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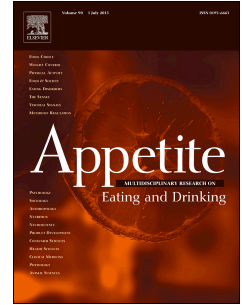
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Predicting Sugar Consumption: Application of an Integrated Dual-Process, Dual-Phase Model

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ACCEPTED MANUSCRIPT

Abstract

Excess consumption of added dietary sugars is related to multiple metabolic problems and adverse health conditions. Identifying the modifiable social cognitive and motivational constructs that predict sugar consumption is important to inform behavioral interventions aimed at reducing sugar intake. We tested the efficacy of an integrated dual-process, dual-phase model derived from multiple theories to predict sugar consumption. Using a prospective design, university students (N = 90) completed initial measures of the reflective (autonomous and controlled motivation, intentions, attitudes, subjective norm, perceived behavioral control), impulsive (implicit attitudes), volitional (action and coping planning), and behavioral (past sugar consumption) components of the proposed model. Self-reported sugar consumption was measured two weeks later. A structural equation model revealed that intentions, implicit attitudes, and, indirectly, autonomous motivation to reduce sugar consumption had small, significant effects on sugar consumption. Attitudes, subjective norm, and, indirectly, autonomous motivation to reduce sugar consumption predicted intentions. There were no effects of the planning constructs. Model effects were independent of the effects of past sugar consumption. The model identified the relative contribution of reflective and impulsive components in predicting sugar consumption. Given the prominent role of the impulsive component, interventions that assist individuals in managing cues-to-action and behavioral monitoring are likely to be effective in regulating sugar consumption.

Key words: sugar intake; intentions; implicit attitudes; reflective-impulsive model; model of action phases; action planning

1 In the context of a global pandemic of obesity and associated chronic illnesses including diabetes,
2 cardiovascular disease, and certain cancers, the impact of high intake of dietary sugar is a principal
3 concern (Swinburn et al., 2011). Research has indicated that consumption of added sugars in the diet (i.e.,
4 sugars added to foods during preparation or processing, or added at the table; Johnson et al., 2009) is
5 related to a number of metabolic problems and adverse health conditions, and is considered a major factor
6 contributing to a positive energy balance and weight gain (Malik, Popkin, Bray, Després, & Hu, 2010).
7 This has led health organizations to publish recommendations for reductions in the intake of added dietary
8 sugars (Johnson et al., 2009; WHO, 2015). For example, the American Heart Association recommends
9 that no more than 100 calories per day (equivalent to about 6 teaspoons of sugar) for women and 150
10 calories per day (about 9 teaspoons of sugar) for men should be taken as added sugars (Johnson et al.,
11 2009). In response to the proliferation of evidence highlighting the need for dietary sugar reduction in the
12 prevention of chronic illnesses and conditions, researchers have begun to explore the determinants of
13 dietary sugar intake, particularly the psychological and behavioral factors (e.g., de Bruijn & van den
14 Putte, 2009; Naughton, McCarthy, & McCarthy, 2015; van der Horst et al., 2007). The goal of such
15 research is to provide formative evidence that can be used as a basis for effective behavioral interventions
16 to reduce sugar intake. The research has identified belief-based factors from social cognitive theories such
17 as attitudes, intentions, and perceived control as important in predicting sugar consumption. However,
18 research adopting these theories has indicated that they explain modest variance in sugar consumption,
19 and fail to account for the multiple factors and processes that underpin sugar consumption (Tak et al.,
20 2011; van der Horst et al., 2007). In the current study, we aim to extend this research by testing the
21 efficacy of an integrated theoretical model in predicting dietary sugar consumption. Recognizing that
22 intake of dietary sugar may not be solely determined by conscious, reflective processes, the model will
23 account for the non-conscious, impulsive processes that lead to sugar consumption (c.f., Keatley, Clarke,
24 & Hagger, 2012; Perugini, 2005; Pesseau et al., 2014). We also aim test the role that volitional processes
25 (e.g., planning) have in predicting individuals to enact their intentions.

26 **Dual-Process Models of Health Behavior**

27 A common assumption of the social cognitive and motivational theories applied to predict health
28 behaviors (e.g., theory of planned behavior, social-cognitive theory, health belief model) is that action is
29 determined by a deliberative process (Biddle, Hagger, Chatzisarantis, & Lippke, 2007; Conner &
30 Norman, 2015). The theories assume that individuals act on the basis of evaluating the available
31 information regarding future courses of action (e.g., weighing up perceived costs and benefits) and make
32 decisions accordingly. Other motivational approaches such as self-determination theory (Deci & Ryan,
33 2000) also assume that actions are based on conscious deliberation. The theory predicts that individuals
34 will be motivated to act if the behavior is perceived as servicing some sort of desired or personally-
35 relevant need. Syntheses of research has demonstrated that constructs from these social cognitive and
36 motivational theories (e.g., internal and external motivation, intentions, attitudes, subjective norm, self-
37 efficacy, risk perceptions) have typically accounted for non-trivial variance in behavior across numerous
38 domains (McEachan et al., 2016; Ng et al., 2012; Rich, Brandes, Mullan, & Hagger, 2015). Nevertheless,
39 effect sizes of the salient predictors on behavior have been modest, with substantive variance in behavior
40 remaining unexplained. Furthermore, there is evidence that measures reflecting factors related to non-
41 conscious, automatic processes such as past behavior and self-reported habit and automaticity account for
42 substantive variance in health behavior independent of the constructs from social cognitive and
43 motivational theories (Allom, Mullan, Cowie, & Hamilton, 2016; Arnautovska, Fleig, O'Callaghan, &
44 Hamilton, 2017; Gardner, 2015).

