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# Are trait self-control and self-control resources mediators of relations between executive functions and health behaviors?

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**Abstract**

This study investigated associations between executive functions (i.e., inhibition, working memory, cognitive flexibility) and individual differences in self-control and health behaviors. We examined whether executive functions predict physical activity, sedentary activity, and healthy and unhealthy diets, and whether trait self-control and self-control resources mediate these associations. Two hundred and eighty-seven participants completed a questionnaire assessing trait self-control and self-control resources, physical activity, sedentary activity, and healthy and unhealthy diets. They also performed three randomly ordered cognitive tasks, a stop-signal task (i.e., inhibition), a letter memory task (i.e., working memory), and a number-letter task (i.e., cognitive flexibility). Structural equation modeling revealed that self-control resources positively predicted physical activity (R2 = .04) and negatively predicted sedentary activity (R2 = .04). Moreover, trait self-control positively predicted a healthy diet (R2 = .11) and negatively predicted an unhealthy one (R2 = .17). However, no evidence was found supporting associations between executive functions and health behaviors, or relations mediated by self-control, despite a significant relation between inhibition and sedentary behavior in a direction opposed to our hypothesis. The findings suggest the importance of trait self-control and self-control resources for health behavior adoption and pave the way for studies exploring the role of the executive functions in an affective context.

**Keywords**: self-control resources, trait self-control, inhibition, working memory, cognitive flexibility, health behaviors

## 1. Introduction

According to the World Health Organization, physical inactivity and an unhealthy diet are among the most important risk factors for noncommunicable diseases, causing one death every seven seconds and one death every three seconds, respectively (Forouzanfar, Afshin, Alexander, Biryukov, et al., 2016; Lee et al., 2012). Changing these unhealthy behaviors by improving the regularity of physical activity and healthiness of diet could prevent 16 million premature deaths each year (Forouzanfar, Afshin, Alexander, Anderson, et al., 2016). Despite widespread declarations of intention to adopt healthy behaviors, most people fail to reach minimum recommendations (Ford et al., 2011). In this context, some promising conflict resolution models could effectively promote health behaviors (Sniehotta et al., 2014).

These models emphasize that health-behavior facilitators (e.g., health-behavior goals, such as an intention to do more physical activity) face barriers (e.g., temptation toward the competing behavior, such as a desire to engage in a sedentary activity), leading to motivational conflicts that need to be resolved (Kotabe & Hofmann, 2015; Rabiau et al., 2006). An adaptative resolution of this conflict (i.e., one in favor of the goal) promotes the health-behavior goal (e.g., going for a run, snacking on an apple). A maladaptive one promotes the competing behavior (e.g., remaining on the couch, snacking on a chocolate bar) (e.g., Gillebaart et al., 2016). Self-control, characterizing the manner people modify and control their behavior, seems to play a key role in promoting the resolution of motivational conflicts, favoring the adoption of healthy behaviors such as physical activity or a healthy diet (de Ridder et al., 2012; Pfeffer et al., 2020; Tangney et al., 2004).

In 2018, Forestier et al. identified individual differences in trait self-control and self-control resources, as two dimensions independently associated with health behaviors. Despite their importance, self-control resources have been mostly considered in ego-depletion research (e.g., Rouse et al., 2013) and rarely on research on self-control and health behaviors (de Ridder et al., 2018). Trait self-control distinguishes individuals with or without a general tendency to successfully resolve motivational conflicts. In parallel, individual differences in self-control resources distinguish individuals with or without a general tendency to experience a high level of self-control resources, crucial for actions of self-control (Forestier et al., 2022) (Forestier et al., 2018). Indeed, a remarkable portion of variance (40%) in self-control resources is found at the between-person level (Smolders et al., 2013). Hence, individuals with high trait self-control consumed a healthier diet, with less unhealthy food, than those with low trait self-control. Likewise, people with high self-control resources practiced more physical activity and were less sedentary than individuals with low self-control resources (Forestier et al., 2018).

Despite these interesting results, the predictors of individual differences in the two self-control dimensions were not specifically examined. Some hypotheses on the executive functions have been already put forward that can partly explain the differences in these dimensions (e.g., Hofmann, Schmeichel, et al., 2012, Table 2). Specifically, inhibitory control, working memory, and cognitive flexibility may be related to self-control, and individuals with higher executive abilities would, therefore, be good self-controllers (Friese et al., 2011; Hofmann et al., 2011). Moreover, executive functions could operationalize the "self-control capacity" that makes self-control success possible (Forestier et al., 2022; Kotabe & Hofmann, 2015). Individuals with high working memory abilities would present high self-control through a better use of goal-relevant information. A better control of interfering thoughts, emotions and behaviors might be related to high levels of inhibitory control. Individuals with cognitive flexibility abilities may effectively update alternative appropriate strategies in goal pursuit. (Hofmann et al., 2011; Hofmann, Schmeichel, et al., 2012).

Empirical studies on self-control consider executive functions to be moderators of the relation between self-control and health behaviors (Hofmann et al., 2009; Pfeffer & Strobach, 2017), but few have tested the direct effect of these executive abilities on self-control. As far as we know, only Saunders et al. (2018) and Necka et al. (2018) have investigated the association between executive functions and self-control. Saunders et al. (2018) found no evidence of a correlation between trait self-control and inhibitory control. Using structural equation modeling, Necka et al. (2018) found no significant association between a "trait self-control" latent variable and an "executive functions" latent variable. However, methodological improvement would allow some results-related pitfalls to be avoided. First, only the relations between latent variables were tested, without examining the independent contribution of each executive function to trait self-control. Second, these previous studies never focused on self-control resources, which are correlated with trait self-control but remain an independent dimension to be considered (Forestier et al., 2018). Third, the possibility that trait self-control and executive functions are associated with health behaviors was not investigated. Yet, the relation between executive functions and health behaviors deserves attention. Indeed, another study showed that individuals with the highest inhibitory control adopted a less unhealthy diet (Hofmann et al., 2009). Similarly, high working memory abilities have been associated with more physical activity (Lambourne, 2006; Pfeffer & Strobach, 2017). Finally, a bi-directional relationship between executive functions and health behavior has been proposed, with individuals with high executive abilities being more likely to adopt a healthy lifestyle that would, in turn, enhance their executive functions in the long run (Allan et al., 2016). Empirical data has recently been reported supporting this relation (Cheval et al., 2020). Accordingly, if executive functions are correlated with self-control, as advanced theoretically (Hofmann, Schmeichel, et al., 2012), they could promote health behaviors through direct and indirect effects, partially mediated by trait self-control and self-control resources. Such assumptions have never yet been tested.

