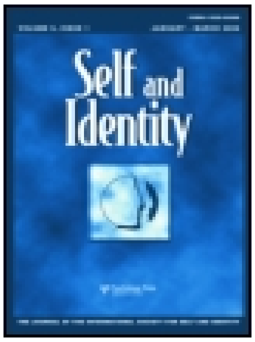

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Environmental constraints on the functionality of inhibitory self-control: Sometimes you should eat the donut

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ABSTRACT

Self-control involves the inhibition of behavior motivated by short-term reward. Self-control is generally considered to be critical to health and well-bring. However, from an evolutionary standpoint, inhibiting short-term reward may not always be functional. We suggest that the functionality of maintaining or ceasing inhibitory self-control is highly context-dependent. We have elsewhere proposed the dual component theory of inhibition regulation (DCTIR). The DCTIR proposes a functional processing mechanism that determines whether to continue or cease inhibitory self-control. According to the DCTIR, the functionality of continued application of inhibition is conditional on the availability of resources and stability of the environment. To test these predictions, we developed an online game called "Food Quest," in which participants are asked to imagine that they are on a journey. They are faced with the decision of whether or not to engage in a behavior with a short-term reward but with a long-term cost. The game environment is manipulated by varying game lifespan as well as the distribution and prevalence of resources. Results were consistent with predictions from the DCTIR that self-control was more functional in environments characterized by longevity and plentiful resources, but not in more dangerous, highly variable environments. Implications and future directions are discussed.

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Self-control; environmental contingencies; dual component theory of inhibition regulation

At its core, self-control involves inhibitory cognitive control of responses motivated by short-term rewards in service of long-term goals (Inzlicht, Schmeichel, & Macrae, 2014). For example, individuals may engage self-control to resist certain foods while on a diet or aggressive behavior during an argument. There is little doubt that self-control is exceedingly important to human behavior (see DeWall, Baumeister, Stillman, & Galliot, 2007; Gottfredson & Hirschi, 1990; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Pratt & Cullen, 2000; Vazsonyi, Pickering, Junger, & Hessing, 2001; Vohs & Heatherton, 2000). The advantages of self-control have been extensively documented. Low self-control is associated with a range of socially undesirable outcomes, including criminal and deviant behavior (Mead, Baumeister, Gino, Schweitzer, & Ariely, 2009; Mischel, 1958; Moffit et al., 2011; Pratt & Cullen, 2000), cheating and aggression (DeWall et al., 2007; Mead et al., 2009), poor academic outcomes (Duckworth,

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Tsukayama, & May, 2010), and unhealthy behavior (Moffit et al., 2011). Not surprisingly then, research has largely focused on finding ways to improve self-control in order to reduce such dysfunctional behaviors.

For example, in their classic demonstration of the ego-depletion effect, Baumeister, Bratslavsky, Muraven, and Tice (1998) studied self-control of eating behavior. They presented individuals with high calorie food (cookies and candy) and low calorie food (radishes), and gave some the instruction to eat the low but not the high calorie food. Eating the high calorie food during the study period was viewed as a failure of self-control (see also Vohs & Heatherton, 2000). Similarly, Hagger et al. (2013) found that individuals who had a high body mass index, and therefore chronically inhibited their eating behavior, ate more cookies and candies after completing an ego-depletion task, compared to high body mass index individuals in the control condition.

Although attempts to improve self-control may often make practical sense in modern society, this approach is limiting in what it tells us about the nature and functionality of self-control. From an evolutionary psychological perspective, there is reason to question whether self-control will be universally advantageous. Moreover, determining when exerting self-control is actually advantageous may help explain why it can prove so difficult in certain situations. Evolutionary psychology provides a perspective concerned with the functionality and context-dependent nature of behavior (Kurzban, 2010; Pinker, 1997). Behavior, in an evolutionary context, is often viewed as involving tradeoffs: costs in some cases, benefits in others (Davies, Krebs, & West, 2012). An evolutionary psychology approach, combined with the methodologies employed in social-cognitive research, creates a unique and powerful way to understand behavior (see also Forgas, Haselton, & von Hippel, 2013). For example, life history theory (LHT) views co-variation in personality and concomitant phenotypic strategies as advantageous or disadvantageous depending on the specific environmental contingencies in which the organism finds itself. According to LHT, individuals fall along a spectrum of traits that characterize a fast or slow life history strategy. Fast life history strategists tend to be more impulsive, demonstrate higher criminality, engage in more short-term mating behaviors, and invest less in parental care, relative to slow life history strategists (Ellis, 1988; Figueredo, Vasquez, Brumbach, & Schnieder, 2004; Figueredo, Vasquez, Brumbach, & Schneider, 2005; Figueredo et al., 2006). Despite the social undesirability of many of these outcomes, being a fast life history strategist is more advantageous (in terms of fitness) in particular environments (Ellis, Figueredo, Brumbach, & Schlomer, 2009). For example, short-term mating strategies are likely to increase reproductive success in environments with high adult mortality (Ellis et al., 2009; Reniers, Brendonck, Roberts, Verlinden, & Vanschoenwinkel, 2015).

Applying this evolutionary perspective to self-control suggests not just that we consider the context, but that we must consider the functionality of self-control itself within given environmental contexts. The purpose of self-control is to inhibit impulsive short-term behaviors (Reynolds & McCrea, 2016). It may be advantageous to inhibit impulsive actions in some environments, but not in others (see also Inzlicht, et al., 2014). These considerations are separate from what is considered to be socially desirable. In sum, an evolutionary perspective suggests that the appropriateness of self-control behavior should be viewed in the context of the environment in which the organism finds itself.

The DCTIR

We recently developed a model of self-control that incorporates this evolutionary perspective with a social-cognitive approach, the dual component theory of inhibition regulation (DCTIR; Reynolds & McCrea, 2016). The DCTIR posits a computational module (i.e., a mechanism designed to carry out a specific function; Ermer, Cosmides, & Tooby, 2007; Kurzban, 2010; Pinker, 1997) that exerts inhibitory control of impulsive, short-term behavior. The inhibitory module proposed by the DCTIR can be viewed as an algorithm, or a set of decision rules. This module has two main components: a monitor and a threshold. The monitor functions to identify impulsive behaviors and calculate the amount of effort needed to inhibit the behavior. For example, if an individual is on a diet and then encounters a high calorie dessert, the monitor would detect that the dessert presents a temptation and measure the degree of temptation experienced.

The threshold is a representational set-point or standard that determines whether to continue or cease inhibitory efforts. The threshold represents the individual's tolerance for inhibitory effort. When total inhibitory effort over a certain period of time reaches this tolerance level, the module will stop inhibiting and allow the impulsive behavior to be carried out. For example, if the individual in the dieting example had refrained from eating for a long period of time, threshold would more likely be met. If threshold was met, inhibition would cease and the individual would eat the dessert. Therefore, the threshold allows for both the inhibition and indulging of temptations.