45 These findings are consistent with dual-process theories in which behavior is viewed as a function
46 of conscious, reflective processes that involve deliberation over a course of action, consistent with the
47 constructs typically identified in social cognitive and motivational theories, and non-conscious processes
48 that reflect impulsive, spontaneous pathways to action that operate beyond an individual's awareness
49 (Evans & Stanovich, 2013; Sheeran, Gollwitzer, & Bargh, 2013; Strack & Deutsch, 2004). The non-
50 conscious processes likely reflect well-learned patterns of action that are driven by organized knowledge
51 structures or 'schema' activated by the cues or contexts linked to the behavioral response in memory.
52 Such knowledge structures may be represented by implicitly-held attitudes or beliefs toward particular
53 concepts or actions. Research has demonstrated that measures of implicit beliefs, such as the implicit

54 association test (IAT; Greenwald, Nosek, & Banaji, 2003), have independent effects on behavior in health
55 contexts when included in predictive models alongside explicitly-measured constructs that reflect
56 deliberative, reflective processes (Keatley et al., 2012; Perugini, 2005; Sheeran et al., 2013). Such
57 research has provided new insight into the relative contributions of the explicit and implicit constructs
58 that determine action. Importantly, behaviors like eating highly palatable foods, such as those high in
59 sugar, are reinforced over time through endogenous reward systems via the dopaminergic pathways in the
60 mesolimbic system in the brain. They are therefore more likely to be determined by non-conscious,
61 impulsive pathways (Stice, Figlewicz, Gosnell, Levine, & Pratt, 2013). Drawing from this research, we
62 aim to examine the extent to which implicit attitudes toward sugar, which reflect the impulsive
63 determinants of behavior, impact sugar consumption in a model that incorporates constructs representing
64 both explicit and implicit processes.

65 **Motivational and Volitional Components of Action: Dual-Phase Models**

66 Research applying social cognitive and motivational models in health behavior has identified a
67 shortfall in the strength of the relation between intentions and behavior (Orbell & Sheeran, 1998; Rhodes
68 & de Bruijn, 2013). While intention-behavior relations are often non-trivial in size and statistically
69 significant, the size of the relation is often modest indicating that many individuals may not enact the
70 health behavior even though they intend to do so (Orbell, 2004). Dual-phase models such as the model of
71 action phases (Heckhausen & Gollwitzer, 1987) and health action process approach (HAPA; Schwarzer,
72 2008) propose that volitional processes such as planning may help 'bridge the gap' between intentions
73 and behavior. Such processes are proposed to act in a 'post-decisional' manner in a volitional phase that
74 follows the motivational phase. For example, the model of action phases suggests that individuals who
75 furnish their intentions with specific action plans¹, stating when and where the behavior will be enacted,
76 are more likely to act on their intentions. In this case, the plans serve to moderate the intention-behavior
77 relationship. According to the HAPA, action plans, along with coping plans that focus on managing
78 potential barriers and setbacks, explain why intentions result in behavioral enactment. In this case, the

¹Action plans and implementation intentions are frequently conceptualized with identical content (Hagger & Luszczynska, 2014). For the purpose of the current article, we consider them synonymous.

79 plans serve as mediators of the intention-behavior relationship. Research has supported the moderating
80 and mediating roles for planning in health behavior research providing confirmatory support for the role
81 for volitional processes in explaining and modifying the effects of intention on action (e.g., Hagger et al.,
82 2016; Zhou et al., 2015). Researchers have, therefore, begun to incorporate volitional components in
83 integrated dual-phase models that aim to provide a comprehensive account of the motivational and
84 volitional processes that lead to action. In the current research we aim to incorporate planning constructs
85 that represent volitional processes in the dual-phase approaches alongside intentions in a comprehensive,
86 integrated account of the factors that impact on sugar consumption.

87 **Proposed Integrated Model and Hypotheses**

88 The aim of the current study was to test an integrated dual-process, dual-phase model derived from
89 multiple theories to predict sugar consumption in a sample of university students. The proposed model is
90 presented in Figure 1 and hypothesized relations among model constructs are summarized in Table 1. The
91 motivational phase comprises hypotheses derived from research integrating self-determination theory
92 (Deci & Ryan, 2000) and the theory of planned behavior (Ajzen, 1991). Conceptual (Hagger &
93 Chatzisarantis, 2014) and meta-analytic (Hagger & Chatzisarantis, 2009) reviews have supported the
94 complementarity of these two theoretical approaches in explaining motivated behavior in health contexts.
95 Self-determination theory, as an organismic, needs-based approach, provides a basis for the origin of the
96 proximal belief-based determinants of motivated action from social cognitive models. The theory of
97 planned behavior is a specific form of the reasoned action approach (Fishbein & Ajzen, 2009; McEachan
98 et al., 2016), a generalizable social cognitive approach that identifies the proximal, belief-based predictors
99 of intentional behavior. According to the integrated approach, individuals are likely to align their beliefs
100 about conducting a target behavior in future, such as those from the theory of planned behavior, if the
101 behavior is perceived as servicing outcomes or actions likely to satisfy the psychological need for
102 autonomy (i.e., to feel as if one's actions are self-endorsed and volitional) from self-determination theory.
103 Research adopting the integrated approaches have confirmed that forms of motivation from self-
104 determination theory serve as distal predictors of the social-cognitive antecedents of action from the
105 theory of planned behavior (Hagger & Chatzisarantis, 2009). In the current context, autonomous

106 motivation to reduce sugar consumption is expected to positively predict intentions to reduce sugar
107 consumption mediated by attitudes, subjective norm, and perceived behavioral control. Controlled
108 motivation is expected to indirectly and positively predict intentions through subjective norm, but not
109 attitudes and perceived behavioral control. Intentions to reduce sugar consumption are expected to
110 mediate effects of the motivational orientations and attitudes, subjective norm, and perceived behavioral
111 control on future sugar consumption. The volitional phase encompasses hypotheses from the model of
112 action phases (Heckhausen & Gollwitzer, 1987) and the HAPA (Schwarzer, 2008). Specifically, action
113 planning is expected to moderate the intention-sugar consumption relationship consistent with the model
114 of action phases, and action planning and coping planning are expected to mediate the effect of intentions
115 on sugar consumption consistent with the HAPA. Taken together, these hypotheses encompass the
116 explicit components that determine action through consciously-mediated, reflective processes. We also
117 predict that implicit attitudes toward sugar will predict sugar consumption independent of the
118 motivational constructs, and there will be no effects of implicit attitudes on intentions, consistent with
119 hypotheses from the reflective impulsive model (Strack & Deutsch, 2004). Model effects are expected to
120 hold when controlling for past sugar consumption. We expect a simultaneous test of the proposed
121 network of relations among model components to exhibit good fit with the data. Results will demonstrate
122 the relative contribution of that constructs from the two phases (motivational and volitional) and two
123 processes (explicit and implicit) make in predicting sugar consumption.

