant (but not comparison) trials. The comparison trials captured decisional conflict but not self-control conflict. This tested our prediction that self-control ability should predict conflict only in the self-control trials and not in the comparison trials. To maintain even trial numbers, we added five additional healthy foods to be used during the healthy-healthy (i.e., comparison) trials.

Self-reported self-control surveys and dieting status. Following the mouse-tracking component of the study, participants completed food-rating items (see the Supplemental Material), dieting questions (with the dieting items in randomized order), the subjective self-control measures and behavioral indicators (order randomized), and exploratory personality variables (see the Supplemental Material).

For our individual-difference measures of self-control ability, we collected both domain-general and domain-specific (i.e., dieting) self-report measures of ability. Collecting both domain-general and domain-specific measures allowed us to test whether this "specificity" factor influences whether self-control ability predicts conflict. For example, it might be that only self-report measures in the domain of dieting predict conflict during dieting decision making, and perhaps only for people who are on a diet. However, if self-control ability is domain general, as some researchers have argued (e.g., Muraven & Baumeister, 2000), then indicators of self-control ability that are not ostensibly about dieting per se (e.g., generalized measures of ability) may predict conflict in a dieting-choice task.

For domain-general self-control ability, we used three existing validated measures, the Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995), the long form of the Tangney Self-Control Scale (Tangney, Baumeister, & Boone, 2004), and the Chen Self-Efficacy Scale (Chen, Gully, & Eden, 2001), as well as the unpublished Kalkstein Self-Control Efficacy Scale (see Appendix SB in the Supplemental Material). We used multiple measures in order to capture a reliable index of this individual difference. We did not have any strong a priori expectations about which would be most related to conflict.

To assess self-control success in the domain of dieting, we asked participants about their beliefs about the efficacy of dieting (e.g., "It is easy for me to eat healthy foods"; 1 = *strongly disagree*, 7 = *strongly agree*), as well as their evaluations of their success with past and future dieting behavior (e.g., "If I were to go on a diet tomorrow I would be able to stick with it"; 1 = *strongly disagree*, 7 = *strongly agree*).

We administered dieting items from a number of sources as well as adding our own (van Strien, Frijters, Bergers, & Defares, 1986; see Appendix SA). These items assessed whether participants were currently dieting, whether participants had and followed health goals, and whether they had dieted in the past or planned to do so in the future. We also asked a number of exploratory questions including how hungry participants were and when their last meal had been, how far away they were from their ideal weight, whether or not they had any food restrictions, and how much they would be willing to pay to "buy" their ideal weight. For these exploratory measures, our predictions were outside the scope of the present research, and we thus do not discuss them further.

Results

Data were prepared as in Study 1, and 8.5% of trials were removed from analysis on the basis of the exclusion criteria used previously. Mean initialization time after outliers were removed was 110.25 ms (SD = 92.98).

Effect of trial type on conflict. We predicted that measured self-control ability should predict real-time mouse-tracking conflict only during self-control-relevant decisions and not during self-control-irrelevant decisions. We therefore chose the control decisions to be difficult but unrelated to self-control (rather than choosing low-conflict control decisions, which might have prevented any effects because of low variability of conflict). Although we did not have any a priori claims about which type of trial would contain more conflict, there was a main effect of trial type; specifically, there was greater conflict on the comparison trials (mean AUC = 1.16, *SD* = 1.54) relative to the self-control trials (mean AUC = 0.97, *SD* = 1.35), $b = -0.08$, 95% CI = [−0.09, −0.07], $SE = 0.006$, $t(46590.10) = -12.34$, $p < .001$. This likely reflects the fact that electing the healthier of two healthy foods can be more ambiguous (and therefore difficult) than choosing the healthy food when the unhealthy food is available.

Effect of self-control on real-time conflict

Domain-general measures. We predicted real-time conflict from self-reported self-control, trial type (self-control-relevant vs. comparison), and their interaction. Because the self-report measures of self-control were correlated (*rs* = .28–.74; see Table S1 in the Supplemental Material), we combined all items into a composite self-report self-control variable (α = .94; see the Supplemental Material for individual analyses separately). As predicted, we found a significant two-way interaction of self-control and trial type on conflict, $b = -0.04$, 95% CI = [−0.09, −0.02], $SE = 0.01$, $t(46240.28) = -3.60$, $p < .001$; self-control predicted reduced conflict in the self-control-relevant trials, $b = -0.13$, 95% CI = [−0.24, −0.03], $SE = 0.05$, $t(280.22) = -2.62$, $p = .009$, but not in the comparison trials, $b = -0.04$, 95% CI = [−0.15, 0.06], $SE = 0.05$, $t(273.81) = -0.93$, $p = .35$. This supports our prediction that self-reported generalized self-control success would be related to reduced conflict on self-control-relevant trials, but not on trials that are irrelevant to self-control.

These results show that generalized self-control ability predicted conflict during choices in the specific domain of healthy eating. In other words, domain-general self-control success predicted conflict in a specific domain. Another way to test this "generality" finding is to examine whether generalized self-control ability was a better predictor of conflict on the mouse-tracking dieting task for dieters than for nondieters. This might happen for at least two reasons. First, among dieters, the generalized self-report measures might be actually tapping dieting ability primarily. Second, dieters may care more than nondieters about the goals of healthy eating as well as indulgence, and therefore may have experienced the healthy-unhealthy conflicts as a self-control dilemma more so than nondieters did. For these participants, self-control ability may have been more influential in the resolution of conflict between healthy and tasty options. Given these possibilities, we expected our findings with reported self-control to be stronger among individuals who have a chronic dieting goal than among those who do not.

Supporting this, we obtained a significant three-way interaction when predicting conflict from trial type (self-control-relevant vs. comparison), self-reported self-control, and dieting status, $b = -0.02$, 95% CI = [−0.04, −0.001], $SE = 0.009$, $t(46008.12) = -2.24$, $p = .03$. Decomposition of this interaction (at ±1 *SD* of dieting status) suggested that the previously described relationship between reported self-control and reduced conflict was strongest for those individuals currently on a diet, $b = -0.20$, 95% CI = [−0.34, −0.06], $SE = 0.07$, $t(273.43) = -2.72$, $p = .007$; all other simple slopes were not significant (see Fig. 4).

We note that the reported two-way interaction between trial type and self-control is one of the few interactions that fell to nonsignificance when controlling for reaction time ($p = .13$). However, the three-way interaction remained significant, $b = -0.02$, 95% CI = [−0.036, −0.003], $SE = 0.0008$, $t(45947.78) = -2.33$, $p = .02$. Further, all simple slopes for this three-way interaction remained unchanged when we controlled for reaction time.