The current study aimed to investigate the independent contribution of each executive function to self-control and health behaviors while considering differences among individuals in their trait self-control and self-control resources. For these purposes, structural equation models were used, one for physical activity versus sedentary activity, and a second for a healthy versus an unhealthy diet, as in Forestier et al., (2018). In line with theoretical discussions (Hofmann, Schmeichel, et al., 2012), we hypothesized that executive functions would positively predict trait self-control and self-control resources (H1) and healthy behaviors (physical activity and healthy diet) (H2), and negatively predict unhealthy behaviors (sedentary activity and unhealthy diet) (H3). Similarly, we hypothesized that trait and self-control resources would positively predict healthy behaviors (H4) and negatively predict unhealthy behaviors (H5). Finally, the mediated relation implies that (H6) executive functions will be positively related to trait self-control and self-control resources, which will in turn be related to health behaviors. Figure 1 summarizes our hypotheses.

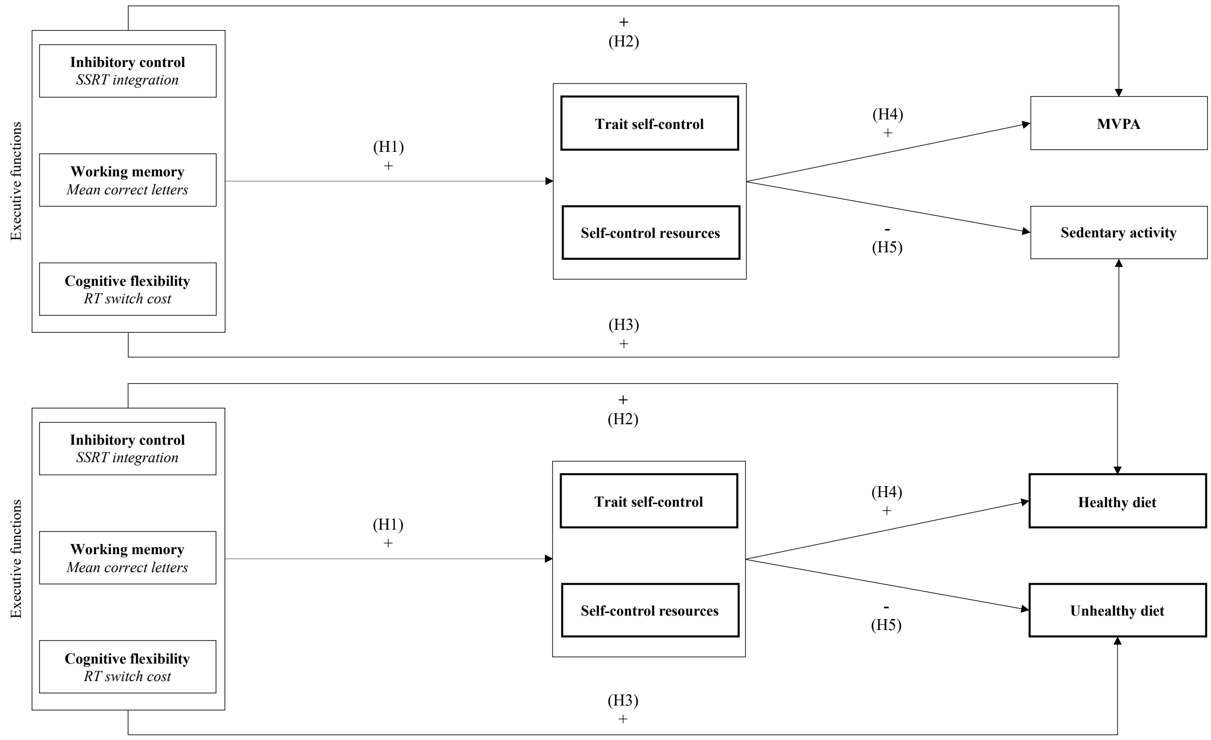


**Figure 1. Hypothetical Models.**

Note. These are summarized hypothetical models. The full model will test the relations between each executive function, trait and state self-control and each behavior. RT = Reaction Time, SSRT = Stop-Signal Reaction Time, MVPA = Moderate to Vigorous Physical Activity. Variables with a bold line are latent. Variables with normal line are observed. H6 is the hypothesis related to the effects of executive functions on health behaviors mediated by self-control and is not illustrated.

## 2. Method

### Overview

Participants were recruited via social media, personal mailing lists, and direct advertising messages during classes. They were all students at sports and psychology faculties of three different universities. Data were collected over three weeks (November 2021) by completion of three cognitive tasks and four questionnaires on Inquisit web version 6.3.2.0 (Computer software) (data hosted by Inquisit, Europe repository) (during a single session lasting 1h15). All procedures in this study complied with APA ethical principles. Informed consent was obtained from all participants before the beginning of the study. It should also be noted that the participants were informed that the online study was anonymous and confidential: only a self-generated code allowed their identification.