Environmental contingencies and the DCTIR

The DCTIR differs from other approaches by proposing that both inhibition and indulging involve costs and benefits, and that neither is inherently advantageous or disadvantageous. It does not assume that self-control should continue indefinitely and proposes a functional mechanism that makes this determination. In other words, stopping inhibition (and thus carrying through with the impulsive behavior) is considered to be the functional output of the module rather than a "failure." The DCTIR predicts that, depending on the specific environmental contingency in which the person finds him or herself, self-control can either be advantageous or disadvantageous. Returning to the dieting example, the individual should inhibit eating sometimes, but not all the time. It is important that the degree of inhibitory self-control matches the demands of the environment, rather than that all impulsive behaviors are inhibited for as long as possible. Even though some of the consequences of engaging in impulsive behaviors may be viewed as socially undesirable (e.g., aggressive actions against others), it may be adaptive to engage in these behaviors in some environments. It is therefore important to have a mechanism that allows these behaviors to occur (see also Inzlicht et al., 2014). It should be noted that, even in contexts in which stopping inhibitory self-control is considered advantageous (or vice versa), it may not be the best strategy in absolute terms. What is considered advantageous or disadvantageous in self-control strategies is defined in terms of relative success.

The DCTIR makes explicit predictions concerning the factors that determine whether self-control will be advantageous or disadvantageous to the individual. Environments characterized by low quality nutritional resources, high mortality rates, unpredictability in nutritional resources or mortality rates, and normative violence are hypothesized to require members of the population to display more impulsive behavior. In other words, in these types of environments it would be advantageous to have a lower threshold or tolerance for inhibitory effort. This would result in meeting threshold more quickly and result in less inhibition of impulsive behavior. For example, if the local ecology is characterized by mostly low quality nutritional resources and discrimination of food resources is less important, the optimal strategy is to consume food whenever it is available. If consumption is inhibited in such a sparse environment, there is a higher probability of death and decreased fitness. Similarly, in a local ecology characterized by high mortality, it may be disadvantageous on average to inhibit behaviors such as aggression, exploitation, and risk taking when these behaviors could provide necessary resources (Nettle, 2010; Promislow & Harvey, 1990).

It is not only the overall level of factors like mortality that are important, but temporal and spatial variability in these factors (Ellis et al., 2009; Roff, 2002). Indeed, applying a life history theory approach, Hill, Ross, and Low (1997) found that risk-taking behavior in the domains of safety, health, sexual behavior, finances, and social relationships, was greater for individuals who believed the future would be unpredictable. In other words, individuals who were uncertain about the stability and manageability of the future tended to engage in riskier behavior.

When there is high unpredictability in nutritional resources or high unpredictability in mortality, a lower threshold would be more advantageous. In the case of resources, it would be advantageous because it is unknown when resources will again be available. In the case of mortality, more short term mating strategies and aggressive behavior might be more successful because it is unknown when mates will be available. In such contexts, long-term strategies may not be ecologically rational. Consider a person who has to decide whether to engage in a risky but high reward behavior now, or inhibiting this behavior to engage in a safer option later. If the environment is predictable such that the availability of a less risky choice is known, self-control can be considered advantageous. However, if the environment is unpredictable, the availability of this safer option is unknown. It is then likely to be disadvantageous to use self-control. In this case, it is better to select the high reward risky option.

We can also conceptualize predictability as the variability in the "reward landscape." If high reward – high risk options, low reward – low risk options, and no reward events vary closely in space and time, self-control is predicted to be advantageous. This is because there is relatively little distance and time between rewards. However, if the landscape is more sporadic, such that there are long distances and time in between rewards, self-control is predicted to be disadvantageous. For example, if the environment alternates between periods of prosperity and poverty, it may be disadvantageous to inhibit high rewards that are available in the prosperity period. Without those resources gained during periods of prosperity, it may be difficult to survive through the periods of poverty. This benefit outweighs the risk of the high reward option. However, if the rewards in the environment are more evenly distributed, the risk involved in the high reward option may no longer be worthwhile. In this case, it will be disadvantageous to select the high reward – high risk choice.

Finally, in a social environment characterized by group norms of violence, a lack of inhibition is more advantageous. For example, gang members may be rewarded or gain status for impulsive or violent behavior. Thus, it may be advantageous to have a lower threshold or even no detection subroutine (see Reynolds & McCrea, 2017) for certain impulsive behaviors among these individuals.

On the other hand, environments characterized by high quality and calorie dense nutritional resources, low mortality rates, predictability in nutritional resources or mortality rates, and when altruism is the group norm are hypothesized by the DCITR to require individuals in that population to display more self-controlled behavior, which on average will be the more successful strategy.

A comparison of modern western nations such as the United States to less advantaged counties such as Chad presents a useful example of our arguments concerning different environmental contingencies. Comparatively, nations like the United States generally experience lower mortality rates, and have high quality, high calorie nutritional resources widely available (Central Intelligence Agency, 2016; Roser, 2016; World Health Organization [WHO], 2016). In this environment, resisting eating tempting high calorie foods and eating lower-calorie options is better for long-term health. Thus, high levels of inhibition are useful in this type of environment. However, in countries like Chad that currently experience high mortality rates coupled with a high rate of starvation, inhibiting in order to accomplish long-term goals may be disadvantageous. Indeed, eating calorie-dense foods would make sense in this type of environment because life-expectancy is short and resources are scarce.

Current research

The purpose of the current work was to test whether these environmental contingencies influence the functionality of self-control behavior. The DCTIR suggests that inhibitory self-control is better or more functional in environments in which longevity is common and resources are plentiful. In more dangerous and sparse environments, it may not be functional to inhibit behaviors motivated by short-term rewards. We sought to design our studies in such a way that we had experimental control over the nature of the environment, and that the decisions participants made were in interaction with this environment. To this end, we developed an online game called "Food Quest" using jsPsych (de Leeuw, 2015). A basic version of the game can be played at https://food.gear.host/example.htm. In the game, participants are asked to imagine that they are on a journey, and must maintain both their energy level and their health. Participants encounter food options with short-term vs. long term rewards and costs. Specifically, participants can choose to eat carrots that have low short-term reward and no long-term health costs, or donuts that have high short-term reward and a high risk of long-term health costs. Resisting the donuts therefore represents a self-control behavior in the context of the game. By manipulating the resource environment (i.e., both the ratio and distribution of carrots and donuts) and lifespan (i.e., the number of trials in the game) for players, we can model different types of real-world environments. The consequences of participants' choices can then be examined in terms of game outcomes.