Domain-specific (dieting-efficacy) measures. We then examined whether the dieting items themselves predicted conflict. To test this, we created a composite variable averaging dieting efficacy, past success, and expected future dieting efficacy (α = .88). Using this measure, we conducted the previous two-way interaction predicting conflict from dieting self-control, trial type, and their interaction. This yielded a marginal interaction, $b = 0.01$, 95% CI = [−0.001, 0.024], $SE = 0.007$, $t(45946.54) = 1.70$, $p = .09$; however, neither simple slope approached significance (*p*s > .46), and the direction of the effect was such that efficacy led to nonsignificantly less conflict in the comparison trials relative to the control trials. Similarly, the three-way interaction of dieting self-control, trial type, and dieting status was not significant, $b = 0.005$, 95% CI = [−0.005, 0.01], $SE = 0.005$, $t(45925.14) = 1.02$, $p = .30$. Together, it appears that the domain-specific variable of self-reported dieting efficacy does not reliably predict (or interact to predict) conflict in either self-control or comparison trials. It is unclear why the dieting-specific measures were not predictive, but they may have been more reactive than general self-control measures (Stice, Sysko, Roberto, & Allison, 2010).

Nature of the mouse trajectories. As in Study 1, we tested whether the nature of trajectories appeared to reflect an abrupt, impulse-inhibition profile or a smooth, dynamic profile. We again tested this by investigating whether or not a trajectory had maximum deviation greater than .9, as well as bimodality of the distribution.

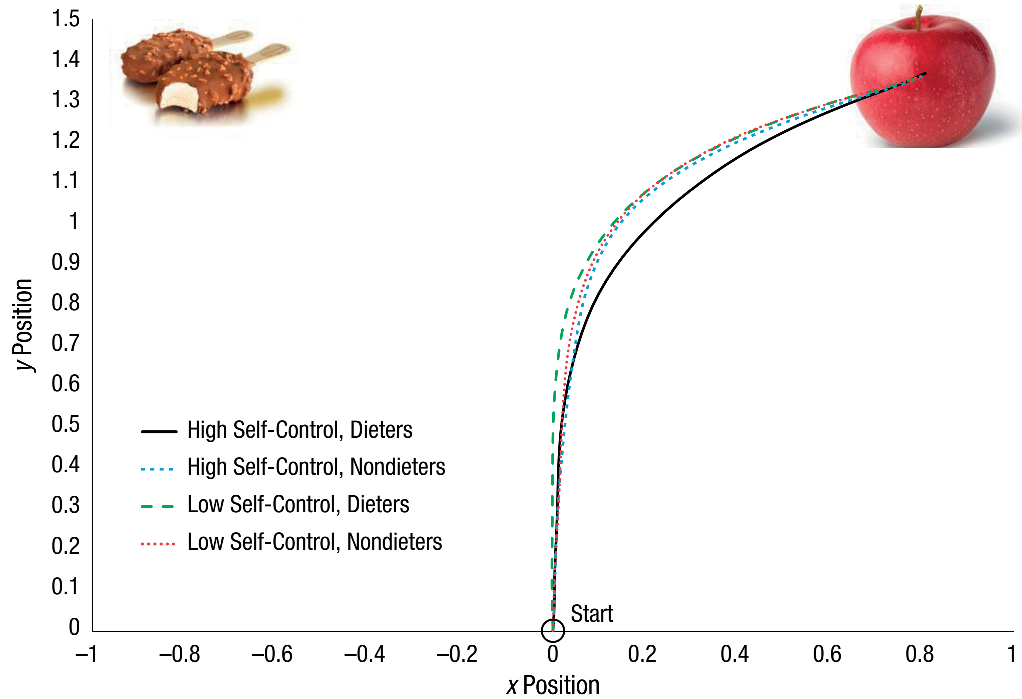

Fig. 4. Mean mouse trajectories for the self-control-relevant trials in Study 2. Results are graphed separately for the four combinations of high and low scores on the self-control composite scale (plotted at ±1 *SD* from the mean) crossed with whether or not participants were currently on a diet (plotted at ±1 *SD* from the mean). The graphed points were obtained by modeling each of the 101 *x* and *y* positions individually and estimating points at ±1 standard deviation from the mean for self-control-relevant trials (see osf .io/3wz2j for all graphing functions).

Maximum deviation. As in Study 1, a majority of trials did not display the midflight correction (as indexed by a maximum deviation < .9; see Table 1). Further, we found a significant interaction between self-reported generalized self-control ability and trial type on trajectory nature, $b = -0.06$, 95% CI = [−0.10, −0.02], $SE = 0.02$, $Z = -3.03$, $p = .002$; participants with better self-control were less likely to demonstrate abrupt trajectories on the self-control trials, $b = -0.20$, 95% CI = [−0.37, −0.04], $SE = 0.09$, $Z = -2.38$, $p = .02$, than on the comparison trials, $b = -0.08$, 95% CI = [−0.25, 0.08], $SE = 0.08$, $Z = -.99$, $p = .32$.

We further predicted that these results would be moderated by dieting status, as participants on a diet would be the most likely to view the self-control trials as self-control conflicts. Supporting this, we found a significant three-way interaction among self-reported self-control, dieting status, and trial type on likelihood of demonstrating abrupt trajectories, $b = -0.05$, 95% CI = [−0.07, −0.02], $SE = 0.01$, $Z = -3.64$, $p < .001$ (see Fig. 5). Investigation of the simple slopes revealed that this effect, whereby better self-control led to fewer abrupt trajectories, was strongest for those on a diet, $b = -0.33$, 95% CI = [−0.56, −0.10], $SE = 0.12$, $Z = -2.86$, $p = .004$; all other simple slopes were not significant. As before, controlling for reaction times rendered the two-way interaction nonsignificant ($p = .17$), while leaving the three-way interaction unchanged.

Bimodality. Replicating Study 1, Study 2 revealed no evidence of bimodality in the distribution of conflict scores for self-control trials, $d = 0.001$, $p = .99$ (Fig. 3). Interestingly, when looking at the comparison trials (for which we made no a priori predictions), we saw strong evidence of bimodality, HDS = .007, $p < .001$.

Discussion

Study 2 revealed that participants with better self-control showed less conflict during self-control-relevant decisions (but not self-control-irrelevant decisions). Studies 1 and 2 provide convergent evidence that conflict resolution was smooth and that participants who showed abrupt (vs. smooth) trajectories reported worse self-control.

Studies 3a and 3b: Temporal Discounting

Studies 3a and 3b extended Studies 1 and 2 by manipulating self-control in a new domain—temporal discounting—and not restricting choice. Temporal discounting was