### Participants and sample size

Two procedures were used for estimating required sample size. First, we used the method specific to structural equation modeling (MacCallum et al., 1996, 2006; MacCallum &

Hong, 1997) to estimate an a priori minimum sample size to obtain a fit index, namely RMSEA, within a given range [0.00; 0.08] (as recommended in the literature, Brown, 2015), with 90% power and $\alpha = .05$. Based on simulations, the minimum sample size was $N = 26$ (data and code for this estimation are available at https://osf.io/hpsjw/?view_only=6e28c8307294494e9eec45d2670efd8d) (MacCallum et al., 2006). Second, we estimated an a priori maximum sample size by using the stopping rule based on resource constraints. Because we endorsed no priors regarding an expected effect size, we decided to recruit as many participants as possible during the running of the online study. During these three weeks, 535 people logged on. Exclusion criteria were individuals who: (1) did not consent to participate; (2) did not fully complete the study (to avoid data imputation); (3) completed the study multiple times; (4) responded incorrectly to seriousness checks (Aust et al., 2013); (5) did not consider regular physical activity and healthy diet as important for them (i.e., below 2 on a 1–7 goal-importance scale, Fishbach et al., 2003). In addition, we used the *performance* package (Lüdecke et al., 2021) for R-Studio (R Core Team, 2021) to identify observations that were influential on the nine variables of interest (see Measures section). Specifically, based on a composite score obtained via the application of multiple outlier detection algorithms (Lüdecke et al., 2021), we excluded participants classified as influential by at least half of the methods used by this package (the data and code of this data cleaning are available at https://osf.io/hpsjw/?view_only=6e28c8307294494e9eec45d2670efd8d). The final sample size was composed of $N = 287$ participants (117 women; $M_{age} = 19.43$, $SD_{age} = 2.87$).

Finally, we conducted a sensitivity power analysis with G*Power 3.1.9.4 (Faul et al., 2007) to estimate the minimal effect size on the most constrained multiple regression of the structural equation models. With $N = 287$, $n_{predictors} = 5$ (see Measures), power = .90, $\alpha = .05$, the smallest detectable effect size was $f^2 = .058$. This is one of the smallest small-to-medium effect sizes (range = .02 to .15), in line with findings on the relationships between self-control and health behaviors (Pfeffer & Strobach, 2018).

## Measures

### *Independent Variables*

#### Inhibitory Control

A recent consensual stop-signal task (Verbruggen et al., 2019) was used to assess inhibitory control. A typical trial started with a central fixation circle presented for 250 ms, followed by display of the stimulus (a right- or left-pointing white arrow within a circle) until the participant's response. The instruction was to respond systematically according to the direction indicated by the arrow by pressing a predefined keyboard button. However, participants had to stop their response (i.e., not press the key) if a signal beep was made after the presentation of the arrow. The delay between the arrow's presentation and the beep was adjusted up or down by 50 ms as a function of the participant's performance, starting with an initial delay of 250 ms. The delay could be increased up to 1150 ms if the previous signal-stop was successful, and decreased down to 50 ms if the previous signal stop failed. This delay is referred to as the Stop-Signal Reaction Time (SSRT) and gives an estimation for response-inhibition latency in milliseconds. We calculated the SSRT by using the integration method

(Verbruggen et al., 2019). The lower the SSRT, the more difficult it is to stop the go-process, and the higher the SSRT, the easier it is to stop the go-process. Accordingly, a lower (higher) SSRT integration means the participant has stronger (weaker) inhibitory control.

**Working Memory**

We used a letter memory task to measure working memory (Friedman et al., 2008). A series of letters appeared consecutively in the center of the screen for a duration of 2.5 s for each letter. Written instructions asked participants to recall, in forward order, the last three letters after the last letter's disappearance, by selecting the correct letters from a letter matrix provided. They had to click "blank" if they skipped a particular letter. The number of letters per series varied randomly through time (5, 7, or 9 letters). In total, 12 measurement trials were completed (four of each length). Answers were scored as correct even if the three letters were not recalled in the correct order (Miyake et al., 2000). The more participants were able to recall letters per trial, the better their working memory was considered.

**Cognitive Flexibility**

Cognitive flexibility was assessed with a number-letter task (Miyake et al., 2000). This task involves two categorization tasks, in which character pairs including a letter and a number (e.g., 3T, 4A) were presented. The participants were asked to categorize the pair depending on whether the letter was a consonant or vowel (i.e., letter task), or depending on whether the number was odd or even (i.e., number task). The tasks alternated between categorizing rules in a clockwise fashion, and thus used predictable location cues in a 2x2 matrix (i.e., the top of the matrix for letter categorization and bottom of the matrix for number categorization). Odd-numbered trials were set as "switch task" trials and even-numbered trials as "non-switch task" trials. Participants responded by button press, and the next stimulus was presented 150 ms after the response. The whole task was composed of 128 trials. The reaction time switch cost was calculated by assessing the difference between the correct latency of switch trials and non-switch trials (Miyake et al., 2000). A positive reaction time switch cost indicates a slower response in switch trials, than in non-switch trials, and conversely. For example, a highly positive reaction time switch cost indicates low cognitive flexibility. Trials with reaction times under 150 ms and above 2000 ms were excluded from analyses.

***Mediating Variables***

**Trait Self-Control**

Trait self-control was assessed with the 13-item version of the Brief Self-Control Scale (Tangney et al., 2004). Participants responded to the following instruction: "For each sentence, choose what suits you best", on a 7-point Likert scale from 1 (*Don't agree at all*) to 7 (*Completely agree*), with regard to the different items ($\alpha = .80$, $\omega = .83$).