In Study 1a, we manipulated the availability of resources by varying resource prevalence, as well as how long people have to live by varying game lifespan. Based on the DCTIR, we predicted that self-control should be disadvantageous in the resource poor (i.e., shorter lifespan, fewer resources) environment, but advantageous in the resource rich (i.e., longer lifespans, more resources) environment. Study 1b provides a replication of this study. In Study 2a, we manipulated the resource variability of the environment. The variable or sporadic environment is characterized by periods of very high and very low resource availability, whereas the stable environment is characterized by more consistent resource availability. Based on the DCTIR, we predicted that self-control should be disadvantageous in the sporadic (i.e., feast or famine conditions) environment, but advantageous in the stable (i.e., consistent resources) environment. Study 2b provides a replication of this study. If the predicted results of these studies are confirmed, it would not only provide evidence for the DCTIR, but challenge the perception that ceasing self-control is necessarily dysfunctional. Conversely, it would suggest that modifying the environment in which individuals find themselves can improve regulatory outcomes.

As additional exploratory questions, we included various individual difference measures across the studies to determine whether they moderated the effects of environmental contingencies. Specifically, we measured trait self-control, sensation-seeking, and impulsivity as they have been related to performance in self-control tasks (Forzano, Michels, Carapella, Conway, & Chelonis, 2011; Jimura, Chushak, & Braver, 2013; Pokhrel, Sussman, & Stacy, 2014). Childhood SES is also potentially relevant to game behavior, in that individuals who experienced greater poverty may have lower tolerance for inhibition (Griskevicius, Delton, Robertson, & Tybur, 2011; Hill, Prokosch, DelPriore, Griskevicius, & Kramer, 2016). Finally, we included a measure of verbal reasoning as some have argued that higher levels of self-control actually reflect greater intelligence (see Duckworth, Tsukayama, & Kirby, 2013, for a discussion). Additionally, this measure allowed us to examine whether game performance simply reflected better understanding of how to win the game. Before presenting the main studies examining the effects of environmental contingencies, we first discuss a pilot study designed to demonstrate that the Food Quest game adequately models aspects of self-control.

Pilot study

Although we did not intend the game to be equivalent to the experience of resisting an actual donut, we nonetheless sought to show that it could engage the same processes proposed by the DCTIR. As described above, a self-control task should reflect (a) the choice of whether to pursue a behavior that fulfills a short-term goal to the detriment of a long-term goal, and (b) requires effortful inhibition or resistance of the short-term behavior. The Food Quest game by design fulfills these criteria. That is, donuts reflect short-term rewards but have long-term consequences, and participants must resist the impulse to eat every donut lest they lose the game. Nonetheless, we sought to determine whether the task was also experienced by participants in this way. According to the DCTIR, encountering a donut should result in a signal of temptation by the monitor that in turn calculates the degree of inhibitory effort that should be applied to resisting the donut. Thus, donuts should generally lead to the production of inhibitory effort.

According to the model, whether inhibitory effort is then applied and the self-control behavior carried out is a function of threshold (i.e., the tolerance for inhibitory effort). One individual difference variable proposed to be associated with threshold is trait self-control. We expected that trait self-control would negatively predict overall donut consumption, controlling for the amount of temptation experienced by participants. Because some individuals might experience more temptation than others, it is important to control for this variable in examining the effects of trait self-control (see also Reynolds & McCrea, 2016, 2017). Although we would expect sensation seeking and childhood SES to be related to donut consumption, we predicted self-control to remain a unique predictor when controlling for these variables.

Participants

We recruited an initial sample of twenty MTurk participants to determine if participants were able to understand task instructions and respond to the task measures in a reasonable manner. We then tripled the overall sample size and a priori analyzed this final sample, $N = 62$. All participants chose to eat at least some carrots, indicating they had taken the game seriously. Three male participants were excluded for failing an attention check item embedded in the individual difference measures (“Please respond with ‘very much’”), leaving a final sample of $N = 59$ (39 female, $M_{age} = 37$).

Food Quest game

In the Food Quest game, participants are told to imagine they are going on a journey. The object of the game is to survive the journey. Traveling costs energy, and so players must replenish their energy by eating items that they encounter along the way. However, some items come at an increased risk of causing obesity. Thus, players must keep a high enough level of energy to complete the journey, but not become too obese. On each trial of the game, a running stick figure is presented to represent that they are completing a segment of the journey. The player then encounters an object represented by a picture of a rock, a donut, or a carrot. Carrots provide low energy, but do not increase obesity. In contrast, donuts provide high energy, but also increase the risk of obesity. Rocks do not provide energy or increase obesity and are included primarily to make it necessary to eat in order to survive the game (i.e., there are trials in which energy is reduced). Participants are told that they must complete the journey without reaching 0 energy points (from a starting point of 50 and a maximum of 100). If they reach 100 obesity points (from a starting point of 0), they will also lose the game.

Participants are not told exactly how much energy is lost per trial or the exact values of the carrots and donuts. In the present version of the task, participants lost between 2 and 7 energy points for traveling. The exact amount on a given trial was randomly determined within this range. Carrots provided 6 points of energy and 0 obesity points, whereas donuts provided 20 points of energy and 0–40 obesity points. The exact obesity point total for each donut was again randomly determined within the specified range. The reason for randomly determining both energy loss and obesity was to provide some uncertainty regarding the consequences of eating or not eating a particular item. In the pilot study version of the game, participants could encounter 10 donuts, 10 carrots, and 14 rocks, for a total of 34 trials. The order of trials was randomized. After each trial, participants were provided feedback concerning their current energy and obesity scores. The game continued until participants completed the maximum number of trials, reached an energy level equal to or less than 0, or reached an obesity score equal to or greater than 100.

Task measures

Monitoring

After reading the instructions regarding the Food Quest game, participants were asked to indicate their agreement with the following statements: “Donuts in the Food Quest game are something you should try NOT to eat, even if you want to” and “Carrots in the Food Quest game are something you should try NOT to eat, even if you want to." Participants responded on a five-point scale (1 = *strongly disagree* to 5 = *strongly agree*). These items were designed to assess whether participants viewed eating the donuts as a short-term/long-term conflict that would require applying inhibitory self-control (Hofmann, Baumeister, Förster, & Vohs, 2012; Reynolds & McCrea, 2016).

Inhibitory effort
Upon encountering an item (a carrot, donut, or rock), participants were asked to indicate how much they felt they were resisting the urge to eat the item, responding on a five-point scale (0 = *not resisting* to 4 = *strongly resisting*). This item was designed to assess whether participants actually felt that they were applying inhibitory control over their choice (Baumeister et al., 1998).

Enactment
Participants were then asked to indicate whether they wanted to eat or not eat the presented item by pressing the "E"-key or the "N"-key, respectively.

Individual difference measures

Self-control
The trait measure of self-control was the Brief Self-Control measure (Tangney, Baumeister, & Boone, 2004). This 13 item measure asks participants to indicate how much each of the items reflect how they typically are on a five-point scale (1 = *Not at all* to 5 = *Very much*; Cronbach's $\alpha = .89$).

Sensation seeking
The Brief Sensation Seeking Scale (BSSS; Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002) was used as the measure of sensation seeking. This eight-item measure asks participants to respond to items on a 5 point scale (1 = *Strongly disagree* to 5 = *Strongly agree*; Cronbach's $\alpha = .83$).