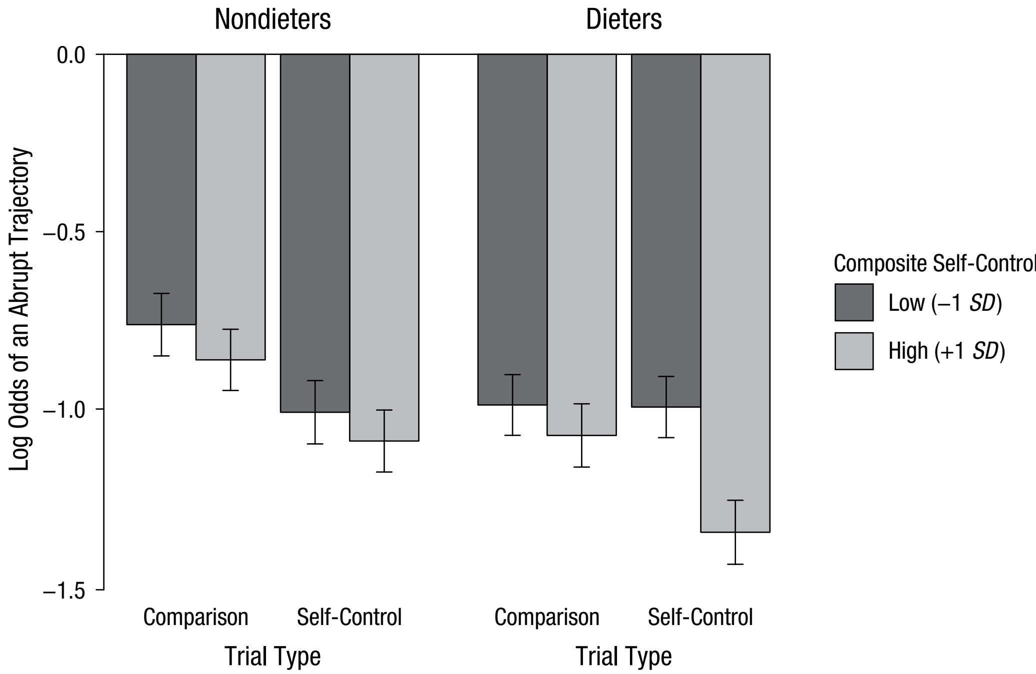

Fig. 5. Results from Study 2: log odds of an abrupt mouse trajectory as a function of trial type and reported self-control, separately for dieters and nondieters. Lower numbers on the *y*-axis correspond to lower likelihoods of displaying an abrupt trajectory. Error bars show standard errors of the point estimates.

assessed in a delay-of-gratification task that pits an immediate smaller reward (smaller-sooner reward), against a larger delayed reward (larger-later reward; Ainslie, 1975; see also Cheng & González-Vallejo, 2015). We used two self-control manipulations that produce differences in temporal discounting—order of considerations (Study 3a; Weber et al., 2007) and construal level (Study 3b; Fujita, Trope, Liberman, & Levin-Sagi, 2006). We predicted that participants in the high-self-control condition would demonstrate less conflict during successful choices than those in the low-self-control condition. We again expected trajectories on successful decisions to be smooth.

Method

Participants. One hundred ninety-one undergraduate students at Cornell University participated in Study 3a for partial completion of course requirements. Condition information was not available for 4 participants, and their data were not analyzed. We collected data from as many participants as we could before the semester ended. One hundred forty undergraduate students at The Ohio State University participated in Study 3b for partial completion of course requirements. The stopping rule was to run participants through the end of the semester (approximately 3 weeks). One participant did not finish, and only completed trials were analyzed.

Self-control manipulations. Past work in query-order theory demonstrates that when individuals generate reasons for choosing the larger-later (vs. the smaller-sooner) option first, they are more likely to elect the larger-later option (Weber et al., 2007). In Study 3a, we adopted a previously used manipulation (Weber et al., 2007, Study 2) in which participants generated reasons to elect both the larger-later and smaller-sooner option, but we critically manipulated (between participants) whether they first generated reasons to elect the larger-later option or the smaller-sooner option.

In Study 3b, we manipulated level of construal. Construal-level theory (Trope & Liberman, 2010) states that people construct representations of events using either low-level construal, which highlights details and idiosyncrasies, or high-level construal, which highlights essential, goal-relevant features. High-level construal promotes self-control in a variety of domains (Fujita et al., 2006). To manipulate level of construal, we had participants complete the why-how task (Freitas, Gollwitzer, & Trope, 2004)—a task that presents participants with an action (e.g., "improve and maintain recycling levels") and asks them to provide either the superordinate goal that action serves (e.g., "save the planet"; high-level construal) or the subordinate means with which to achieve that action (e.g., "use reusable water bottles"; low-level construal). This task has been reliably found to prime high- and low-level construal,

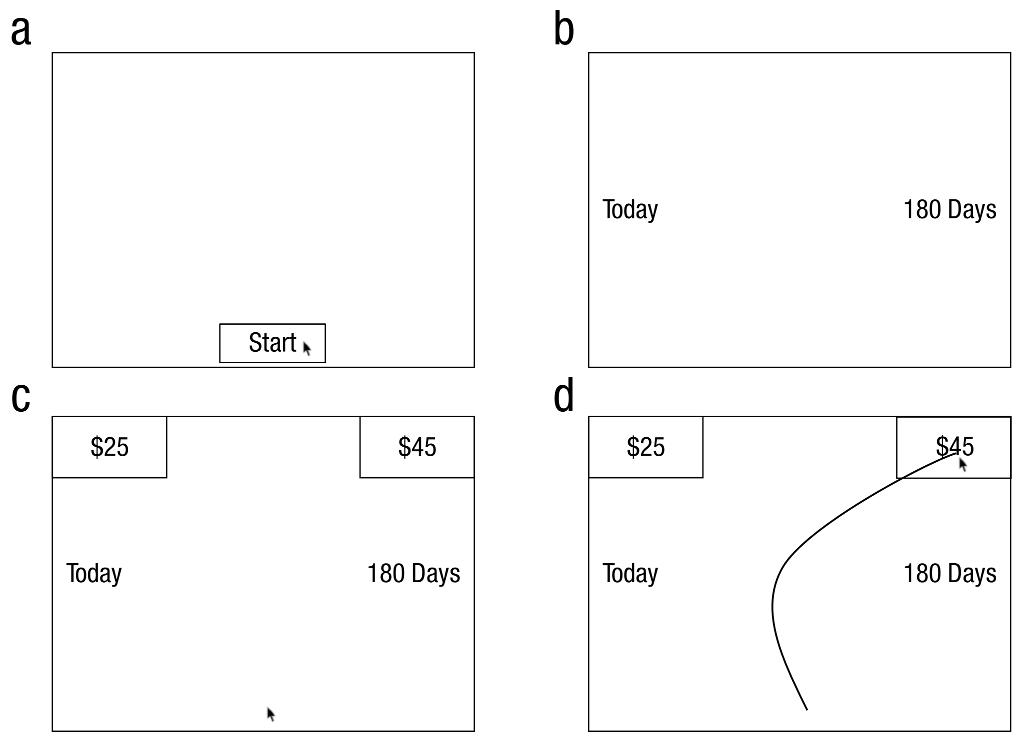

Fig. 6. Example trial sequence from Studies 3a and 3b. Participants first pressed the "Start" button (a), after which delay periods appeared on each side of the screen (b). After 1 s, the smaller-sooner and larger-later amounts appeared, respectively, in the top-left and top-right corners of the screen (c; counterbalanced across participants). Participants then used the mouse to indicate which option they preferred (d).

respectively, such that engaging in high-level construal on the why-how task carries over to subsequent tasks (Fujita et al., 2006).