124 **Method**

125 **Participants, Design and Procedure**

126 Participants were students studying at two universities in Australia. Students were recruited via an
127 online pool of research study participants and either received course credit or an opportunity to enter a
128 prize draw to win department store vouchers for participation. The study received approval from the
129 institutional review boards of each university. A prospective correlational design was used with
130 participants completing study measures in an initial laboratory visit (T1). Participants completed a follow-
131 up survey containing behavioral measures at a second point in time (T2), two weeks later.

133 *Table 1.* Summary of hypothesized direct and indirect effects in the integrated dual-process, dual-phase
 134 model for sugar consumption.

Hypothesis	Independent variable	Dependent variable	Mediator(s)	Prediction ^a
Explicit processes, motivational phase				
H ₁ : SDT motivation → Social cognitive constructs				
H _{1a}	Autonomous motivation	Attitude	–	Effect (+)
H _{1b}	Autonomous motivation	Subjective norm	–	Effect (+)
H _{1c}	Autonomous motivation	Perceived behavioral control	–	Effect (+)
H _{1d}	Controlled motivation	Attitude	–	No effect
H _{1e}	Controlled motivation	Subjective norm	–	Effect (+)
H _{1f}	Controlled motivation	Perceived behavioral control	–	No effect
H ₂ : Social cognitive variables → Intention/Behavior				
H _{2a}	Attitude	Intention	–	Effect (+)
H _{2b}	Subjective norm	Intention	–	Effect (+)
H _{2c}	Perceived behavioral control	Intention	–	Effect (+)
H _{2d}	Intention	Sugar consumption	–	Effect (–)
H ₃ : Social cognitive variables → Intention → Behaviour				
H _{3a}	Attitude	Sugar consumption	Intention	Effect (–)
H _{3b}	Subjective norm	Sugar consumption	Intention	Effect (–)
H _{3c}	Perceived behavioral control	Sugar consumption	Intention	Effect (–)
H ₄ : SDT motivation → Social cognitive variables → Intention/behavior				
H _{4a}	Autonomous motivation	Intention	Attitude Subjective norm Perceived behavioral control	Effect (+)
H _{4b}	Controlled motivation	Intention	Attitude Subjective norm Perceived behavioral control	Effect (+)
H _{4c}	Autonomous motivation	Sugar consumption	Attitude Subjective norm Perceived behavioral control Intention	Effect (–)
H _{4d}	Controlled motivation	Sugar consumption	Attitude Subjective norm Perceived behavioral control Intention	Effect (–)
H ₅ : Past behaviour → All variables				
H _{5a}	Past sugar consumption	Attitude	–	Effect (–)
H _{5b}	Past sugar consumption	Subjective norm	–	Effect (–)
H _{5c}	Past sugar consumption	Perceived behavioral control	–	Effect (–)
H _{5d}	Past sugar consumption	Autonomous motivation	–	Effect (–)
H _{5e}	Past sugar consumption	Controlled motivation	–	Effect (–)
H _{5f}	Past sugar consumption	Intention	–	Effect (–)
H _{5g}	Past sugar consumption	Action planning	–	Effect (–)
H _{5h}	Past sugar consumption	Coping planning	–	Effect (–)
H _{5i}	Past sugar consumption	Sugar consumption	–	Effect (–)
H _{5j}	Past sugar consumption	Implicit attitude	–	Effect (+)
H _{5k}	Past sugar consumption	Action planning	–	Effect (–)
H _{5l}	Past sugar consumption	Coping planning	–	Effect (–)
Implicit processes, motivational phase				
H ₆ : Implicit attitude → Intention/behavior				
H _{6a}	Implicit attitude	Intention	–	Effect (+)
H _{6b}	Implicit attitude	Sugar consumption	–	Effect (–)
H _{6c}	Implicit attitudes	Sugar consumption	Intention	Effect (–)

Explicit processes, volitional phase

H ₇ : Intention→Planning				
H _{7a}	Intention	Action planning	–	Effect (+)
H _{7b}	Intention	Coping planning	–	Effect (+)
H ₈ : Planning→Behavior				
H _{8a}	Action planning	Sugar consumption	–	Effect (–)
H _{8b}	Coping planning	Sugar consumption	–	Effect (–)
H _{8c}	Action planning x Intention	Sugar consumption	–	Effect (–)
H ₉ : Intention→Planning→Behavior				
H _{9a}	Intention	Sugar consumption	Action planning	Effect (–)
H _{9b}	Intention	Sugar consumption	Coping planning	Effect (–)

135 *Note.* SDT = Self-determination theory; ^aDenotes whether the hypothesis specifies a positive (+) effect, a
 136 negative (–) effect, or no effect.

137
 138 At T1 participants completed a survey containing self-report measures of psychological and
 139 behavioral constructs and questions capturing demographic characteristics. They also completed an
 140 implicit association test (IAT) measuring their implicit preference for sugar. The IAT was conducted in a
 141 sound-proofed research laboratory on a personal computer with the task administered using the
 142 SocialSci™ experimental software. Participants' data across each time points was anonymized and
 143 matched across time points using a unique code identifier created by the participant. We conducted a
 144 statistical power analysis to provide an estimate of the minimum required sample size to test our proposed
 145 model. Our estimate was based on the smallest expected effect size among the psychological predictors of
 146 the key dependent variable in the model: self-reported sugar consumption at T2. Research applying social
 147 cognitive models such as the theory of planned behavior and HAPA in the context of eating behaviors
 148 have typically identified medium-sized effects of social cognitive variables (e.g., intentions, self-efficacy)
 149 on behavior (e.g., McDermott et al., 2015), while research examining effects of implicit attitudes on
 150 behavioral outcomes in similar contexts have indicated small effect sizes (e.g., $r = .25$, Pavlović, Žeželj,
 151 Marinković, & Sučević, 2016; $r = .22$, Perugini, 2005)². We therefore used the aggregate effect size for
 152 implicit attitudes across the latter studies converted to Cohen's f^2 as the input effect size for our power
 153 analysis. We expected this to provide the most conservative minimum sample size estimate for testing our
 154 model. We computed our minimum sample size using the G*Power program (Faul, Erdfelder, Lang, &
 155 Buchner, 2007) for a linear multiple regression analysis with eight predictors, with the effect size (f^2) set

²As there have been no previous studies examining effects of implicit attitudes towards sugar on sugar consumption, we focused on studies examining closely-related behaviors as sources of potential effect sizes including preference for candy (sweets) over fruit (Pavlović et al., 2016) and preferences for snacks over fruit (Perugini, 2005, Study 2).