Childhood SES
Participants answered three items measuring the extent to which they felt resource-deprived during their childhood (Griskevicius et al., 2011). Items included "My family usually had enough money for things when I was growing up." Participants responded on a seven-point scale (1 = *strongly disagree* to 7 = *strongly agree*; Cronbach's $\alpha = .84$).

Procedure

Participants read the Food Quest instructions, completed the task, and then provided their age and gender. They then completed the individual difference measures. These were placed after the task to reduce demand effects.

Results and discussion

As expected, participants thought that the donuts presented a self-control problem. They agreed that eating donuts was something one should try not to do ($M = 3.80$, SD = 1.30), relative to eating carrots ($M = 2.14$, SD = 1.48), $t(58) = 7.38$, $p < .001$, $d = .96$, and relative to the scale midpoint of 3, $t(58) = 4.72$, $p < .001$, $d = .61$.

We next calculated the average resistance score to each type of food that had been encountered by the participant during the game. Higher scores therefore indicate that the individual felt that they were resisting the urge to eat the item. These scores were higher for donuts ($M = 2.56$, SD = 1.07) than for carrots ($M = .20$, SD = .39), $t(58) = 15.82$, $p < .001$, $d = 2.06$.

Finally, we examined whether the individual difference measures predicted donut consumption after controlling for resistance scores. We therefore entered the average resistance scores for donuts and carrots along with trait self-control, sensation seeking, and childhood SES into models predicting number of donuts eaten and the percent of donuts eaten (see Table 1). As expected, individuals who reported greater resistance to the donuts were less likely to eat the donuts. Somewhat surprisingly, resisting the carrots predicted eating more donuts. This could reflect participants who did not completely understand the task, though this measure was negatively associated with eating the carrots as would be expected. Controlling for the number of carrots eaten also did not eliminate this effect, suggesting that individuals were not simply compensating for foregone opportunities to replenish their energy. Rather, the effect of resisting the carrots could represent an inhibition termination effect (ego-depletion effect), such that higher level of inhibitory effort led to reduced resistance to the donuts (Baumeister, Vohs, & Tice, 2007; Reynolds & McCrea, 2016). Finally, trait self-control was negatively associated with eating the donuts, but only after controlling for level of inhibitory effort. In contrast, the zero-order associations of trait self-control with total ($r = -.18$, $p > .18$) and percent donut consumption ($r = -.12$, $p > .33$) were not significant, nor was trait self-control associated with resistance to the donuts ($r = -.10$, $p > .42$). As proposed by the DCTIR, trait self-control seems to relate to threshold (i.e., chronic tolerance for inhibitory self-control) in the Food Quest task. Neither sensation seeking nor childhood SES predicted donut consumption in these models.

The pilot study therefore validated the Food Quest game as a model of self-control. Participants indicated that the donuts presented a short-term/long-term conflict that resulted in applying inhibitory effort. This inhibitory effort was negatively correlated with donut consumption. Consistent with the DCTIR, trait self-control was negatively predictive of donut consumption, but only after controlling for level of inhibitory effort. Having

Table 1. Predictors of donut consumption, pilot study.

	Number of donuts eaten				Percent of donuts eaten			
Term	*B*	se	*t*	*p*	*B*	se	*t*	*p*
Resistance to carrots	1.21	.49	2.45	.018	.18	.06	2.95	.005
Resistance to donuts	−.38	.17	2.24	.029	−.04	.02	1.81	.077
Trait self-control	−.65	.26	2.51	.015	−.07	.03	2.28	.027
Sensation seeking	−.07	.15	.49	.626	−.01	.02	.50	.620
Childhood SES	−.12	.12	.97	.338	−.02	.02	1.14	.260

Note: $N = 59$.

validated the Food Quest task, we now turn to the effects of environmental contingencies that were of primary interest to our research.

Study 1a and 1b – Resource richness

In Study 1a, we compared the effects of rich and poor resource environments using a student sample. The resource poor environment is characterized by high mortality (short game lifespan) and scarcity of resources. The resource rich environment is characterized by low mortality (longer game lifespan) and high availability resources. The resource rich environment is more similar to modern western nations, such as the United States, in which individuals live longer and have access to higher calorically dense resources. Environments in the game are manipulated by varying the length of the journey and the availability of food resources. In all cases, eating donuts represents an impulsive, short-term behavior with a long-term risk to health. We hypothesize that in the resource poor condition, participants who display greater donut consumption will be more likely to survive the game. In the resource rich condition, participants who will display more inhibition (eating fewer donuts) will either be more likely to survive or will experience no extra benefit. In other words, we predict that self-control behavior, which we have operationalized as donut consumption, will be more or less advantageous in the different conditions. If self-control is not context dependent, and the traditional view is correct, donut consumption should be uniformly disadvantageous.

We also administered a number of individual difference measures to explore whether they would moderate the effects of environmental contingencies. We expected trait self-control to have the largest effect on donut consumption. However, we did not measure inhibitory effort in these studies to avoid drawing attention to the hypotheses, meaning we could not control for this variable. Study 1b was largely similar to Study 1a, but recruited participants from Amazon's Mechanical Turk and included measures of verbal reasoning and impulsivity.

Method

Participants and design

Participants in Study 1a were 89 (54 female, $M_{age} = 19$) psychology students at the University of Wyoming. Data collection began 7 March 2016 and continued until the last day of the semester (5 May 2016). Participants were randomly assigned to the resource rich or resource poor game. Eight participants (six from the resource poor condition) failed to eat any carrots or donuts during the game, suggesting they either did not understand the rules of the game or were not motivated to play the game.[1] We therefore excluded these data from the analyses (remaining $N = 81$; $n = 39$ resource poor condition; $n = 42$ resource rich condition).

Participants in Study 1b were 145 (100 female, $M_{age} = 36.25$) participants recruited from Amazon's Mechanical Turk. Data collection continued until at least 140 participants completed the study. Participants were randomly assigned to the resource rich or resource poor game. Twenty participants (twelve from the resource poor condition) failed to eat any carrots or donuts during the game and were excluded from the analyses. We included two attention checks. Two participants failed one but not both checks, and the results remained unchanged when excluding these individuals. We therefore retained these individuals (remaining $N = 125$; $n = 66$ resource poor condition; $n = 59$ resource rich condition). All other observations were retained. We report all measures and conditions that were collected. Data collection was not dependent on analyses for either study.

Individual difference measures

Self-control (Study 1a Cronbach's $\alpha = .80$; Study 1b Cronbach's $\alpha = .88$), sensation-seeking (Cronbach's $\alpha = .84$), and childhood SES (Cronbach's $\alpha = .90$) were measured as in the pilot study.

Impulsivity

Impulsivity was measured using the English version of the impulsivity-8 (I-8; Kovelava, Beierlein, Kemper, & Rammstedt, 2012). This eight-item measure asks individuals to rate whether the statements apply to them on a five-point scale (1 = *Doesn't apply at all* to 5 = *Applies completely*; Cronbach's $\alpha = .73$).