**Self-Control Resources**

Self-control resources were assessed by the subjective vitality scale, as in previous studies (Forestier et al., 2018). Participants were asked to answer the 5-item questionnaire (e.g., "At the moment, I feel alive and full of vitality"), with the following instruction: "For each item, please indicate the general feeling you have experienced over the past 7 days, by selecting the most appropriate number" on a 7-point Likert scale from 1 (*Don't agree at all*) to 7 (*Completely agree*) ($\alpha$ = .89, $\omega$ = .92).

***Dependent Variables***

**Physical Activity and Sedentary Activity**

Physical activity and sedentary activity were measured using the International Physical Activity Questionnaire (Craig et al., 2003). Participants were asked to indicate how much time they had spent doing moderate-intensity and vigorous-intensity physical activities (i.e., MVPA), how much time they had spent walking, and how much time they had spent sitting and/or lying down (i.e., sedentary activity) in minutes, in their daily life over the last 7 days.

**Healthy and Unhealthy Diet**

Healthy and unhealthy diets were assessed using the Healthy Eating Behavior Scale (Pelletier et al., 2004), composed of two subscales: four items related to a healthy diet (e.g., "I eat fruit and vegetables") and the remaining items related to an unhealthy diet (e.g., "I use white sugar"). Participants indicated their consumption frequency on a 7-item scale ranging from 1 (*once or twice per month*) to 7 (*more than three times per day*).

## 3. Results

Descriptive statistics and Pearson's correlation coefficients are provided in the Supplementary Materials (Tables S1 and S2).

**Structural Equation Modelling**

***Analytical Strategy***

The hypotheses were tested using structural equation modeling with the *Lavaan* package (version 0.6-8, Rosseel, 2012) in R-Studio (RStudio Team, 2015) (the R script, raw data, and analysis dataset can be found in the Open Science Framework, at https://osf.io/hpsjw/?view_only=6e28c8307294494e9eec45d2670efd8d). We used a two-step approach (Anderson & Gerbing, 1988). The first step is a confirmatory factor analysis (CFA). Hence, we verified the construct validity of the measurement model to estimate a reliable one, by examining factor loadings, modification indices and model fit indices. Second, after a satisfactory fit was achieved for the measurement model, we tested the structural model (i.e., the hypothesized relationships between the variables). The results section presents only the structural models (see Measurement Models in Supplementary Materials). Model fit was assessed by examining the comparative fit index (CFI), Tucker–Lewis Index (TLI), and root-mean-square error of approximation (RMSEA), with a satisfactory model having a CFI and a TLI over 0.90, a RMSEA below 0.05 (Brown, 2015). Finally, after an estimation of the full hypothetical model, non-significant paths were removed to estimate model's parsimony reliability (MacCallum & Austin, 2000). The statistical significance was set at $\alpha$ = .05. Data were standardized prior to model estimation. Indirect effects (i.e., mediation) were estimated if independent variables and mediators were significantly associated with the dependent variables.

### *Physical Activity and Sedentary Activity Structural Model*

The physical activity and sedentary activity structural model contained two latent variables (trait self-control and self-control resources) and five observed variables (inhibitory control score, working memory score, cognitive flexibility score, MVPA score, and sedentary activity). Moreover, compared with the measurement model, we added covariances between the three executive function scores. The full structural equation model yielded good model-fit indices ($\chi^2$ (133) = 152.17, RMSEA = 0.02, 90% CI [0.00, 0.04], CFI = 0.99, TLI = 0.98). Contrary to our hypotheses (H1, H2, and H3), executive function scores were not significantly associated with trait self-control and self-control resources, or with physical activity and sedentary activity, except for the inhibitory control score that was significantly negatively associated with sedentary activity (β = -.17, 95% CI [-.29, -.05], p = .004, $R^2$ = .04). In partial accordance with H4 and H5, only the self-control resources positively predicted MVPA (β = .20, 95% CI [.06, .35], p = .006, $R^2$ = .04) and negatively predicted sedentary activity (β = -.15, 95% CI [.29, .00], p = .046, $R^2$ = .04). Trait self-control was not significantly associated with healthy or unhealthy behaviors. Because executive scores were not significantly associated with any mediators (trait or self-control resources), no indirect effects were estimated; the mediation hypothesis (H6) was rejected. Figure 2 shows this structural model. The most parsimonious model with non-significant paths deleted showed the same pattern of results, with good model-fit indices ($\chi^2$ (146) = 161.39, RMSEA = 0.02, 90% CI [0.00, 0.04], CFI = 0.99, TLI = 0.99).