156 at 0.07, statistical power set at .80, and alpha (p) set at .05. The analysis yielded a minimum sample size
157 estimate of 90.

158 **Measures**

159 Psychological constructs were measured on previously-validated psychometric instruments
160 developed using standardized guidelines (Ajzen, 2003; Ryan & Connell, 1989) adapted to make reference
161 to the target behavior in the current study. Details of the measures are provided next and a full set of items
162 and responses to scales are available in Appendix A (supplemental materials). Items from each instrument
163 were used as indicators of latent variables representing each model construct in a structural equation
164 model. Participants were initially presented with a written definition of foods and beverages with high
165 added sugar content. High added-sugar foods and beverages were defined as those containing more than
166 22.5 grams (4.5 teaspoons) of sugar per 100 grams (Rex & Nelson, 2014). Participants were then
167 provided with a list of high-sugar food types with illustrative examples: full-sugar soft drinks (not diet),
168 sweets and candies, buns, pastries, pies, cakes, cookies, biscuits, chocolate snack bars (e.g., Snickers),
169 desserts (e.g., ice-cream), and other items with added sugar (e.g., breakfast cereals, ketchup, jams and
170 sugary spreads). They were asked to consider this definition when responding to subsequent survey items
171 and think about the next two weeks.

172 **Sugar consumption.** The target behavior was dietary sugar consumption over a two-week period.
173 Participants were asked to report their consumption of high-sugar foods and beverages over the previous
174 two weeks at T1 and T2 on two items reflecting general sugar intake (e.g., “In the course of the past 2
175 weeks, how often have you consumed foods or beverages that are high in sugar?”) and four items
176 reflecting sugar intake from specific high-sugar food items (e.g., “During the last 2 weeks, I consumed...
177 full-sugar soft drinks”). Items were based on food frequency questionnaire items used in previous
178 research on sugar consumption and foods high in added sugar (Naughton et al., 2015).

179 **Intention.** Intentions to limit consumption of high-sugar foods and beverages in the next two
180 weeks was measured on a single item (“I try hard to avoid consuming foods and beverages that are high
181 in sugar”).

182 **Attitude.** Attitude towards limiting consumption of high-sugar foods and beverages was assessed
183 on four semantic differential items (e.g., unpleasant-pleasant) using a common stem: “For me, avoiding
184 consuming foods and beverages that are high in sugar is...”

185 **Subjective norm.** Subjective norm was measured on four items assessing how likely significant
186 others would want the individual to reduce their intake of high-sugar foods and beverages (e.g., “Most
187 people who are important to me would want me to avoid consuming foods and beverages that are high in
188 sugar”).

189 **Perceived behavioral control.** Perceived behavioral control was assessed on four items relating
190 to control beliefs over intake of high sugar foods and beverages (e.g., “How much personal control do
191 you have in avoiding consuming foods and beverages that are high in sugar?”).

192 **Autonomous and controlled motivation.** A measure of autonomous and controlled reasons for
193 reducing consumption of high-sugar foods and beverages was developed based on Ryan and Connell’s
194 (1989) measure. Participants were presented with a common stem: “I avoid consumption of high-sugar
195 foods and beverages because...” followed by six reasons relating to autonomous (e.g., “...I like to avoid
196 consuming sugar”) and controlled (e.g., “...others would be angry at me if I did not.”) motives.

197 **Action and coping planning.** Action and coping planning were measured by three items each
198 assessing the extent to which participants planned to avoid high-sugar foods and beverages in the next
199 two weeks (action planning; e.g., “I have already planned on how I want to avoid consuming foods and
200 beverages that are high in sugar”) and planned to deal with setbacks (coping planning; e.g., “I have
201 already planned what to do if something interferes with my plans.”).

202 **Implicit attitude.** Implicit attitude towards sugar were measured using a single-category implicit
203 association test (SC-IAT; Karpinski & Steinman, 2006) developed for the current study. The SC-IAT was
204 thought to be the most appropriate measure as the target category (sugar) had no clear opposing category,
205 which is necessary for measures using the traditional IAT. Items representing the target category in the
206 SC-IAT were selected from a pool of candidate words and synonyms identified in a thesaurus search that
207 were considered representative of the word ‘sugar’. Items for the attribute categories comprised positive
208 and negative word sets used in previous IATs. Items for the target and attribute categories are provided in

Table 2. The SC-IAT included five blocks of trials. Blocks 1, 2, and 4 were practice blocks consisting of 20 trials. Blocks 3 and 5 were the test blocks comprising 72 trials. The practice blocks were to familiarize participants with the response keys and required participants to respond to the positive and negative attribute categories only using the keyboard. In the test blocks, participants were presented with items from the target category and were required to match them with the appropriate positive or negative attribute category. Response latencies for each item were logged by the computer. Averaged response latencies for items in blocks 3 and 5 were used to compute the *D* measure of implicit attitudes toward sugar consumption using Greenwald et al.'s (2003) improved scoring algorithm, with lower, negative scores representing stronger attitudes.

Table 2. Items used in single-category implicit association test as a measure of implicit attitudes toward sugar

Target category item	Positive attribute category items	Negative attribute category items
Sugar	Smile	War
Syrup	Love	Crime
Candy	Friend	Hate
Sucrose	Trust	Torture
Glucose	Fun	Murder
Honey	Happiness	Lies
Lolly	Relax	Disease
Caramel	Joy	Death
Bonbon	Beautiful	Horrible
Icing	Pleasure	Painful

Demographic variables. Participants self-reported their age in years, gender, smoking status, University degree type, weight in kilograms, height in metres, ethnicity, and the highest education level attained by their parents. These data were used to describe the sample and to test for variations in sample composition due to attrition. As we aimed to examine the unique effects of the theory-based factors on sugar consumption independent of socio-demographic factors, we also planned to control for age, gender, and body mass index (BMI) in our main analysis as these demographic factors are likely to correlate with health behaviors (e.g., Lo, Waller, Vrinten, Kobayashi, & von Wagner, 2015; Mesters, Wahl, & Van Keulen, 2014). Research has indicated the importance of social cognitive and motivational factors predicting health behavior beyond the effects of socio-demographic variables (Smith et al., 2016; von

Wagner, Good, Whitaker, & Wardle, 2011), and studies examining social cognitive predictors of sugar consumption (e.g., Tak et al., 2011; van der Horst et al., 2007) have typically controlled for these factors.