Verbal reasoning

Participants completed Baddeley's (1968) grammatical reasoning test. Participants must indicate whether a statement accurately describes the relationship of a two-letter string (e.g., "A precedes B: AB"). Participants respond to each item with true or false. They complete as many items as possible (up to 64) in a three minute period.

Food Quest

The Food Quest game proceeded as in the pilot study with the following exceptions. We did not include the questions concerning whether one should try to not eat the donuts or the carrots, and did not ask participants to rate how much they were resisting the urge to eat the object. Participants were given 2.5 s to press the "E"-key if they wanted to eat the item. Not responding before 2.5 s was considered to be a "Do not eat" response, and the game proceeded to the feedback screen.

The resource rich environment game was the same as in the pilot study. In the resource poor environment game, the journey lasted only 28 trials and resources were scarce. Specifically, participants could encounter 5 donuts, 7 carrots, and 16 rocks, for a total of 28 trials. The ordering of trials was randomized in both versions of the game.

Procedure

Participants were randomly assigned to environmental condition, given instructions, and then played the game. They were then told the outcome of the game, provided their sex and age, and then completed measures of trait self-control. Participants in Study 1a additionally completed measures of sensation seeking and childhood SES. Participants in Study 1b additionally completed measures of impulsivity and verbal reasoning.

Results

Study 1a

Overall effects of environment

To control for length of game and the possibility that participants "died" before experiencing every trial, we calculated the percentage of donuts encountered that were eaten. The same calculation was made for carrots. We then examined differences in donut and carrot consumption, final life score, final obesity score, and game survival (see Table 2). Participants in the resource poor condition ate a greater proportion of donuts, had less final energy, and had lower final obesity scores than did those in the resource rich environment condition. Overall survival rates were comparable. Individuals were more likely to run out of energy in the resource poor environment, but more likely to hit the obesity limit in the resource rich environment.

Functionality of self-control behavior

We next examined overall survival rates as predicted by the proportion of donuts eaten, environmental condition, and their interaction, in a logistic regression using the glm function in R (R Core Team, 2016). Survival (survival = 1; dying = 0) and environmental condition (resource poor = 1; resource rich = 2) were dummy coded. Proportion of donuts eaten ($\beta = 9.283$, $z = 2.70$, $p = .007$), environmental condition ($\beta = 4.222$, $z = 2.45$, $p = .014$), and their interaction predicted game survival ($\beta = 9.659$, $z = 2.40$, $p = .016$). In the resource rich environment, proportion of donuts eaten had no relationship to survival ($\beta = -.376$, $z = .18$, $p = .857$). In the resource poor environment, proportion of donuts eaten predicted increased likelihood of survival ($\beta = 9.283$, $z = 2.70$, $p = .007$).

Individual differences

Correlations of the individual difference variables with the game outcomes are presented in Table 3. Individuals higher in trait self-control ate a lower proportion of donuts. There were no other zero-order effects. We also examined whether individual differences moderated the effects of environment on self-control behavior or game survival. No significant interaction effects were observed.

Study 1b

Overall effects of environment

Analyses were conducted as in Study 1a, see Table 2. Participants in the resource poor condition again ate a greater proportion of donuts, had less final energy, and had lower final obesity scores than did those in the resource rich environment condition. Individuals were more likely to run out of energy in the resource poor environment, but more likely to hit the obesity limit in the resource rich environment. Overall survival rates were comparable.

Functionality of self-control behavior

We next examined overall survival rates as predicted by the proportion of donuts eaten and environmental condition. Proportion of donuts eaten ($\beta = 4.979$, $z = 3.24$, $p = .001$), environmental condition ($\beta = 2.640$, $z = 2.47$, $p = .014$), and their interaction predicted game survival ($\beta = 5.578$, $z = 2.40$, $p = .016$). In the resource rich environment, proportion of donuts eaten

Table 2. Means and frequency of survival, Studies 1a and 1b.

	Study 1a					Study 1b				
Measure	Resource poor	Resource rich	*t*	*p*	*d*	Resource poor	Resource rich	*t*	*p*	*d*
% Carrots consumed										
M	97.74	99.50	1.39	.167	.31	95.42	97.50	1.33	.186	.24
SD	7.82	2.28				10.89	5.30			
% Donuts consumed										
M	50.94	34.95	3.70	.0004	.83	53.56	37.06	4.53	.000	.82
SD	22.69	15.83				23.44	16.08			
Final energy										
M	19.87	31.79	2.34	.022	.53	19.38	30.37	2.80	.006	.50
SD	19.62	25.50				17.91	25.61			
Final obesity										
M	46.28	65.64	3.15	.002	.71	44.50	70.31	5.27	.000	.95
SD	22.89	31.41				27.07	27.66			
Measure	Resource poor	Resource rich	χ^2	*p*	Cramer's *V*	Resource poor	Resource rich	χ^2	*p*	Cramer's *V*
Low energy death										
f	11	6				18	10			
High obesity death										
f	1	8	Exact test	.015	.51	2	8	Exact test	.027	.39
Survived										
f	27	28	.06	.807	.03	46	41	.00	.980	.00
n	39	42				66	59			

Table 3. Descriptive statistics for Studies 1a and 1b.

	Carrots	Donuts	Life	Obesity	Self-control	Impulsivity	Verbal reasoning	Sensation seeking	SES
Carrots	–	−.04	.06	.05	−.07	–	–	.19	−.01
Donuts	−.07	–	.68***	.49***	−.25*	–	–	.21	−.07
Final life	−.08	.60***	–	.67***	−.17	–	–	.17	.00
Final obesity	−.05	.41***	.72***	–	−.09	–	–	.10	.01
Trait self-control	.00	.06	.05	−.02	–	–	–	−.32**	.12
Impulsivity	−.12	.14	.09	.11	−.68***	–	–	–	–
Verbal reasoning	.15	−.01	−.08	−.11	−.11	.16	–	–	–
Sensation seeking	–	–	–	–	–	–	–	–	.10
Childhood SES	–	–	–	–	–	–	–	–	–
Study 1a									
M	98.65	42.65	26.05	56.32	43.09	–	–	35.60	12.98
SD	5.70	20.92	23.49	29.15	7.53	–	–	10.15	4.38
Study 1b									
M	96.40	45.71	24.57	56.68	43.62	20.60	37.95	–	–
SD	8.76	21.82	22.48	30.16	9.32	4.90	11.87	–	–

Notes: Correlations for Study 1a are presented above the diagonal ($N = 81$), correlations for Study 1b are presented below the diagonal ($N = 125$).
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

had no relationship to survival ($\beta = -.599$, $z = .34$, $p = .731$). In the resource poor environment, proportion of donuts eaten predicted increased likelihood of survival ($\beta = 4.979$, $z = 3.24$, $p = .001$).

Individual differences

Correlations of the individual difference variables with the game outcomes are presented in Table 3. There were no zero-order effects of these variables on game scores. We also examined whether individual differences moderated the effects of environment on self-control behavior or game survival. No significant interaction effects were observed.