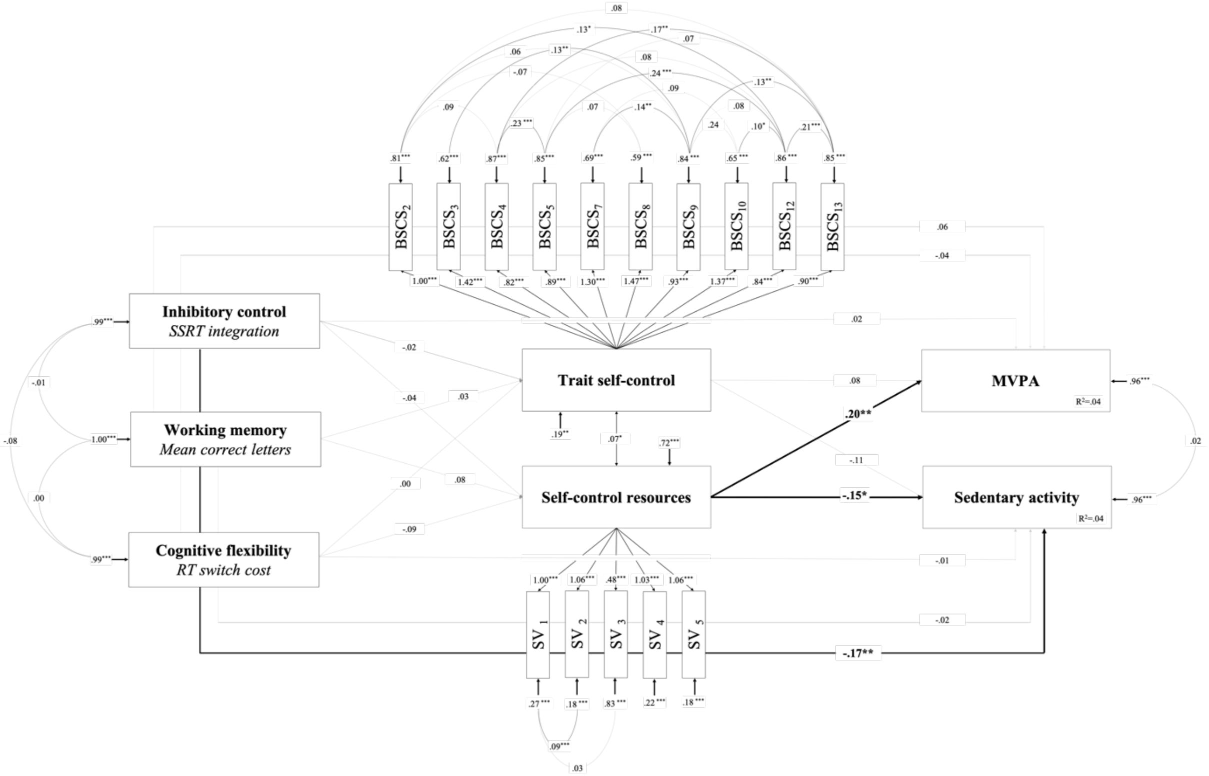


**Figure 2. Physical Activity and Sedentary Activity Full Structural Model**

Note. *p<0.05, **p<0.01, ***p<0.001. SSRT = Stop-Signal Reaction Time, RT = Reaction Time, BSCS = Brief Self-Control Scale, SV = Subjective Vitality, MVPA = Moderate to Vigorous Physical Activity. Path darkness level distinguishes significant and non-significant relations.

***Healthy and Unhealthy Diet Structural Model***

The healthy and unhealthy diet structural model contained four latent variables (trait self-control and self-control resources, and healthy and unhealthy diet scores), three observed variables (i.e., inhibitory control, working memory, and cognitive flexibility scores), and the covariances between the three executive function scores. The full structural equation model yielded good model-fit indices ($\chi^2$ (191) = 214.39, RMSEA = 0.02, 90% CI [0.00, 0.03], CFI = 0.99, TLI = 0.98). Contrary to H1, H2, and H3, there was no significant association of executive functions and trait self-control and self-control resources with healthy or unhealthy diets. In partial accordance with H4 and H5, results revealed that only trait self-control positively predicted a healthy diet (β = .35, 95% CI [.08, .62], p = .01, $R^2$ = .11) and negatively predicted an unhealthy (β = -.27, 95% CI [-.53, -.00], p = .05, $R^2$ = .17). Because executive scores were not significantly associated with any mediators, no indirect effects were found and the mediation hypothesis H6 was rejected. Figure 3 shows this structural model. The most parsimonious model with non-significant paths deleted showed the same pattern of results and also had good model-fit indices ($\chi^2$ (145) = 163.86, RMSEA = 0.02, 90% CI [0.00, 0.04], CFI = 0.99, TLI = 0.99). Table 1 summarizes regression coefficients of our two structural models (the complete tables are available in the Supplementary Materials, Tables S3 and S4).