Data Analysis

We used variance-based structural equation modeling (VB-SEM) to test our hypothesized model. VB-SEM is similar to covariance-based SEM, but is based on ranked data and is therefore distribution-free and is less affected by model complexity, sample size, or departures from normality. Models were estimated using the Warp PLS v5.0 software (Kock, 2015). Missing data were treated using stochastic hierarchical regression imputation. Items from the measures of the psychological and behavioral constructs were set as indicators of latent variables. All paths among constructs detailed in Figure 1 and the hypotheses listed in Table 1 were specified as free parameters in the model. In addition, we statistically controlled for the effects of age, gender, and BMI by releasing free parameters between these variables and all variables in the model.

Validity of the proposed measures was assessed by observing the parameters of the measurement aspects of the SEM. The loading of each indicator on its respective latent factor were expected to exceed .700. Composite reliability coefficients (ρ) and average variance extracted (AVE) statistics, which test the sufficiency of scale items as indicators the latent variables and whether the items account for sufficient variance in the factor, both indicators of construct validity, were expected to exceed .700 and .500, respectively. Overall model fit was evaluated using multiple criteria: the goodness-of-fit (GoF) index with values of .100, .250, and .360 corresponding to small, medium, and large effect sizes, respectively, the average path coefficient (APC) and the average R^2 (ARS), both of which should be significantly different from zero for an adequate model, and the average variance inflation factor for model parameters (AVIF) statistic, with values less than 5.000 indicating a well-fitting model (Kock, 2015). Model parameter estimates and standard errors were computed using a robust bootstrap resampling method with 999 replications of the model in samples drawn from, and equal in size to, the actual sample.

Results

Participants and attrition analyses

256 Twenty-one participants dropped out of the study after completing the initial survey at T1 resulting
257 in a final sample of 90 participants. Demographic characteristics of the sample at the two time points are
258 presented in Appendix B (supplemental materials). Attrition analyses indicated that there were no
259 significant differences in age ($t(109) = 0.73, p = .466, d = 0.14$), gender ($\chi^2(1) = 0.57, p = .451$), BMI
260 ($t(108) = 0.02, p = .983, d < 0.01$), degree type ($\chi^2(1) = 0.48, p = .491$), highest education level attained
261 by participants' mother ($\chi^2(4) = 1.48, p = .830$) and father ($\chi^2(4) = 2.38, p = .667$), ethnicity ($\chi^2(7) = 6.13,$
262 $p = .525$), and levels of the psychological and behavioral variables (attitude, subjective norm, perceived
263 behavioral control, intention, autonomous motivation, controlled motivation, action planning, coping
264 planning, IAT *D* score, and past sugar consumption; Wilks' Lambda = .92, $F(9,101) = 0.99, p = .457, d =$
265 $.19$) between participants that dropped out of the study and those that remained in the final sample.

266 Preliminary Analyses

267 Measurement model statistics from the VB-SEM confirmed that the latent variables met criteria for
268 construct and discriminant validity. Factor loadings for each latent factor exceeded the .700 criterion
269 supporting the validity of the factors. Composite and Cronbach alpha (α) reliability coefficients, AVE,
270 and intercorrelations for model variables are presented in Table 3. Reliability coefficients exceeded the
271 .700 criterion and alpha coefficients indicated adequate internal consistency (α range = .783 to .891). AVE
272 values approached or exceeded the recommended .500 criterion. We estimated the reliability of the SC-
273 IAT separately using Karpinski and Steinman's (2006) protocol. While the reliability coefficient (adjusted
274 $r = .48$) was slightly lower than the average for standard IATs (Schnabel, Asendorpf, & Greenwald,
275 2008), it was comparable to that attained for other SC-IATs (2006) and higher than reliabilities observed
276 in other latency-based implicit measures (e.g., Olson & Fazio, 2003). Correlations among the latent
277 variables also indicated no problems with discriminant validity. Goodness of fit statistics revealed
278 acceptable overall fit of the model with the data according to the multiple indices adopted (GoF Index =
279 $.498$; APC = $.164, p = .027$, ARS = $.322, p < .001$; AVIF = 1.176).

280 *Table 3.* Factor intercorrelations, composite reliabilities, and average variance extracted for latent variables in the integrated dual-process, dual phase model
 281 for sugar consumption.

Variable	AVE	α	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Sugar consumption	.481 ^{***}	.783	.847													
2. Past behavior	.501 ^{***}	.792	.726 ^{***}	.855												
3. Intention	–	–	-.337 ^{**}	-.288 ^{**}	–											
4. Implicit attitude	–	–	-.320 ^{**}	-.161	.032	–										
5. Attitude	.691 ^{***}	.851	-.345 ^{***}	-.388 ^{***}	.457 ^{***}	.109	.899									
6. Subjective norm	.631 ^{***}	.803	-.024	.059	.329 ^{**}	.119	.206	.872								
7. PBC	.755 ^{***}	.892	-.328 ^{**}	-.415 ^{***}	.306 ^{**}	.170	.574 ^{***}	.145	.925							
8. Action planning	.811 ^{***}	.883	-.248 [*]	-.266 ^{**}	.635 ^{***}	.023	.551 ^{***}	.319 ^{**}	.451 ^{***}	.928						
9. Coping planning	.821 ^{***}	.891	-.244 [*]	-.252 [*]	.392 ^{***}	.067	.364 ^{***}	-.027	.439 ^{***}	.544 ^{***}	.932					
10. Aut. motivation	.546 ^{***}	.878	-.362 ^{***}	-.300 ^{**}	.565 ^{***}	.087	.707 ^{***}	.287 ^{**}	.487 ^{***}	.573 ^{***}	.467 ^{***}	.905				
11. Con. motivation	.465 ^{***}	.834	-.037	.024	.235 [*]	.007	.183	.380 ^{***}	-.038	.285 ^{**}	.091	.445 ^{***}	.874			
12. Gender	–	–	.088	.143	.058	-.046	-.062	.016	-.156	-.005	-.032	-.040	.174	–		
13. BMI	–	–	.050	-.098	.106	.026	.124	.145	.033	.181	-.111	-.010	-.014	-.301 ^{**}	–	
14. Age	–	–	-.188	-.230 [*]	.147	.021	.344 ^{***}	.062	.221 [*]	.193	.116	.195	-.091	-.169	.318 ^{**}	–

282 *Note.* Composite reliability coefficients shown on principal diagonal; AVE = Average variance extracted; α = Cronbach alpha coefficient; Past behavior =

283 Past sugar consumption; PBC = Perceived behavioral control; Aut. motivation = Autonomous motivation; Con. motivation = Controlled motivation

284 *** p < .001 ** p < .01 * p < .05.