Discussion

In Study 1a and 1b, we manipulated the availability of resources and lifespan in the game environment. According to the DCTIR, it is disadvantageous to inhibit the riskier decision (i.e., to engage in self-control) in a resource poor environment. In a resource rich environment, it is advantageous to inhibit the risky decision. The results of both studies largely supported our predictions.

Consistent with our hypotheses, indulging in eating the donuts was associated with higher survival rates in the resource poor environment, but had no relationship to survival in the resource rich environment. Put another way, a long-term strategy of eating proportionally fewer donuts was associated with better outcomes in the resource rich environment than in the resource poor environment. Furthermore, individuals were more likely to hit the obesity limit in the resource rich environment, consistent with our expectations. Results with a student sample were closely replicated with an online MTurk sample. Combined, our findings provide strong support for the notion that maintaining self-control is only advantageous within specific contexts.

In Study 1a, we observed that high trait self-control predicted reduced donut consumption. However, this effect was not observed in Study 1b. Individual differences generally had little relationship to game outcomes. Based on the results of the pilot study and the notion that trait self-control represents threshold (Reynolds & McCrea, 2016), we argue that it is necessary to control for the level of inhibitory effort in order to observe consistent effects of trait self-control. As we did not want to introduce a demand effect by calling attention to inhibitory effort, we did not collect these measures in Studies 1a and 1b. Future research could include these measures to more directly examine how level of inhibitory effort changes across environmental contexts as well as clarify the role of trait self-control in the Food Quest task.

Studies 2a and 2b – Environmental variability

A second environmental characteristic that could influence the functionality of self-control behavior is the spatial and temporal distribution of rewards. In some environments, the distribution of resources could be close in time and space. In such stable environments, there is little distance in space and time between rewards. In other environments, the distribution of resources may vary far in time and space. There could be temporal variation (e.g., times of feast or famine) or great physical distance (e.g., fertile valleys separated by deserts or mountains) between rewards. In the case where rewards are distributed sporadically (e.g., between periods of prosperity and poverty), self-control is predicted to be disadvantageous. This prediction stems from the likelihood that stockpiling resources will enable the organism to overcome the sparse period. In Studies 2a and 2b we varied the sequence of resources to be sporadic or stable. We predict that donut consumption will increase survivability in the sporadic condition. Donut consumption should either lower survivability or at least have no beneficial effect (as in the resource rich condition in Study 1a and 1b) in the stable condition.

Method

Participants and design

Participants in Study 2a were 133 (74 female, $M_{age} = 36$) MTurk workers, randomly assigned to the stable or sporadic environment game. Seventeen participants (12 from the stable condition) failed to eat any carrots or donuts during the game, suggesting they either did not understand the rules of the game or were not motivated to play the game. We therefore excluded these data from the analyses (remaining $N = 116$; $n = 60$ sporadic condition; $n = 56$ stable condition). Participants in Study 2b were 135 (80 female, $M_{age} = 36$) MTurk workers, randomly assigned to the stable or sporadic environment game. Nineteen participants (9 from the stable condition) failed to eat any carrots or donuts during the game, suggesting they either did not understand the rules of the game or were not motivated to play the game. We therefore excluded these data from the analyses (remaining $N = 116$; $n = 55$ sporadic condition; $n = 61$ stable condition). All other observations were retained. We report all measures and conditions that were collected. Data collection was not dependent on analyses for either study.

Food Quest

The food game was largely the same as in Study 1 with slight changes to the environmental manipulation. In the stable environment, participants could encounter 10 donuts, 10 carrots, and 15 rocks, for a total of 35 possible trials. The ordering of trials was completely randomized in the stable environment. The stable environment condition was thus comparable to the resource rich environment of Studies 1a and 1b, with the exception that there was an additional "rock" trial introduced to be consistent with the sporadic environment condition.

In the sporadic environment game, the journey also lasted 35 trials with 10 donuts, 10 carrots, and 15 rocks. However, the trials were organized into five-trial blocks of rich (either two carrots and three donuts or three carrots and two donuts) and poor (five rocks) resources. Trials were randomized within blocks and the blocks alternated between rich and poor resources.

Procedure

Participants were randomly assigned to environmental condition, given instructions, and then played the game. They were then told the outcome of the game, provided their sex and age, and completed the measure of trait self-control (Study 2a Cronbach's $\alpha = .86$; Study 2b Cronbach's $\alpha = .88$). Participants in Study 2a additionally completed measures of sensation seeking (Cronbach's $\alpha = .86$) and childhood SES (Cronbach's $\alpha = .86$, as in Study 1a). Participants in Study 2b additionally completed measures of impulsivity (Cronbach's $\alpha = .80$) and Baddeley's verbal reasoning task, as in Study 1b.

Results

Study 2a

Due to a programming error, only the first 34 trials of the stable environment were presented. We therefore conducted all analyses for the result of the 34th rather than the 35th trial to keep game length consistent across the analyses.

Overall condition differences

We examined differences in donut and carrot consumption, final life score, final obesity score, and game survival (see Table 4). Participants in the stable environment had higher final obesity scores than did those in the variable environment condition. All other scores were comparable. Overall survival rates or causes for losing the game did not differ across conditions.

Functionality of self-control

We next examined overall survival rates as predicted by the proportion of donuts eaten and environmental condition. A logistic regression was conducted using the glm function in R. Survival (survival = 1; dying = 0) and environmental condition (stable resources = 1; sporadic resources = 2) were dummy coded. Proportion of donuts eaten ($\beta = -2.63$, $z = 1.97$, $p = .049$), environmental condition ($\beta = -2.41$, $z = 2.59$, $p = .010$), and their interaction predicted game survival ($\beta = 5.73$, $z = 2.69$, $p = .007$). In the stable environment, proportion of donuts eaten predicted lower rates of survival ($\beta = -2.63$, $z = 1.97$, $p = .049$). In the sporadic environment, proportion of donuts eaten tended to predict increased likelihood of survival ($\beta = 3.11$, $z = 1.87$, $p = .062$).

Individual differences

Correlations of the individual difference variables with the game outcomes are presented in Table 5. There were no zero-order effects of the individual differences variables. We also examined whether individual differences moderated the effects of environment on self-control behavior and game survival. No significant interaction effects were observed.

Study 2b

Overall condition differences

We examined differences in donut and carrot consumption, final life score, final obesity score, and game survival at trial 35 (see Table 4). There were no differences in game scores by condition. Participants were less likely to survive in the sporadic environment than in the stable environment. Causes for not surviving the game did not differ across conditions.

Table 4. Means and frequency of survival, Studies 2a and 2b.