Procedure. Following the self-control manipulation, participants completed 180 temporal-discounting trials. In Study 3b, participants completed an additional 15 trials in which the rewards were offered at a delay of 1,000 days (see Appendix SC in the Supplemental Material for the full list). Each trial pitted a smaller-sooner option available immediately (e.g., $25 today) against a larger-later outcome available after some delay (e.g., $45 in 180 days). As in Studies 1 and 2, one option on each trial would appear in the upper left corner and one option would appear in the upper right corner. The location (left vs. right) of the smaller-sooner and larger-later options stayed constant throughout the study and was counterbalanced between participants. Participants would press a start button in the bottom center of the screen and then move their mouse to the option they preferred. To eliminate the need to process a number of different variables at once, we had participants complete trials in blocks, in each of which there was a different delay (e.g., 1 week, 1 month, 1 year). At the start of each block, we informed participants of the delay for the larger-later option (the smaller-sooner option was always available "today"). Therefore, on each trial, participants knew when each reward would be paid off but did not know the magnitude of either reward (see Fig. 6). After participants pressed the start button, the length of the delays would appear on screen for 1 s before the magnitude options appeared.

Additionally, Study 3a incentivized participants' performance using a modified random-lottery procedure. We told participants that a decision of one participant would be chosen at random and would be paid with real money. In Study 3b, to both give participants a break as well as ensure the manipulation had not worn off, we asked participants to complete a second why-how prompt halfway through the trials, "improve and maintain health."

Results

Data were again prepared as in Study 1; 5.5% and 4% of trials from Study 3a and 3b, respectively, were removed from analysis on the basis of the exclusion criteria used previously. Mean initialization time after outliers were removed was 195.02 ms (*SD* = 215.37) and 156.47 ms (*SD* = 193.94) in Study 3a and 3b, respectively.

Effect of manipulation on real-time conflict. We first tested the effect of our manipulations of real-time conflict on successful choices. We predicted that participants in the high-self-control condition would show significantly reduced conflict when making better self-control decisions (i.e., choosing the larger-later option).

Study 3a. We predicted that participants who generated reasons to take the larger-later option first (vs. the smaller-sooner option first) would show significantly reduced conflict when making better self-control decisions (i.e., choosing the larger-later option). We therefore analyzed conflict during each trial as a function of query-order condition and whether or not participants chose the larger-later option (dummy coding: 0 = smaller-sooner, 1 = larger-later). This yielded a significant query-condition-by-option-chosen interaction, $b = -0.07$, 95% CI = [−0.12, −0.04], $SE = 0.02$, $t(31564) = -3.88$, $p < .001$ (see Fig. 7). Decomposition of this interaction revealed that, as expected, for trials on which participants chose the larger-later option, having listed reasons to choose the larger-later option first (mean AUC = 0.74, $SD = 1.45$) versus the smaller-sooner option first (mean AUC = 0.95, $SD = 1.59$) promoted significantly less conflict, $b = -0.08$, 95% CI = [−0.17, −0.003], $SE = 0.04$, $t(204.48) = -2.09$, $p = .04$. There was no effect of our manipulation on trials in which participants chose the smaller-sooner option, regardless of whether participants listed reasons to take the larger-later option first ($M = 1.04$, $SD = 1.69$) or second ($M = 1.01$, $SD = 1.71$), $b = -0.007$, 95% CI = [−0.09, 0.07], $SE = 0.04$, $t(213) = -0.18$, $p = .86$. We note that when we controlled for reaction times, the interaction remained significant, but the simple effect of condition when participants chose the larger-later option dropped to nonsignificance ($p = .14$).

Study 3b. We predicted that participants induced to high-level construal would show reduced conflict when succeeding in self-control. Consistent with this hypothesis, results showed a significant interaction between construal and whether or not participants chose the larger-later option, $b = -0.13$, 95% CI = [−0.17, −0.09], $SE = 0.02$, $t(25875.13) = -6.64$, $p < .001$ (see Fig. 8). Decomposition of this interaction revealed that, as expected (and mirroring the results of Study 3a), for trials on which participants chose the larger-later option, high-level construal (mean AUC = 0.72, $SD = 1.32$)

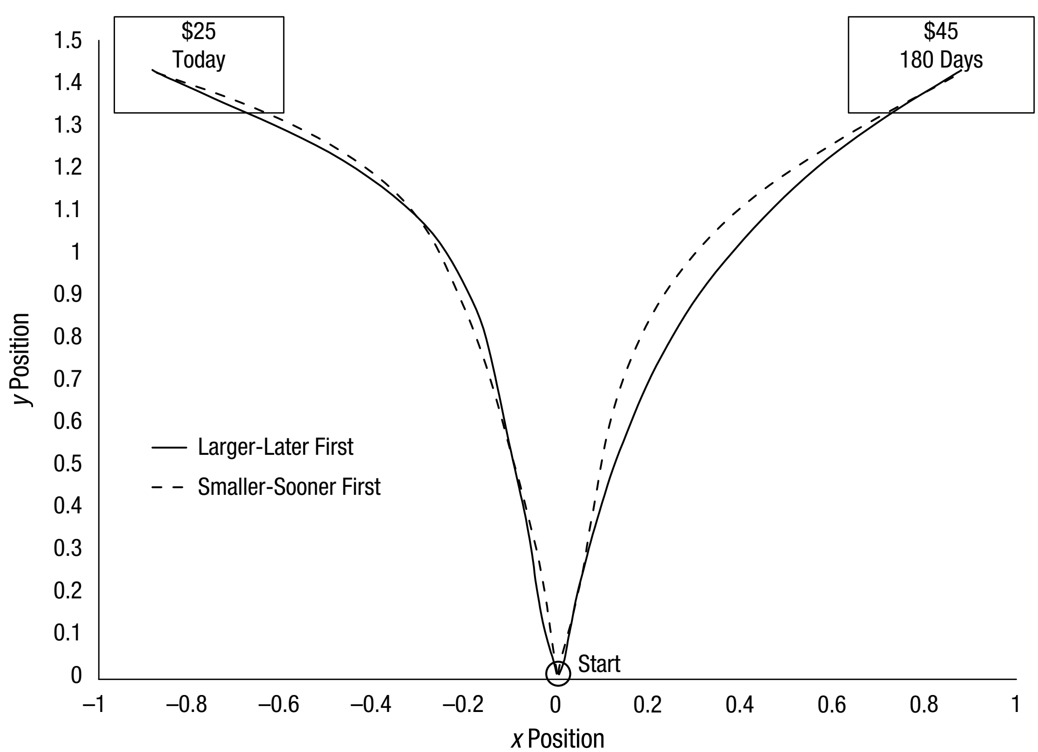

Fig. 7. Mean mouse trajectories to each of the two reward options in Study 3a. Results are graphed separately for participants who generated reasons beforehand to take the smaller-sooner option or the larger-later option first. Trials in which participants chose the larger-later option are shown as rightward trajectories, whereas trials in which participants chose the smaller-sooner option are shown as leftward trajectories. The graphed points were obtained by modeling each of the 101 x and y positions individually and estimating points at ±1 standard deviation from the mean (see online code for all graphing functions).