285

Model Effects

Standardized parameter estimates for hypothesized relations among model factors are presented in Figure 1³. Overall, the model accounted for 29.6% of the variance in intentions to reduce sugar intake and 69.2% of the variance in sugar consumption. Tests of hypothesized effects in the model outlined in Table 1 are reported in the next sections.

Explicit processes, motivational phase. We predicted effects of motives from self-determination theory on the social cognitive variables from the theory of planned behavior (H_1). As predicted, autonomous motivation had statistically significant and positive direct effects on attitudes (H_{1a}), subjective norm (H_{1b}), and perceived behavioral control (H_{1c}), and controlled motivation had a significant positive effect on subjective norm (H_{1e}), but no effect on attitudes (H_{1d}). Contrary to hypotheses, we found a significant negative effect of controlled motivation on perceived behavioral control (H_{1f}). We also predicted that the social cognitive variables would predict intentions and behavior, consistent with the theory of planned behavior (H_2). As hypothesized, attitudes (H_{2a}) and subjective norm (H_{2b}) were significant positive predictors of intentions, but perceived behavioral control was not, leading us to reject this hypothesis (H_{2c}). There was a significant negative effect of intentions on sugar consumption, as predicted (H_{2d}). We also predicted indirect effects of the social cognitive variables in sugar consumption mediated by intentions (H_3). There were significant negative indirect effects of attitudes (H_{3a}) and subjective norm (H_{3b}) on sugar consumption mediated by intentions as predicted, but no indirect effects of perceived behavioral control (H_{3c}) on sugar consumption, leading to a rejection of the latter hypothesis. We also expected indirect effects of self-determined motives on intentions and behavior mediated by the social cognitive variables (H_4). We found a significant positive indirect effect of autonomous motivation on intention mediated by attitudes, subjective norm, and perceived behavioral control consistent with our hypothesis (H_{4a}). There was, however, no indirect effect of controlled motivation on intention, so this hypothesis was rejected (H_{4b}). There was a significant negative indirect effect of autonomous motivation (H_{4c}) on sugar consumption consistent with our hypothesis, but no indirect effect of controlled motivation

³Full parameter estimates including direct, indirect, and total effects are presented in the table in Appendix C (supplemental materials).

(H_{4d}) on sugar consumption, so we rejected this hypothesis. Past sugar consumption was a significant predictor of the majority of the model variables, as predicted (H₅); effects of past consumption on subjective norm (H_{5b}), intention (H_{5f}), and action planning (H_{5g}) were the exceptions.

Implicit processes, motivational phase. We predicted that implicit attitudes toward sugar would predict intentions and sugar consumption (H₆). We found a statistically significant negative direct effect of implicit attitudes on sugar consumption (H_{6b}), but no effect of implicit attitudes on intention (H_{6a}) and no indirect effect of implicit attitudes on sugar consumption through intentions (H_{6c}).

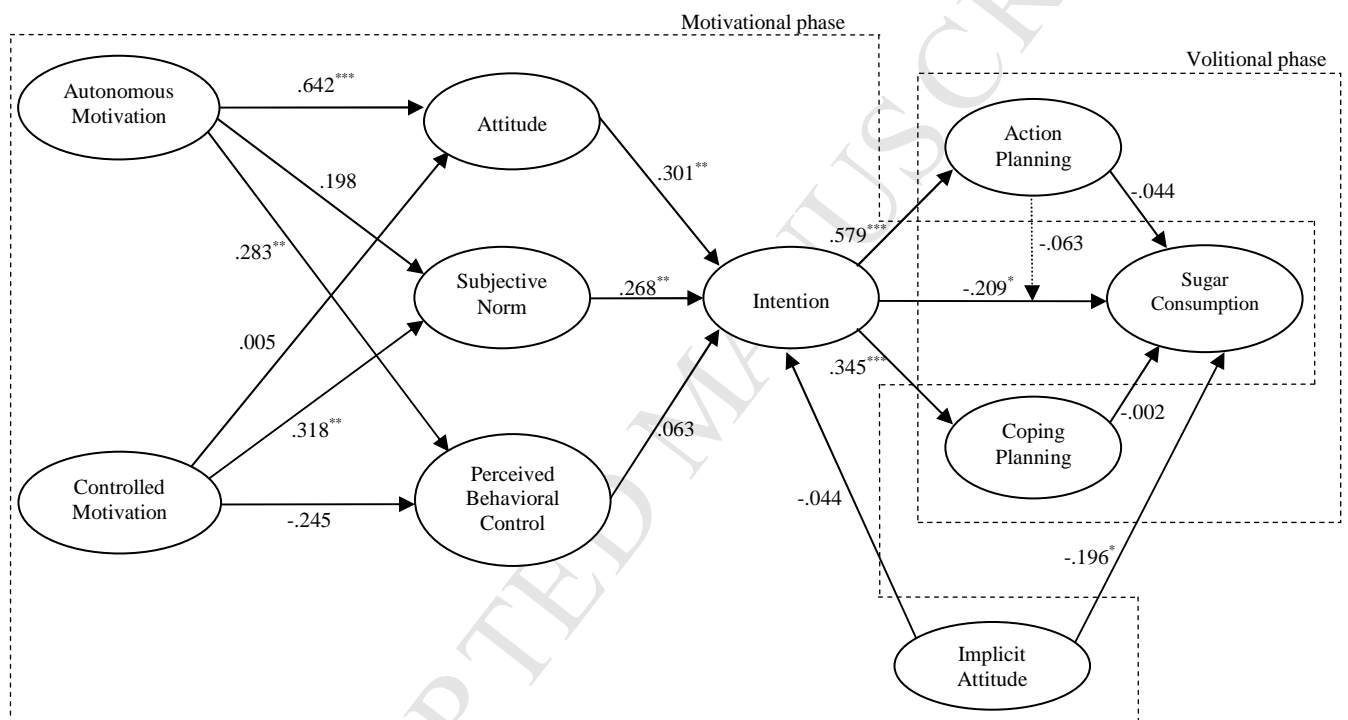


Figure 1. Standardized path coefficients for structural equation model of relations among the integrated dual-process, dual-phase model of sugar consumption. All variables depicted were measured at the initial laboratory visit (T1) with the exception of sugar consumption, which was measured at follow-up two weeks later (T2). Effects of control variables (past behavior, BMI, age, and gender) are not shown in the diagram. Intention, implicit attitudes, and the control variables (age, gender, BMI) were estimated as single-indicator latent variables with their variance fixed at unity. By convention, these constructs are represented by ellipses rather than rectangles. However, these constructs are not considered “true” latent variables as their measurement error is not explicitly modeled (Kock, 2015).