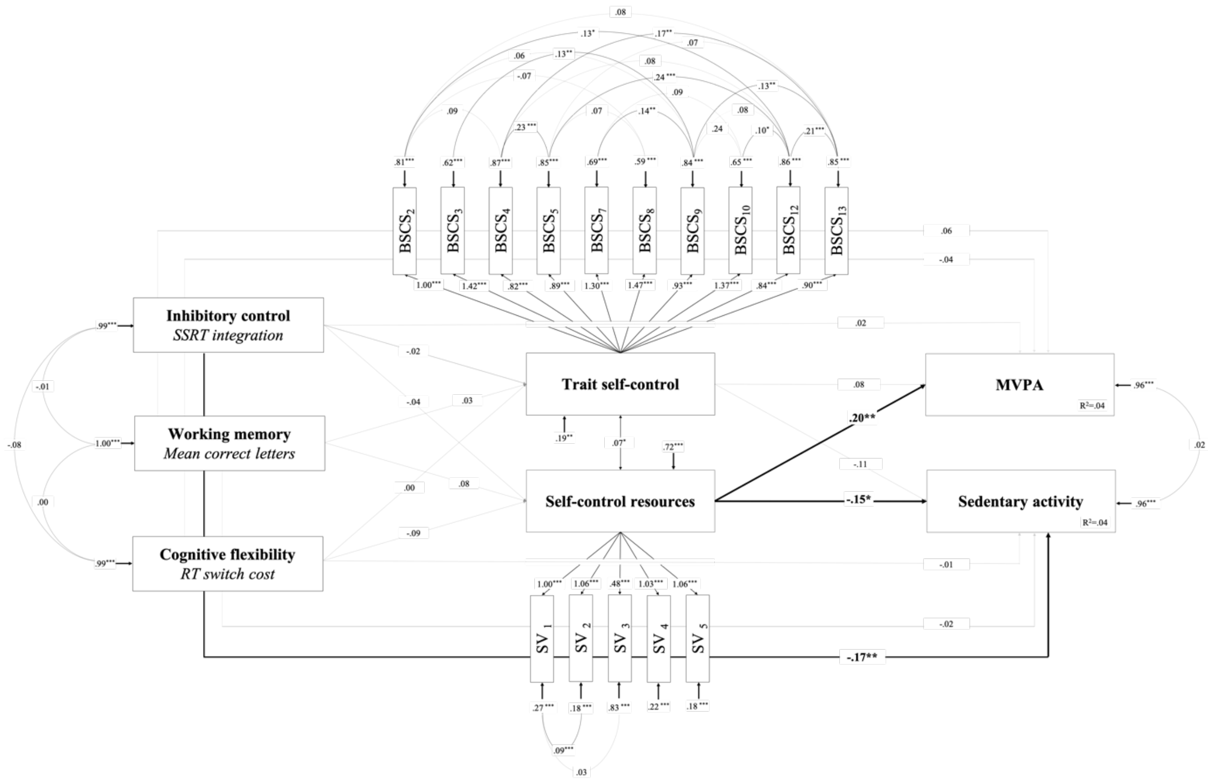


**Figure 3. Healthy and Unhealthy Diet Full Structural Model.**

Note. *p<0.05, **p<0.01, ***p<0.001. SSRT = Stop-Signal Reaction Time, RT = Reaction Time, BSCS = Brief Self-Control Scale, SV = Subjective Vitality, HBES = Healthy Eating Behavior Scale. Path darkness level distinguishes significant and non-significant relations.

**Table 1. Regression Coefficients from Structural Equation Models.**

| Independent variable | Dependent variable | Estimate | Estimate 95%CI [LL, UL] | Std. Err. | z | p | $R^2$ |
|---|---|---|---|---|---|---|---|
| **Physical Activity and Sedentary Time Model** | | | | | | | |
| *Regression Slopes* | | | | | | | |
| SSRT integration (IC) | Self-control resources | -0.04 | [-0.14, 0.07] | 0.05 | 0.70 | .484 | .02 |
| Mean correct letters (WM) | | 0.08 | [-0.02, 0.19] | 0.05 | 1.62 | .106 | |
| RT switch cost (CF) | | -0.09 | [-0.19, 0.02] | 0.05 | 1.64 | .100 | |
| SSRT integration (IC) | Trait self-control | -0.02 | [-0.08, 0.04] | 0.03 | 0.67 | .500 | .01 |
| Mean correct letters (WM) | | 0.03 | [-0.03, 0.09] | 0.03 | 0.91 | .365 | |
| RT switch cost (CF) | | 0.00 | [-0.06, 0.06] | 0.03 | 0.00 | .998 | |
| SSRT integration (IC) | MVPA | 0.02 | [-0.09, 0.14] | 0.06 | 0.40 | .687 | .04 |
| Mean correct letters (WM) | | 0.06 | [-0.05, 0.17] | 0.06 | 1.01 | .311 | |
| RT switch cost (CF) | | -0.04 | [-0.16, 0.07] | 0.06 | 0.74 | .459 | |
| Self-control resources | | **0.20**$^{**}$ | **[0.06, 0.35]** | **0.07** | **2.77** | **.006** | |
| Trait self-control | | -0.11 | [-0.43, 0.21] | 0.16 | 0.69 | .491 | |
| SSRT integration (IC) | Sedentary activity | **-0.17**$^{**}$ | **[-0.28, -0.05]** | **0.06** | **2.89** | **.004** | .04 |
| Mean correct letters (WM) | | -0.02 | [-0.14, 0.09] | 0.06 | 0.42 | .676 | |
| RT switch cost (CF) | | -0.01 | [-0.12, 0.11] | 0.06 | 0.15 | .881 | |
| Self-control resources | | **-0.15**$^{*}$ | **[-0.29, 0.00]** | **0.07** | **2.00** | **.046** | |
| Trait self-control | | 0.08 | [-0.24, 0.40] | 0.16 | 0.51 | .611 | |
| *Fit Indices* | | | | | | | |
| $\chi^2$ | | 152.17 | | | | | |
| $\chi^2$_df | | 133.00 | | | | | |
| p_$\chi^2$ | | 0.12 | | | | | |
| CFI | | 0.99 | | | | | |
| TLI | | 0.98 | | | | | |
| RMSEA | | 0.02 | [0.00, 0.04] | | | | |
| **Healthy and Unhealthy Diet Model** | | | | | | | |
| *Regression Slopes* | | | | | | | |
| SSRT integration (IC) | Self-control resources | -0.04 | [-0.14, 0.07] | 0.05 | 0.70 | .484 | .02 |
| Mean correct letters (WM) | | 0.08 | [-0.02, 0.19] | 0.05 | 1.62 | .106 | |
| RT switch cost (CF) | | -0.09 | [-0.19, 0.02] | 0.05 | 1.64 | .100 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SSRT integration (IC) | Trait self-control | -0.02 | [-0.08, 0.04] | 0.03 | 0.67 | .500 | .01 |
| Mean correct letters (WM) | | 0.03 | [-0.03, 0.09] | 0.03 | 0.91 | .365 | |
| RT switch cost (CF) | | 0.00 | [-0.06, 0.06] | 0.03 | 0.00 | .998 | |
| SSRT integration (IC) | Healthy diet | -0.09 | [-0.18, 0.01] | 0.05 | 1.80 | .072 | .11 |
| Mean correct letters (WM) | | 0.07 | [-0.02, 0.16] | 0.05 | 1.53 | .125 | |
| RT switch cost (CF) | | 0.02 | [-0.07, 0.12] | 0.05 | 0.53 | .596 | |
| Self-control resources | | 0.06 | [-0.05, 0.17] | 0.06 | 1.04 | .298 | |
| Trait self-control | | **0.35*** | **[0.08, 0.62]** | **0.14** | **2.57** | **.010** | |
| SSRT integration (IC) | Unhealthy diet | 0.00 | [-0.04, 0.05] | 0.02 | 0.19 | .852 | .17 |
| Mean correct letters (WM) | | -0.05 | [-0.12, 0.01] | 0.03 | 1.66 | .097 | |
| RT switch cost (CF) | | 0.04 | [-0.01, 0.10] | 0.03 | 1.50 | .135 | |
| Self-control resources | | 0.05 | [-0.02, 0.12] | 0.04 | 1.44 | .151 | |
| Trait self-control | | **-0.26*** | **[-0.53, 0.00]** | **0.13** | **1.96** | **.050** | |
| *Fit Indices* | | | | | | | |
| $\chi^2$ | | 214.39 | | | | | |
| $\chi^2$_df | | 191.00 | | | | | |
| p_$\chi^2$ | | 0.12 | | | | | |
| CFI | | 0.99 | | | | | |
| TLI | | 0.98 | | | | | |
| RMSEA | | 0.02 | [0.00, 0.03] | | | | |