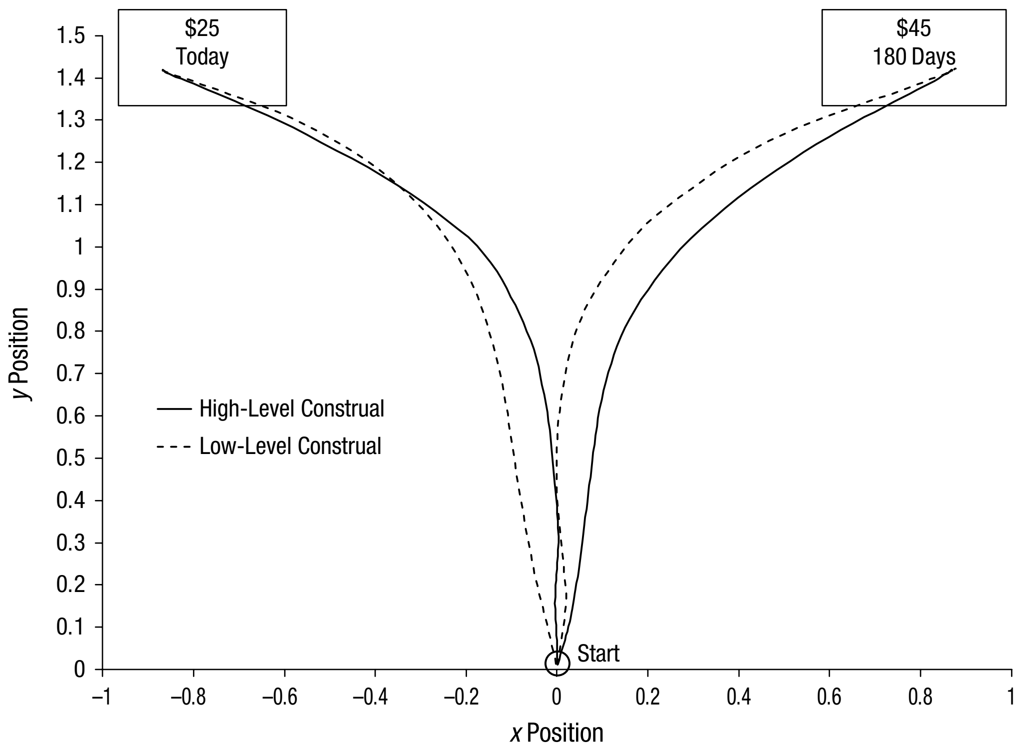

Fig. 8. Mean mouse trajectories to each of the two reward options in Study 3b. Results are graphed separately for participants induced to construe options at high and low levels. Trials in which participants chose the larger-later option are shown as rightward trajectories, whereas trials in which participants chose the smaller-sooner option are shown as leftward trajectories. The graphed points were obtained by modeling each of the 101 x and y positions individually and estimating points at ±1 standard deviation from the mean (see online code for all graphing functions).

promoted significantly less conflict relative to low-level construal (mean AUC = 0.93, SD = 1.50), b = −0.11, 95% CI = [−0.21, −0.02], SE = 0.05, t(152.20) = −2.32, p = .02. For trials in which participants chose the smaller-sooner option, there was no significant effect of construal, although the means were in the opposite direction; specifically, high-level construal (M = 0.83, SD = 1.43) led to nonsignificantly more conflict relative to low-level construal (M = 0.80, SD = 1.46), b = 0.02, 95% CI = [−0.07, 0.11], SE = 0.05, t(148.83) = 0.41, p = .68. These results were unchanged when we controlled for reaction times.

Relationship between real-time conflict and decisions. The results so far show that both manipulations of self-control influenced the real-time conflict shown during successful choices in the predicted direction. But did real-time conflict on successful decisions predict overall success on the task (choosing delayed options)? To test this, we analyzed our data controlling for the self-control manipulations. Our temporal-discounting paradigm allowed us to investigate how conflict while making the choices predicted the actual choices. If curvature toward a competing option (i.e., real-time conflict) revealed information about how tempting that option was, then the average degree of curvature toward the unchosen option across all trials should predict the overall number of choices in the entire task that were consistent with that option. We thus calculated two averages for each participant: average conflict for trials in which they chose the smaller-sooner reward, and average conflict for trials in which they chose the larger-later reward. As predicted, in both Study 3a and Study 3b, we found that conflict when choosing the larger-later option negatively predicted the proportion of larger-later decisions overall—Study 3a: b = −26.03, 95% CI = [−29.90, −22.15], SE = 1.96, t(180) = −13.26, p < .001; Study 3b: b = −28.31, 95% CI = [−33.97, −22.66], SE = 2.86, t(133) = −9.90, p < .001. In other words, the less conflict participants showed when choosing larger-later options, the greater the overall proportion of larger-later options they chose across the entire task. Similarly, higher conflict when choosing the smaller-sooner option significantly predicted more larger-later decisions overall—Study 3a: b = 28.29, 95% CI = [24.70, 31.87], SE = 1.82, t(180) = 15.61, p < .001; Study 3b: b = 40.61, 95% CI = [34.68, 46.54], SE = 3.00, t(133) = 13.55, p < .001 (see Fig. S3 in the Supplemental Material).

One potential concern with these analyses is that they used conflict and choice information from the same trials. To address this, we calculated average conflict, broken down by choice, on the first half of blocks (Study 3a: Blocks 1–6, Study 3b: Blocks 1–7) and number of larger-later decisions on the second half of blocks. Mirroring the previous findings, these results showed that participants chose more larger-later decisions when they had higher conflict when making smaller-sooner decisions—Study 3a: b = 12.34, 95% CI = [9.81, 14.87], SE = 1.28, t(175) = 9.63, p < .001; Study 3b: b = 13.65, 95% CI = [9.31, 17.98], SE = 2.19, t(123) = 6.23, p < .001—and less conflict when making larger-later decisions—Study 3a: b = −13.05, 95% CI = [−15.76, −10.34], SE = 1.37, t(175) = −9.49, p < .001; Study 3b: b = −15.23, 95% CI = [−19.64, −10.83], SE = 2.22, t(123) = −6.85, p < .001.

Overall, not only were these metrics significantly related to choice, but they also appeared to be capturing a large amount of the variance within overall choices—Study 3a: R^2 = .77, Study 3b: R^2 = .69 (R^2 = .55 and .39, respectively, when predicting the second half of choices from conflict in the first half of choices). Finally, although average reaction times showed similar patterns as average conflict, each significantly predicted choice data when we controlled for the other, which again suggests that real-time conflict captured distinct variance from reaction time. The one exception to this was average conflict when choosing the smaller-sooner option in the first half of Study 3b predicting choice in the second half, which dropped to marginally significant when we controlled for reaction times, b = 4.45, 95% CI = [−0.54, 9.45], SE = 2.52, t(121) = 1.77, p = .08.