Explicit processes, volitional phase. We expected intentions to predict the planning constructs (H₇). Intentions statistically significantly and positively predicted both action (H_{7a}) and coping planning (H_{7b}), as hypothesized. We also predicted that the planning variables, and their interaction with intention, would predict sugar consumption (H₈), consistent with the model of action phases (Heckhausen & Gollwitzer, 1987). However, contrary to hypotheses, there were no effects of action planning (H_{8a}) and

333 coping planning (H_{8b}), or their interaction (H_{8c}), on sugar consumption. We also hypothesized that the
334 planning variables would mediate effects of intentions on sugar consumption (H_9), consistent with the
335 HAPA (Schwarzer, 2008). However, we found no indirect effects of intention on sugar consumption
336 mediated by action (H_{9a}) and coping (H_{9b}) planning.

337 Discussion

338 The purpose of the current study was to test a comprehensive dual-process, dual-phase integrated
339 model derived from multiple theories to identify the processes that determine dietary sugar consumption.
340 The model proposed that sugar consumption is a function of conscious, deliberative processes
341 encompassed by motivational orientations and social cognitive beliefs from self-determination theory and
342 the theory of planned behavior, respectively, and impulsive, non-conscious processes represented by
343 implicit attitudes toward sugar. The model also proposed that enactment of intentions is determined by
344 action and coping planning in a post-decisional volitional phase of action. Results indicated that
345 intentions to limit sugar intake, representing the reflective process of action, and implicit attitudes toward
346 sugar, representing impulsive processes, were significant predictors of sugar consumption. Intentions
347 were predicted by attitudes, subjective norm, and, indirectly, autonomous motives. There were no
348 significant effects for controlled motives and perceived behavioral control. There were also significant
349 indirect effects of autonomous motivation on sugar consumption through the social cognitive variables
350 and intentions, but not for controlled motivation. Action planning and coping planning were predicted by
351 intentions, but did not mediate the intention-behavior relationship, and there was no interactive effect of
352 action planning and intention on sugar consumption.

353 Effects of intentions and implicit attitudes on behavior implicate both reflective and impulsive
354 processes in the prediction of sugar intake. This is consistent with dual process models of behavior (e.g.,
355 Evans & Stanovich, 2013; Hagger, 2016; Strack & Deutsch, 2004) and previous research (e.g., Keatley et
356 al., 2012; Perugini, 2005; Proulx et al., 2014) that has simultaneously investigated effects of both
357 processes in other health behaviors. Although there is increased recognition of the importance of
358 accounting for both processes when predicting health behavior, the most salient emerging question from
359 such research is not whether the two processes predict, but, rather, the relative contribution of each. In the

360 context of sugar consumption, current evidence indicates that both processes are of equal importance.

361 Findings are consistent with previous research on the social cognitive predictors of behaviors related to
362 sugar consumption, such as consumption of high-sugar soft drinks, which has identified the prominent
363 role of intentions, but also important contributions from variables reflecting impulsive processes, such as
364 self-reported behavioral automaticity (de Bruijn & van den Putte, 2009; Naughton et al., 2015; Tak et al.,
365 2011; van der Horst et al., 2007). The current study is, however, the first to demonstrate the role for
366 implicitly-held cognitions as a predictor of dietary sugar consumption in the context of a dual process
367 model. Current findings are congruent with the notion that sugar consumption is an extremely rewarding
368 behavior regulated by well-learned behavioral patterns reinforced by dopamine-mediated pathways in the
369 mesolimbic system in the brain (Stice et al., 2013). Implicit attitudes toward sugar, therefore, reflect these
370 impulsive tendencies and are likely developed over time through the rewarding experience of sugar
371 consumption. The intentional constructs to reduce sugar consumption must, therefore, compete with
372 implicit beliefs in accounting for behavior.

373 It must, however, be stressed that the size of the effects for both explicit and implicit constructs
374 were small. In addition, the majority of the explained variance (35.1%) was accounted for by past
375 behavior. This shortfall in explanatory value of the current model could be attributed to constructs that
376 were not measured in the current research and methodological artifacts. Unmeasured constructs may be
377 other implicitly-held beliefs that may account for variance in the behavior, such as self-control and
378 motives. They may also include individual difference constructs that may have pervasive effects on
379 impulsive actions, such as impulsivity and self-regulatory capacity.

380 Intentions to reduce sugar consumption were a function of attitudes and subjective norm, and,
381 indirectly, autonomous motivation. This is consistent with other research integrating self-determination
382 theory and the theory of planned behavior in health contexts (e.g., Hagger & Chatzisarantis, 2009;
383 Hamilton, Cox, & White, 2012). Current findings corroborate the importance of self-endorsed motives
384 that are congruent with the individual's true sense of self as the basis for the beliefs that determine
385 intentions. Individuals who hold personally-endorsed motives to reduce dietary sugar are more likely to
386 align their attitudes and norms to reduce their sugar consumption in future, and more likely to intend to

387 do so. Controlled motives seem to have a less important role, consistent with research on self-
388 determination theory suggesting that such beliefs are less likely to be related to uptake and maintenance
389 of health behavior. Interestingly, perceived behavioral control was unrelated to autonomous motivation
390 and intentions to reduce sugar consumption. This was contrary to hypotheses, and the majority of research
391 in health behavior, which has typically provided support for the role of perceived behavioral control in
392 predicting intentions (McEachan et al., 2016; Rich et al., 2015), including behaviors related to sugar
393 consumption (de Bruijn & van den Putte, 2009; Naughton et al., 2015; van der Horst et al., 2007). In the
394 current study, it may be that effects of perceived behavioral control were subsumed by other constructs in
395 the model. Correlations between perceived behavioral control and attitudes, past behavior, and the
396 planning constructs, in particular, were large in magnitude and statistically significant (see Table 3),
397 which means any effects of perceived behavioral control may have been attenuated by these constructs.
398 The constructs that remained as predictors, therefore, reflect those that account for unique variance in
399 intentions to reduce sugar consumption.