Note. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$. MVPA = Moderate to vigorous physical activity, SSRT = Stop-Signal Reaction Time, IC = Inhibitory control, WM = Working memory, CF = Cognitive flexibility

## 4. Discussion

The present study tested the role of executive functions as predictors of individual differences in trait self-control and self-control resources, which are likely also associated with health behaviors (physical activity, healthy diet, sedentary activity, and unhealthy diet). Contrary to our hypotheses, we found no evidence supporting the role of executive functions as predictors of individual differences in trait self-control or self-control resources. Similarly, no direct role of these functions regarding healthy and unhealthy behaviors was observed. Nevertheless, in support of our hypotheses, there was an association between individual differences in self-control and health behaviors. Individuals with higher self-control resources practiced more physical activity, and spent less time being sedentary than individuals with lower self-control resources. It also indicated that individuals with higher trait self-control adopted a healthier diet than individuals with lower trait self-control. This main finding provides a confirmation of the role of self-control for adopting sustainable health behaviors.

***Relations Between Executive Functions, Self-Control, and Health Behaviors***

In line with Necka et al. (2018) and Saunders et al. (2018), our study did not find evidence of significant associations between executive functions and self-control. However, our intention was to examine the contribution of each executive function to self-control and health behaviors. Indeed, it was proposed that working memory and inhibitory control might be the most important executive functions for self-control, enabling a better representation of the goal and a better inhibition for fighting a threatening temptation (Hofmann, Schmeichel, et al., 2012). In contrast, individuals with high cognitive flexibility could present lower self-control compared to those with low cognitive flexibility as this flexibility could promote quick and efficient disengagement from a goal-oriented mindset to a mindset oriented toward the pursuit of tempting alternatives (Hofmann, Schmeichel, et al., 2012). However, our study does not confirm these suggestions. One reason could be that the executive tasks used were composed of neutral stimuli (e.g., arrows, letters, number-letter couples), capturing *cold* (purely cognitive) executive functions, instead of *hot* ones (Salehinejad et al., 2021). Apart from the fact that the *hot* and *cold* executive functions involve distinct cortical and subcortical brain structures, *hot* executive function tasks were recently proposed as more appropriate in self-control (Forestier et al., 2022). Accordingly, the absence of affective charge on the current executive tasks may explain the absence of relations between cognitive abilities and self-control. Future studies could investigate the role of affectively charged executive functions (e.g., Mobbs et al., 2008; Pawliczek et al., 2013) in self-control and health behaviors.

Our findings support the absence of direct relations between executive functions, trait self-control and physical activity observed in some previous studies. Pfeffer and Strobach (2017) showed that most composite executive functions scores they calculated were not correlated with trait self-control, except for two cognitive-flexibility scores that were modestly associated with trait self-control (i.e., task-cueing $R^2 = .04$, alternating-runs $R^2 = .03$; Pfeffer & Strobach, 2017). They also revealed that most executive function scores, assessed with self-reported questionnaires as in our study, were not significant direct predictors of intention-behavior gap, except for working memory score. Taken together, the findings of Pfeffer and Strobach (2017) highlighted no direct relations either between executive functions and self-control or between executive functions and a physical activity, which is consistent with the current results. Note that the difference regarding working memory as a predictor of a reduced intention-behavior gap may be explained by the specificity of the physical activity identified: Pfeffer and Strobach (2017) considered only intense physical activity, while we assessed moderate-to-vigorous physical activity, as recommended (Bull et al., 2020; Gebel et al., 2015; WHO, 2019a, 2019b). Interestingly, Pfeffer et Strobach (2017) found that half of the executive-function scores they considered (one inhibitory-control, one working-memory, and one cognitive-flexibility score) moderated the effects of trait self-control on the physical activity intention-behavior gap. Together with our results, this suggests that executive functions are not direct predictors of individual differences in self-control and physical activity but moderate the relation between self-control and this behavior. However, because the other half of the executive-function scores they considered (one inhibitory-control score, one working-memory score, and one cognitive-flexibility score) showed no interaction with self-control to predict physical activity, further investigations are required.

Similarly, the fact that we found no significant direct relations between executive functions and unhealthy diet were consistent with Hofmann et al. (2009). Indeed, when they assessed candy consumption (i.e., unhealthy behavior) and measured automatic affective reactions to candies and three components of inhibitory control (executive attention, behavioral inhibitory control and affect regulation), no direct correlation between candy consumption and different components of inhibitory control was shown, but executive attention, behavioral inhibitory control and affect regulation consistently moderated the relations between automatic affective reactions and candy consumption. All other things being equal, our study and the aforementioned results (Necka et al., 2018, Pfeffer & Strobach, 2017, Hofmann et al., 2009) taken together suggest that executive functions are not direct predictors of self-control or healthy or unhealthy behaviors, but could moderate relations between affective reactions (e.g., automatic affective reactions or conscious experience of temptations) and behaviors, and between self-control and health behaviors. Investigations of executive functions as moderators of the relation between self-control and health behaviors would be of particular interest.