Effect of manipulation on choices. We then tested whether our manipulations significantly influenced the likelihood of electing the larger-later option on a given trial. In Study 3a, generating reasons to elect the larger-later option first (M = 97.86 larger-later decisions, SD = 47.42) versus second (M = 92.20 larger-later decisions, SD = 47.15) was in the predicted direction but was not significantly associated with choice on a given trial, b = 0.11, 95% CI = [−0.12, 0.34], SE = 0.12, Z = −0.96, p = .34 (larger-later first: M = 97.88, SD = 47.42; smaller-sooner first: M = 91.15, SD = 47.90). It is possible this failure to replicate the original Weber and colleagues (2007) study comes from differences in procedure, as we asked our participants to make forced choices between two options across many different time and monetary combinations, as opposed to the relatively shorter choice-titration procedure used by Weber and colleagues. In Study 3b, however, high-level construal led to a higher probability of electing the larger-later options (M = 95.31, SD = 52.50) relative to low-level construal (M = 80.62, SD = 52.51),

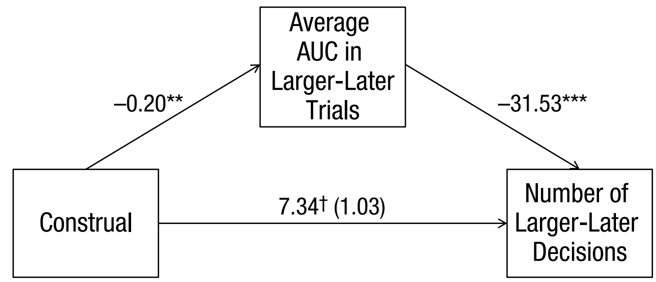

Fig. 9. Results of the analysis from Study 3b showing the influence of construal on the number of larger-later decisions, as mediated by average area under the curve (AUC) in trials for which participants chose the larger-later option. Unstandardized coefficients are given; the value in parentheses is the direct effect after controlling for the mediator. Symbols indicate significant (**p < .01, ***p < .001) and marginally significant (†p = .1) paths.

b = 0.29, 95% CI = [0.002, 0.57], SE = 0.15, Z = 1.97, p < .05, which replicated previous work (e.g., Fujita et al., 2006).

Mediation analyses. We next conducted a bootstrap mediation analysis (Hayes, 2013) to investigate whether the effect of our manipulations on decisions was mediated by reduced real-time conflict when participants chose the larger-later option. In Study 3a, presumably because of the nonsignificant effect of query condition on choice, we found no indirect effect through conflict. In Study 3b, however, we found a significant indirect effect; specifically, high-level construal led to decreased conflict on trials in which participants chose the larger-later option, which subsequently led to significantly more larger-later decisions, b = 6.32, 99% CI = [0.62, 12.26], SE = 2.25 (see Fig. 9). This indirect effect remained significant when we controlled for average conflict when participants selected the smaller-sooner option (99% CI = [0.31, 10.46]). Together, these results suggest that conflict is a significant predictor of decision making and that the construal manipulation promoted self-control in part through reduced low-level conflict during self-control decision making.

Nature of trajectories

Maximum deviation. As in previous studies, there were less abrupt trajectories than smooth trajectories in Study 3a (82% in our critical condition; see Table 2). Second, and more important, we were interested in whether our manipulation affected whether trajectories appeared abrupt when participants chose the larger-later option. Although we found no main effects of condition (larger-later first vs. smaller-sooner first) and option chosen (smaller-sooner vs. larger-later) on the likelihood of having a trajectory with a maximum deviation greater than .9, consistent with our predictions, there was a significant interaction between these two factors, b = −0.15, 95%

Table 2. Distribution of Trials in Which Mouse Trajectories Were Abrupt or Smooth as a Function of Option Chosen and Self-Control Condition in Studies 3a and 3b

Option chosen and self-control condition	Abrupt (*n*)	Smooth (*n*)	Smooth (%)
Study 3a			
Larger-later option			
Larger-later option first	1,702	7,986	82
Smaller-sooner option first	1,853	6,168	77
Smaller-sooner option			
Larger-later option first	1,963	5,607	74
Smaller-sooner option first	1,780	5,426	75
Study 3b			
Larger-later option			
High-level construal	1,054	5,046	83
Low-level construal	1,372	4,675	77
Smaller-sooner option			
High-level construal	1,172	4,792	80
Low-level construal	1,538	6,561	81

Note: Study 3a manipulated query order (whether participants listed reasons to choose the larger-later or smaller-sooner option first); Study 3b manipulated construal level (high vs. low).

CI = [−0.21, −0.09], $SE = 0.03$, $Z = -4.78$, $p < .001$ (see Fig. 10). Decomposition of this interaction revealed that on trials in which participants chose the larger-later option, having listed reasons to choose the larger-later option first made participants significantly less likely to demonstrate an abrupt trajectory, $b = -0.15$, 95% CI = [−0.28, −0.008], $SE = 0.07$, $Z = -2.09$, $p = .04$. There were no effects of condition when participants chose the smaller-sooner option, $b = 0.006$, 95% CI = [−0.13, 0.14], $SE = 0.07$, $Z = 0.09$, $p = .93$.

As in Study 3a, the majority of trajectories in Study 3b were smooth rather than abrupt (83% in our critical condition; see Table 2). We again found no main effects of construal or option chosen on likelihood of having a trajectory with maximum deviation greater than .9. We did, however, find a significant construal-by-option-chosen interaction, $b = -0.22$, 95% CI = [−0.30, −0.15], $SE = 0.04$, $Z = -5.92$, $p < .001$ (see Fig. 10). Inspection of this interaction revealed that although construal had no effect when participants chose the smaller-sooner option, $b = 0.02$, 95% CI = [−0.17, 0.21], $SE = 0.09$, $Z = 0.2$, $p = .84$, when participants chose the larger-later option, high-level construal was related to significantly lower likelihood of an abrupt than a smooth trajectory, $b = -0.21$, 95% CI = [−0.39, −0.02], $SE = 0.1$, $Z = -2.12$, $p = .03$. Together with the results of Studies 1 and 2, this suggests that when participants succeed in self-control, overall trajectories appear to be smooth rather than abrupt. Further, participants who had less self-control or made less successful choices were more likely to show trajectories consistent with impulse inhibition.

Bimodality. We then analyzed the bimodality of the distribution of real-time conflict. Because we were most interested in the nature of participants' trajectories when they succeeded at self-control, we focused on the trials in which participants chose the larger-later option.

In contrast to Studies 1 and 2, Study 3a did reveal evidence of bimodality in the distribution of conflict when participants chose the larger-later option, $d = 0.008$, $p < .001$ (see Fig. 3). Furthermore, this did not change when we divided up the data on the basis of our manipulation, larger-later first: $d = 0.008$, $p < .001$, smaller-sooner first: $d = 0.01$, $p < .001$.

Inconsistent with Study 3a, and consistent with Studies 1 and 2, Study 3b revealed no evidence of bimodality when participants chose the larger-later option, $d = 0.003$, $p = .48$ (Fig. 3). Dividing the data set further by construal did not change this conclusion—high-level construal: $d = 0.003$, $p = .99$; low-level construal: $d = 0.005$, $p = .49$. Interestingly, we did see evidence of bimodality when examining trials in which participants elected the smaller-sooner option, $d = 0.005$, $p = .02$. This effect, however, was muted when we divided the data set into high- and low-level construal, and therefore should be interpreted with caution—high-level construal: $d = 0.005$, $p = .30$; low-level construal: $d = 0.006$, $p = .11$. Overall, then, we found no evidence of bimodality in three out of four studies.