	Study 2a					Study 2b				
Measure	Sporadic	Stable	*t*	*p*	*d*	Sporadic	Stable	*t*	*p*	*d*
% Carrots consumed										
M	95.78	94.32	.68	.497	.13	95.43	97.94	1.30	.197	.24
SD	8.76	13.97				9.50	11.17			
% Donuts consumed										
M	38.36	42.30	1.04	.299	.19	43.12	41.22	.50	.619	.09
SD	18.20	22.36				19.30	21.53			
Final energy										
M	29.00	31.88	.54	.589	.10	35.84	32.26	.65	.514	.12
SD	27.51	29.61				30.45	28.39			
Final obesity										
M	62.40	73.93	2.00	.048	.37	72.93	73.26	.05	.957	.01
SD	30.81	31.39				35.27	31.32			
Measure			χ^2	*p*	Cramer's *V*			χ^2	*p*	Cramer's *V*
Low energy death										
f	16	9				13	8			
High obesity death										
f	7	11	2.65	.103	.25	16	13	.23	.632	.07
Survived										
f	37	36	.09	.770	.03	26	40	3.95	.047	.18
n	60	56				55	61			

Table 5. Studies 2a and 2b.

	Carrots	Donuts	Life	Obesity	Self-control	Impulsivity	Verbal reasoning	Sensation seeking	SES
Carrots	–	−.28**	−.14	−.06	−.03	–	–	.14	.06
Donuts	.09	–	.90***	.74***	−.03	–	–	−.07	−.07
Final life	.10	.90***	–	.65***	−.01	–	–	−.08	−.07
Final obesity	.11	.77***	.69***	–	.07	–	–	−.14	−.03
Trait self-control	.01	−.05	−.03	−.07	–	–	–	−.17	.04
Impulsivity	−.03	.00	−.04	−.01	−.64***	–	–	–	–
Verbal reasoning	.19*	−.11	−.08	.00	.11	−.11	–	–	–
Sensation seeking	–	–	–	–	–	–	–	–	.40***
SES	–	–	–	–	–	–	–	–	–
Study 2a									
M	95.08	40.26	30.39	67.97	43.61			31.75	9.71
SD	11.54	20.32	28.45	31.49	8.77			11.52	4.83
Study 2b									
M	96.75	42.11	33.96	73.10	44.97	19.74	35.10		
SD	10.44	20.43	29.31	33.10	9.53	5.51	12.13		

Notes: Correlations for Study 2a are presented above the diagonal ($N = 116$), correlations for Study 2b are presented below the diagonal ($N = 116$).
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Functionality of self-control

We next examined overall survival rates as predicted by the proportion of donuts eaten and environmental condition. Proportion of donuts eaten ($\beta = -2.90$, $z = 2.10$, $p = .036$) and environmental condition ($\beta = -2.06$, $z = 2.21$, $p = .027$) predicted game survival. The interaction was not significant but followed the same pattern as Study 2a ($\beta = 3.08$, $z = 1.56$, $p = .119$). In the stable environment, proportion of donuts eaten predicted lower rates of survival ($\beta = -2.90$, $z = 2.10$, $p = .036$). In the sporadic environment, proportion of donuts eaten did not predict likelihood of survival ($\beta = .17$, $z = .13$, $p = .899$).

Individual differences

Correlations of the individual difference variables with the game outcomes are presented in Table 5. There were no zero-order effects of the individual differences variables. We also examined whether individual differences moderated the effects of environment on self-control behavior and game survival. No significant interaction effects were observed.

Discussion

In studies 2a and 2b we manipulated the variability of the environment. Across both studies, we observed that self-control was advantageous when the environment was relatively stable. Although there were no overall condition differences in survival rates, the proportion of donuts eaten predicted lower rates of survival in the stable environment. In contrast, donut consumption tended to predict higher rates of survival in the sporadic environment in Study 2a and was unrelated to rates of survival in the sporadic environment in Study 2b. These findings are consistent with the DCTIR in that environmental contingencies moderated the functionality of inhibiting temptation. In highly variable and unpredictable environments, self-control may not be the optimal strategy.

Interestingly, self-control was not associated with survival in the resource rich conditions in Studies 1a and 1b, but was advantageous in the stable environment in Studies 2a and 2b. We attribute this slight difference to the introduction of the additional "rock" (no resource) trial in the latter studies. The longer game and additional reduction in energy likely resulted in the higher proportion of donuts consumed, higher obesity scores, and greater number of deaths due to obesity that we observed in this version of the game. The sporadic resource condition did not prove as detrimental for self-control as was the resource poor condition in Study 1a and 1b. It is important to note that the sporadic condition differed from the stable condition only in the variability of resources, not the overall amount or the length of the game. Thus, the manipulation in Study 2a and 2b was in some sense more subtle.

Largely consistent with Studies 1a and 1b, there were no significant effects of the individual difference variables, including trait self-control. Again, in light of the results of the pilot study it would seem necessary to control for the level of inhibitory effort put forth by participants to observe effects of trait self-control on behavior in the food quest game.

General discussion

One of the key tenets of the DCTIR is that self-control is not considered to be unconditionally advantageous. Rather, the functionality of self-control is thought to depend on the environment. In some environments, regulatory mechanisms should allow impulsive behaviors to be expressed. In other environments, it is better to inhibit those impulsive behaviors. We tested these predictions across two different types of environments. Specifically, we created a game environment to simulate environments with different patterns of resource availability and mortality. As predicted, resource availability and variability moderated the functionality of self-control behavior as assessed by donut consumption. In resource poor environments, eating the high reward but risky donuts was advantageous. In the sporadic resource environment, this behavior was only weakly related to game survival. In contrast, inhibiting this behavior was unrelated to survival in the resource rich and advantageous in the stable environment conditions. The implication of this finding is that individuals who do not exert self-control in poorer or more sporadic environments cannot be said to be exhibiting poor self-control. In fact, these individuals fared better in these environments. Thus, it is important to consider the environmental context when evaluating the importance of self-control. Self-control is not beneficial for all individuals in all situations. Finally, no participant in any study survived the task by exerting unrelenting self-control (even after excluding participants who failed to eat any of the safe food items). That is, it was necessary to cease inhibition and eat a donut on occasion. Theory must contend with the fact that self-control cannot (and in fact should not) be exerted indefinitely. Approaches such as the classic ego-depletion and marshmallow tasks assume the experimenter-defined persistence period is ideal, but this has not been systematically tested. In this sense, labeling the cessation of self-control a "failure" is questionable.

Our studies also explored whether individual differences moderated behavior and game outcomes. In the pilot study, trait self-control predicted donut consumption when controlling for resistance/inhibition of donuts. Furthermore, trait self-control was negatively related to donut consumption in Study 1a, but this association was not replicated in any other study. We have detailed elsewhere that threshold could be measured through an assessment of an individual's self-control behavior for a variety of goals, their level of temptation applied to those goals, the inhibitory effort used to stop those impulsive behaviors, and a person's behavioral enactment on a self-control task (see Reynolds & McCrea, 2017). We have however also argued that a more simple measure of threshold is self-report trait self-control. Ideally, when using trait self-control in this manner, temptation and/or inhibition should be accounted for. Although we were only able to do this in the pilot study, that is indeed where the strongest effect of trait self-control occurred. Thus, the effects of trait self-control largely fit our predictions.