400 It is important to note that the indirect effects of autonomous motivation, attitudes, and subjective
401 norm on sugar consumption were relatively small (β range = -.055 to -.063). While indirect effects are
402 typically smaller than direct effects in multiple mediator models, the main reason for the small effects is
403 the relatively modest effect of intentions on behavior. Aside from measurement limitations, the weak
404 intention-behavior effect may be due to the strong and pervasive influence of past behavior in model. Past
405 sugar consumption was highly correlated with sugar consumption ($r = .718, p < .001$; Table 3), had the
406 strongest effect on sugar consumption in the final model, as well as significant effects on the majority of
407 the other variables in the model, and accounted for almost half of the explained variance in sugar
408 consumption. This should not be surprising given the relatively close proximity (two weeks) in the two
409 measures. Together, the strong and pervasive effects of past behavior on sugar consumption likely
410 reduced the effect of intentions. The fact that we found independent effects for intention and implicit
411 attitudes, and indirect effects of distal predictors, in the context of the strong effects for past behavior is
412 notable and indicates that, despite limitations of the current study, our data support the predictive validity
413 of our model in accounting for unique variance in sugar consumption.

414 In addition, while the volitional components of action and coping planning were related to
415 intentions, they had no mediation or moderation effect with intention on sugar consumption, despite
416 significant correlations between the planning measures and sugar consumption (see Table 3). This finding
417 may also be due to the pervasive effects for past sugar consumption in the model. These limitations
418 notwithstanding, current results do not provide evidence to support the role of volitional components in
419 the effect of intention on sugar consumption. Ruling out a role for planning in determining sugar
420 consumption may be premature based on these data alone, especially since the current model is a static
421 depiction of the decision-making process rather than a dynamic depiction that describes changes in
422 constructs over time. However, the current model should provide an initial basis to question the multiple
423 roles of planning in the conversion of intentions to action. And the current research is not the first to
424 question the role of planning, other research has revealed null effects and suggest that effects of planning
425 may vary by behavior type (e.g., Jackson et al., 2005; Meslot, Gauchet, Allenet, François, & Hagger,
426 2016).

427 **Study limitations**

428 The current research has numerous strengths including (a) a focus on sugar consumption, a
429 relatively under-researched, but important, dietary behavior; (b) the adoption of an integrated dual-
430 process, dual-phase theoretical approach and appropriate measures; and (c) a the use of confirmatory
431 analytic techniques to test model effects. However, there are a number of limitations that should be
432 acknowledged. First, the relatively small effects observed between model variables may reflect problems
433 with the methods used. For example, we used a single item measure of intentions, so we were unable to
434 estimate the reliability of this measure. Further, measurement of behavior through a relatively brief self-
435 report measure is also an important limitation. Although many studies have adopted self-reported
436 behavioral measures in model tests in health behavior contexts, corroboration through more
437 comprehensive diaries or tracking sugar intake using ecological momentary assessment (Carels,
438 Douglass, Cacciapaglia, & O'Brien, 2004) or photographic methods (Ovaskainen et al., 2007) may
439 provide more accurate estimates. In addition, although our short-term follow up of behaviour (two weeks)
440 had the advantage of maximizing participants' recall in our self-report measure of sugar consumption, the

441 short-term follow-up should be recognised as an important limitation as it did not enable assessment of
442 long-term predictive validity. Using more comprehensive measures of sugar consumption over an
443 extended period would provide effective evaluation of long-term model effectiveness. It should also be
444 recognized that relations among the psychological constructs measured at T1 were based on theory alone
445 as the current design did not permit inferences of directionality or causation (Hagger & Chatzisarantis,
446 2016). Longitudinal designs, particularly panel designs that enable cross-lagged relations among model
447 constructs, are advocated in future tests to better account for the ordering and directionality of effects in
448 the model.

449 A further caveat is that the variables included in our model were confined to those identified in
450 previous conceptual (Hagger & Chatzisarantis, 2014) and empirical (Hagger & Chatzisarantis, 2009;
451 Keatley et al., 2012; Penseau et al., 2014) research integrating motivational, volitional, and implicit
452 components. While there is increasing research supporting such approaches, it is important to note that
453 they may not account for all processes or components. For example, different types of self-efficacy and
454 risk perceptions identified in the HAPA (Schwarzer, 2008) and emotional processes (Conner, McEachan,
455 Taylor, O'Hara, & Lawton, 2015) were not considered. We view the integrated model tested in the current
456 study as a flexible framework to guide the identification of the multiple components and processes that
457 relate to health behavior. We hope the test will provide impetus for future research that seeks to further
458 extend the model and integrate additional components. Finally, we acknowledge that the final sample size
459 was relatively small which may have affected the stability of model parameter estimates and the precision
460 of the standard errors. Our bootstrap resampling method with a large number of replications provided
461 robust parameter estimates and standard errors. However, such simulation analyses should not be
462 considered a panacea for the need for large sample sizes or true replications of model effects. We
463 advocate replication of the current findings in larger, more diverse samples, which may provide
464 converging evidence for the generalizability of proposed pattern of effects in our model.

465 **Conclusion**

466 Current findings support the basic premises of an integrated dual-process, dual-phase model in
467 predicting dietary sugar consumption. Intentions to reduce sugar intake and implicit attitudes toward

468 sugar were independent predictors of sugar consumption, albeit with small effects. Results are consistent
469 with findings of other research that has applied models incorporating multiple processes to explain health
470 behavior, and provide preliminary evidence for the contribution both reflective and impulsive processes
471 in predicting sugar consumption. Current findings should be viewed as preliminary given this is a single
472 study in a student sample. Corroboration of current effects should be considered a priority for future
473 research. Confirmation of consistent effects of implicit attitudes as predictors of dietary sugar intake may
474 have ramifications for the types of interventions likely to be effective in regulating sugar consumption.
475 For example, environmental restrictions and self-monitoring may be effective means to control cue
476 presentation and restrict the enactment of automatic behavioral tendencies in behaviors that have a strong
477 automatic component.

478

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