Coda. As we obtained no evidence for bimodality in Studies 1, 2, and 3b, but evidence for bimodality in Study 3a, we wanted to further investigate the likelihood of

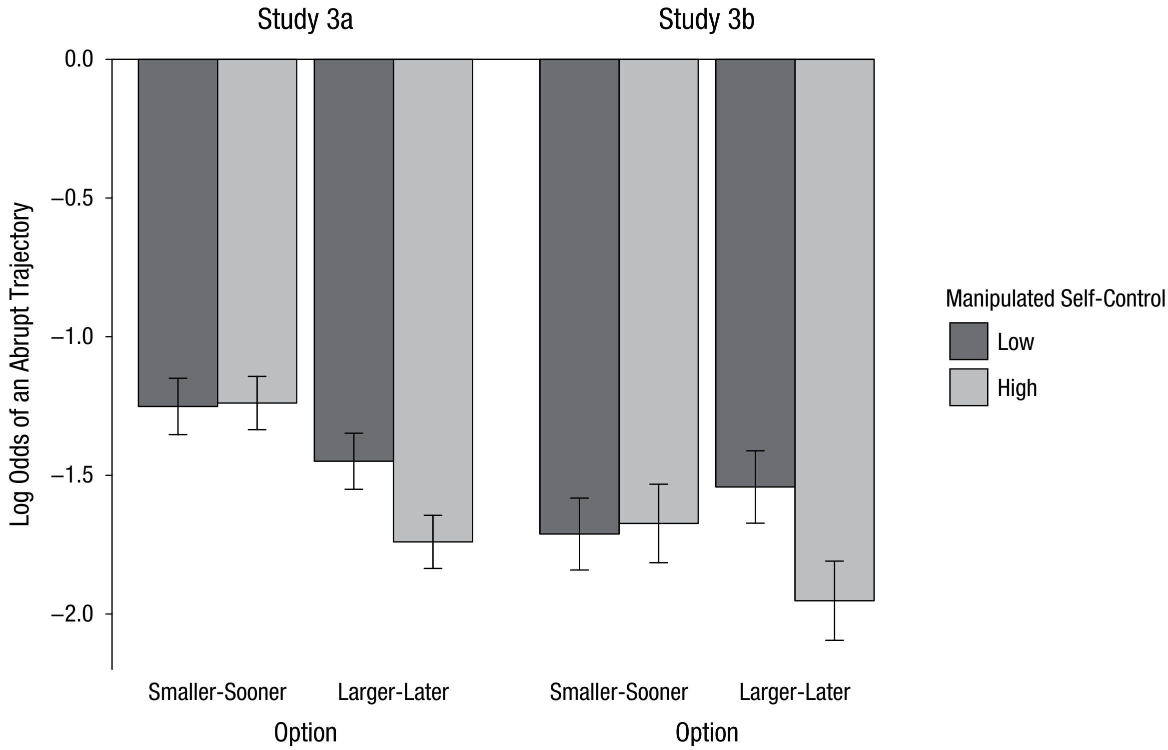

Fig. 10. Results from Studies 3a and 3b: log odds of an abrupt mouse trajectory as a function of option chosen and condition (query order for Study 3a, construal level for Study 3b). Lower numbers on the *y*-axis correspond to lower likelihoods of displaying an abrupt trajectory. Error bars show standard errors of the point estimates.

bimodality in the distribution of real-time conflict across these studies. To this end, we calculated bimodality using conflict from our conditions of interest in all four studies—self-control trials for Studies 1 and 2 and trials in which participants chose the larger-later option and in which participants were manipulated to have better self-control (Studies 3a and 3b; see Fig. 3). If there were indeed hints of bimodality within Studies 1, 2, and 3b, by combining them together with one another and Study 3a, we might have been able to detect bimodality. Contrary to this hypothesis, however, we found no evidence of bimodality when pooling across the studies, $d = 0.001$, $p = .99$. It thus appears that, overall, we did not find strong evidence for bimodality and instead found that response distributions were largely unimodal among self-control-relevant and successful choices. We report further analyses of distributions in the Supplemental Material.

General Discussion

These results across four studies constitute the first behavioral evidence of real-time conflict resolution during self-control decisions. The real-time conflict captured by mouse tracking seems uniquely reflective of self-control decision making rather than general decisional ambivalence. It varied with self-control ability and uniquely predicted real food and money decisions. For example, in Studies 3a and 3b, it predicted up to 77% of the variance in intertemporal choices and did not overlap with reaction times or other mouse-tracking metrics. As such, this metric is a powerful new tool to investigate the degree of unintentional, real-time conflict during self-control-relevant choices and behaviors.

The findings also reveal for the first time the way in which conflict is resolved during successful self-control choices. Across all four studies, we found evidence for smooth (rather than abrupt) trajectories during successful self-control choices, which suggests dynamic competition between goals and temptations rather than sequential unfolding (e.g., impulse inhibition). This evidence of smooth conflict resolution will critically inform theories about successful self-control going forward. Indeed, although our results most parsimoniously align with a dynamic-processes over a strict dual-systems approach, both approaches might be further specified to accommodate evidence for either smooth or abrupt resolution (see Freeman, 2014). These findings open the door to more accurate theoretical accounts of understanding the way in which cognitive processes unfold to allow people to resist temptations.

Action Editor

Leaf Van Boven served as action editor for this article.

Author Contributions

P. E. Stillman and M. J. Ferguson developed the study concept. All of the authors contributed to designing and running the studies. P. E. Stillman and M. J. Ferguson analyzed the data and wrote the manuscript.

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.

Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617705386

Open Practices

All data and materials have been made publicly available via the Open Science Framework and can be accessed at osf.io/3wz2j. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617705386. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

Notes

1. This requirement was relaxed in Studies 3a and 3b.
2. We revisited dieting status and self-control ability, and also measured self-control, in Study 2.
3. All analyses remained unchanged when controlling for initialization times.
4. Across all four studies, all mixed effects and general-linear-model analyses remained unchanged if we set AUC scores over 3 equal to 3, except for this one. In this analysis, significance dropped (p = .12).
5. To provide further support for this metric, we randomly sampled 1,000 trials from across our four studies and had two coders (who were blind to hypotheses) judge trajectories as abrupt versus smooth (coding instructions are available at osf.io/3wz2j). Coders agreed on 83% of trials, and of these, their evaluation of the trajectory was consistent with whether the maximum deviation was greater than .9 in almost 93% of cases, which suggests that it is a valid indicator of trajectory nature (see the Supplemental Material for full details).
6. This was the case across all four studies.