None of the other individual differences significantly predicted game behavior or outcomes. The lack of effects of verbal reasoning and sensation seeking suggests outcomes were not a function of better reasoning skills or interest in novelty. As with trait self-control, it is possible that impulsivity would relate to game behavior when level of temptation is taken into account.

Finally, the Food Quest game actually modeled some of the negative outcomes that have been documented in other self-control work (Brook, Zhang, Brook, & Finch, 2014; Crescioni et al., 2011). For example, the stable environment (designed to reflect modern societies such as the U.S.A.) produced high levels of obesity. Thus, the game produces results that mimic real life even though it is necessarily an artificial environment.

Limitations and future directions

In the present research, we chose to manipulate resource availability and variability of the environment. Future studies could instantiate these environmental differences in other ways. For example, harshness of the environment could be manipulated by starting individuals at different values of life points or introducing random catastrophic events. This could entail varying the probability of losing energy points in the game from random violence or weather. Introducing unpredictability of mortality would theoretically make it even more disadvantageous to exhibit self-control. Additional work could also examine different domains of self-control. For example, rather than eating food, other resources and strategies for attaining them could be required for game success. Thus, an advantage of the present methodology is that it is relatively easy to manipulate environmental factors as well as alter the behavior of interest.

We note that, even though there are environmental contexts in which low self-control is more advantageous, that does not mean that it will be advantageous for every behavior even within that context. For example, behavior that is adaptive for attaining resources and mates may increase predation risk. Rather, it is our view that self-control involves certain tradeoffs. Thus, a direction for future research would be to add other types of costs to investigate other possible tradeoffs.

A strength of the Food Quest paradigm is that it allows us to separately assess the level of temptation from the threshold, or tolerance for inhibition. This can be accomplished by varying the costs and benefits (e.g., point values) of different options or by measuring inhibitory effort (as in the pilot study). Many self-control tasks do not allow for this distinction. For example, the well-known marshmallow task simply assesses whether and how long the child resists eating the single marshmallow when promised a second (Mischel, 2014). According to the DCTIR, success or failure at this task is a function not only of the tolerance of the child to wait, but also the extent to which he or she is actually tempted by the marshmallow relative to the perceived reward of having a second. Similarly, self-report measures of self-control and impulsivity assess (subjective) behavioral outcomes, not the underlying mechanisms that produce these outcomes. These measures also do not capture the person's beliefs about the environment (e.g., whether the promise of a second marshmallow will actually be kept, Michaelson, de la Vega, Chatham, & Munakata, 2013). The Food Quest game allows us to vary the predictability of long-term reward.

These advantages aside, more research will be required to determine the extent to which behavior in the Food Quest task can be used to predict life outcomes like academic success. Thus, a future direction would be to use behavior in the game to predict self-control in other contexts. As it stands, there is no evidence to suggest that Food Quest could be used to predict future life outcomes as in the marshmallow task.

Implications

Limitations notwithstanding, there are a number of important implications of this work. First and foremost, this research demonstrates that self-control is unlikely to be unconditionally advantageous. Indeed, this research demonstrates that the functionality of self-control behavior is conditional on the environment in which the organism finds itself. Researchers should therefore be careful to refrain from language that presumes the functionality of exerting self-control in a different context. Indeed, a more fruitful approach may be to consider how perceived environmental contingencies influence the individual's decision to exert inhibitory self-control or not. An example of this approach would be to examine the role of socioeconomic status in self-control behavior. In both research and popular press, it is considered irrational that individuals with little monetary resources nonetheless own televisions and smartphones, have high rates of teenage pregnancy, substance use, and increased rates of criminal behavior (Delisi, 2001; Merling, 2013; Rector & Sheffield, 2011). Individuals raised in lower SES environments tend to be more impulsive (see Griskevicius et al., 2013). Research also shows when people perceive the environment as harsh their food choices can be altered and individuals may consume higher calorie foods (Laran & Salerno, 2013). In a low SES environment, where there are higher mortality rates and resource availability is low and variable, it simply may not be advantageous to engage in self-control. To fully understand the implications for this research on self-control behavior, it will be necessary to move outside game environments and examine how individuals in these environments perceive the contingencies and whether self-control behavior produces an advantage in light of these contingencies.

Conversely, to the extent that self-control is socially desirable, research should examine the ways in which perceived environmental contingencies could be altered to promote such behavior. Although much research has focused on training individuals to overcome temptation (see for example Muraven, 2010; Muraven, Baumeister, & Tice, 1999), it may be more efficacious to change the environment such that this behavior is viewed as more advantageous. Thus, reducing the harshness of the environment (e.g., improving the availability of basic resources and reducing the rate of conspecific violence and homicide) should encourage self-control behavior. Similarly, it might be possible to change the way in which the environment is perceived. For example, some individuals falsely believe that crime is increasing, partly because they read about crime in the news (Mohan, Twigg, & Taylor, 2011; Roberts & Hough, 2005). It is then a matter of influencing people's perception of the environment to encourage self-control behavior.

This research may also be used to decrease negative attitudes and stigma about self-control. For example, people may believe that obese individuals simply lack self-control and discipline. Research has shown that bias against obese individuals can have major impacts on hiring decisions and can negatively impact patient care (Agerström & Rooth, 2011; Waller, Lampman, & Lupfer-Johnson, 2012). Yet, eating high calorie food options can be advantageous in some contexts. Modern environments like in the U.S.A., where conditions are largely stable and resources are relatively plentiful can be challenging from a self-control perspective. Perhaps if people better understood eating behavior in an environmental context instead of attributing their behavior solely to their own lack of will, bias against obese individuals could be reduced.

This research is also evidence for the DCTIR itself (Reynolds & McCrea, 2016, 2017), and demonstrates that this theory can make novel predictions. Finally, this research demonstrates how fruitful an evolutionary social-cognitive approach can be. By integrating these diverse perspectives, we have been able to apply novel methodology to an innovative theory.

Conclusions

Although impulsive behaviors are often conceptualized as representing failures of self-control in many studies of self-regulation, the present research clearly shows that self-control is not advantageous in all environments. Future research should seek to better understand the relationship between environmental contingencies and self-control behavior. Finally, this work represents a first step toward testing the specific mechanisms proposed by the DCTIR and provides a paradigm that will allow researchers to better examine how temptation and tolerance for inhibitory self-control produce behavior.

Note

1. To further determine whether participants who failed to eat any carrots were pursuing a strategy or simply inattentive, we examined how much time participants spent reading instructions concerning the value of the items (i.e., the second and third pages of the instructions). In both Study 1a and 1b, participants who failed to eat any carrots had also spent significantly less time reading these instructions (Study 1a: retained $M = 31.2$ s, excluded $M = 17.7$ s, $p < .001$; Study 1b: retained $M = 31.4$ s, excluded $M = 22.6$ s, $p = .03$). Thus, excluded participants were likely not motivated or had not comprehended the instructions due to inattention. The number of exclusions did not differ across conditions in any study (all $ps > .12$).

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