References

Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin*, *82*, 463–496. doi:10.1037/h0076860

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new General Self-Efficacy Scale. *Organizational Research Methods*, *4*, 62–83. doi:10.1177/109442810141004

Cheng, J., & González-Vallejo, C. (2015). Action dynamics in intertemporal choice reveal different facets of decision process. *Journal of Behavioral Decision Making*, *30*, 107–122. doi:10.1002/bdm.1923

Critcher, C. R., & Ferguson, M. J. (2016). "Whether I like it or not, it's important": Implicit importance of means predicts self-regulatory persistence and success. *Journal of Personality and Social Psychology*, *110*, 818–839. doi:10.1037/pspa0000053

Dale, R., Kehoe, C., & Spivey, M. J. (2007). Graded motor responses in the time course of categorizing atypical exemplars. *Memory & Cognition*, *35*, 15–28. doi:10.3758/BF03195938

Ferguson, M. J. (2007). On the automatic evaluation of end-states. *Journal of Personality and Social Psychology*, *92*, 596–611. doi:10.1037/0022-3514.92.4.596

Fishbach, A., Friedman, R. S., & Kruglanski, A. W. (2003). Leading us not into temptation: Momentary allurements elicit overriding goal activation. *Journal of Personality and Social Psychology*, *84*, 296–309. doi:10.1037/0022-3514.84.2.296

Fishbach, A., & Trope, Y. (2005). The substitutability of external control and self-control. *Journal of Experimental Social Psychology*, *41*, 256–270. doi:10.1016/j.jesp.2004.07.002

Fishbach, A., Zhang, Y., & Trope, Y. (2010). Counteractive evaluation: Asymmetric shifts in the implicit value of conflicting motivations. *Journal of Experimental Social Psychology*, *46*, 29–38. doi:10.1016/j.jesp.2009.09.008

Freeman, J. B. (2014). Abrupt category shifts during real-time person perception. *Psychonomic Bulletin & Review*, *21*, 85–92. doi:10.3758/s13423-013-0470-8

Freeman, J. B., & Ambady, N. (2009). Motions of the hand expose the partial and parallel activation of stereotypes. *Psychological Science*, *20*, 1183–1188. doi:10.1111/j.1467-9280.2009.02422.x

Freeman, J. B., & Ambady, N. (2010). MouseTracker: Software for studying real-time mental processing using a computer mouse-tracking method. *Behavior Research Methods*, *42*, 226–241. doi:10.3758/BRM.42.1.226

Freeman, J. B., & Ambady, N. (2011). A dynamic interactive theory of person construal. *Psychological Review*, *118*, 247–279. doi:10.1037/a0022327

Freeman, J. B., & Dale, R. (2012). Assessing bimodality to detect the presence of a dual cognitive process. *Behavior Research Methods*, *45*, 83–97. doi:10.3758/s13428-012-0225-x

Freeman, J. B., Dale, R., & Farmer, T. A. (2011). Hand in motion reveals mind in motion. *Frontiers in Psychology*, *2*, Article 59. doi:10.3389/fpsyg.2011.00059

Freitas, A. L., Gollwitzer, P., & Trope, Y. (2004). The influence of abstract and concrete mindsets on anticipating and guiding others' self-regulatory efforts. *Journal of Experimental Social Psychology*, *40*, 739–752. doi:10.1016/j.jesp.2004.04.003

Fujita, K. (2011). On conceptualizing self-control as more than the effortful inhibition of impulses. *Personality and Social Psychology Review*, *15*, 352–366. doi:10.1177/1088868311411165

Fujita, K., Trope, Y., Liberman, N., & Levin-Sagi, M. (2006). Construal levels and self-control. *Journal of Personality and Social Psychology*, *90*, 351–367. doi:10.1037/0022-3514.90.3.351

Galla, B. M., & Duckworth, A. L. (2015). More than resisting temptation: Beneficial habits mediate the relationship between self-control and positive life outcomes. *Journal of Personality and Social Psychology*, *109*, 508–525. doi:10.1037/pspp0000026

Gillebaart, M., Schneider, I. K., & De Ridder, D. T. D. (2016). Effects of trait self-control on response conflict about healthy and unhealthy food. *Journal of Personality*, *84*, 789–798. doi:10.1111/jopy.12219

Gold, J. I., & Shadlen, M. N. (2001). Neural computations that underlie decisions about sensory stimuli. *Trends in Cognitive Sciences*, *5*, 10–16. doi:10.1016/S1364-6613(00)01567-9

Hartigan, J. A., & Hartigan, P. M. (1985). The dip test of unimodality. *The Annals of Statistics*, *13*, 70–84.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: Guilford Press.

Hofmann, W., Baumeister, R. F., Förster, G., & Vohs, K. D. (2012). Everyday temptations: An experience sampling study of desire, conflict, and self-control. *Journal of Personality and Social Psychology*, *102*, 1318–1335. doi:10.1037/a0026545

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and self-control from a dual-systems perspective. *Perspectives on Psychological Science*, *4*, 162–176. doi:10.1111/j.1745-6924.2009.01116.x

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Kleiman, T., & Hassin, R. R. (2011). Non-conscious goal conflicts. *Journal of Experimental Social Psychology*, *47*, 521–532. doi:10.1016/j.jesp.2011.02.007

McKinstry, C., Dale, R., & Spivey, M. J. (2008). Action dynamics reveal parallel competition in decision making. *Psychological Science*, *19*, 22–24. doi:10.1111/j.1467-9280.2008.02041.x

Mischel, W. (2014). *The marshmallow test: Mastering self-control*. New York, NY: Little, Brown.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin*, *126*, 247–259. doi:10.1037/0033-2909.126.2.247

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology*, *51*, 768–774. doi:10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Shiv, B., & Fedorikhin, A. (1999). Heart and mind in conflict: The interplay of affect and cognition in consumer decision making. *Journal of Consumer Research*, *26*, 278–292. doi:10.1086/209563

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). *A 21 word solution* (SSRN Report No. 2160588). Retrieved from http://papers.ssrn.com/abstract=2160588

Spivey, M. (2008). *The continuity of mind*. New York, NY: Oxford University Press.

Stice, E., Sysko, R., Roberto, C. A., & Allison, S. (2010). Are dietary restraint scales valid measures of dietary restriction? Additional objective behavioral and biological data suggest not. *Appetite*, *54*, 331–339. doi:10.1016/j.appet.2009.12.009

Sullivan, N., Hutcherson, C., Harris, A., & Rangel, A. (2014). Dietary self-control is related to the speed with which attributes of healthfulness and tastiness are processed. *Psychological Science*, *26*, 122–134. doi:10.1177/0956797614559543

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, *72*, 271–324. doi:10.1111/j.0022-3506.2004.00263.x

Trope, Y., & Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review*, *117*, 440–463. doi:10.1037/a0018963

van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders*, *5*, 295–315. doi:10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T

Weber, E. U., Johnson, E. J., Milch, K. F., Chang, H., Brodscholl, J. C., & Goldstein, D. G. (2007). Asymmetric discounting in intertemporal choice: A query-theory account. *Psychological Science*, *18*, 516–523. doi:10.1111/j.1467-9280.2007.01932.x

Wojnowicz, M. T., Ferguson, M. J., Dale, R., & Spivey, M. J. (2009). The self-organization of explicit attitudes. *Psychological Science*, *20*, 1428–1435. doi:10.1111/j.1467-9280.2009.02448.x