The most serendipitous result is that inhibitory control was significantly and negatively associated with sedentary activity. This suggests that the individuals with the best inhibition were the most sedentary. This result is contrary to studies proposing that inhibition is a key process to regulate behavioral tendencies toward sedentary behaviors (Cheval et al., 2021). However, none of these studies measured the behavior, and a gap could exist between the self-control strategy and the behavior (e.g., inhibition is an effortful self-control strategy and effortful self-control strategies could promote self-control fatigue that favors self-control failure, Forestier et al., 2022). First, our result should be interpreted strictly in terms of individual differences, especially because between-person variation can differ from within-person variation in direction (e.g., the typing-speed paradox: individuals who types the quickest are also those that make only a few typos, but increasing individual typing-speed increases typos, Mehl. et al., 2011). Second, at the between-person level, this relation could be explained regarding the preferential self-control strategies that the individuals adopt. Several strategies can be chosen, including the inhibitory strategy (Fujita, 2011). Parallelly, a meta-analysis showed that the regular use of inhibition increases its performance in the long-term (Jones et al., 2016). With regard to this strategy, it has been shown that individuals using inhibition to resolve motivational conflicts are also the worst self-controllers, due to their ineffectiveness in anticipating the motivational conflict situations with pro-active self-control strategies (Hofmann, et al., 2012). In addition, inhibitory self-control strategy seems to be very poorly related to successful conflict resolution (Forestier et al., 2018). Accordingly, the negative relationship between inhibition and sedentism could be explained by the fact that these individuals often resolve conflicts with the inhibitory strategy, and thus “use and overuse” inhibitory control, leading to its improvement. However, this does not ensure appropriate conflict resolution, such as when a poor self-controller who adopts unhealthy behaviors like sedentary activities or an unhealthy diet.

### *Relations Between Self-Control and Health Behaviors*

All the relations found between self-control and health behaviors are consistent with the literature (de Ridder et al., 2011, 2012; Forestier et al., 2018). Specifically, self-control was associated positively with healthy behaviors and negatively with unhealthy ones. Furthermore, self-control aspects have different effects depending on the behavior examined, with quite a similar effect size previously estimated (Forestier et al., 2018). Once more, self-control resources were related to physical activity behaviors, while trait self-control was not related to these behaviors. However, trait self-control was related to diet behaviors while self-control resources were only related to a healthy diet. As "many roads lead to Rome" (Hennecke & Bürgler, 2020, p. 16), these results reaffirm that different self-control aspects lead to healthy behaviors and to efficient self-control. Further validation studies are required to improve our understanding of the specificity of behavioral self-control aspects and improve the design of investigations to more accurately select the correct self-control strategies associated with the targeted health behavior. This behavioral specificity of self-control dimensions may be explained by the difference in the features of these behaviors. Healthy behaviors, physical activity, and a healthy diet are comparable as they require to be initiated, while sedentary activity and an unhealthy diet are both things that need to be stopped (McEachan et al., 2010). However, physical activity requires more effort to be initiated than a healthy diet (McEachan et al., 2010), and sedentary activities appear to be attractive because they preserve energy expenditure (Cheval & Boisgontier, 2021), while unhealthy food seems attractive because of the immediate pleasure it provides (Appelhans, 2009; Volkow et al., 2011). Because of these differences, an interesting perspective could be to investigate the influence of behavioral features on self-control aspects that could be effective or ineffective in the conflict resolution.

**Strengths, Limitations, and Future Work Perspectives**

Several limitations of the present study need to be addressed. First, our study sample consisted of young and relatively healthy students, with a good level of physical activity. Psychological determinants driving behavior maintenance could differ from those driving behavior change (e.g., habit vs. coping planning). Hence the current results need to be replicated in individuals engaged in health behavior change processes. Second, the cross-section of the current study is insufficient to enable us to understand the role of within-person variations in executive functions and self-control in daily fluctuations of health behaviors. Nevertheless, the within-person variations of inhibitory control seem more predictive of snack consumption (i.e., unhealthy diet) than individual differences in inhibition (Powell et al., 2017). In addition, an important part of the variance of self-control resources is found at the within-person level (i.e., 60%) despite variance at the between-person level (Smolders et al., 2013). Thus, longitudinal study designs with daily repeated measures will be required to properly examine the relationships of within-person executive functions and self-control resource variations with health behavior fluctuations. Third, our study considered executive functions and self-control as predictors of the overall level of health behaviors over a week, without measuring the participant's intention to engage in these behaviors. Despite including only individuals who considered physical activity and healthy diet important for them, it remains possible that they did not support a particular intention to engage in healthy behaviors during the week we considered. For example, some participants may not have practiced physical activity because they did not intend to, rather than because of low self-control. Future studies could assess intention-behavior gap instead of health behaviors' global level over a week. In line with previous studies (Pfeffer et al., 2020; Pfeffer & Strobach, 2017), participants could be asked their intention to engage in a certain quantity of physical activity, to avoid a certain quantity of sedentary activity, to adopt a healthy diet, and to avoid unhealthy food before and after all the measurements. Then the discrepancy between intention endorsed and behaviors actually adopted (i.e., intention-behavior gap) could be assessed to examine the role of executive functions and self-control in reducing this gap. Finally, another limitation is that an incomplete response was an exclusion criterion, which could increase selection bias.

This study, nevertheless, has several strengths. We first examined the relative and distinct role of the three executive functions, namely inhibitory control, working memory, and cognitive flexibility, by using executive tasks according to recent literature (e.g., Verbruggen et al., 2019). We also tested our hypotheses with structural equation modeling, which increases the reliability of scores and relations by (a) explicitly assessing the measurement error; (b) estimating latent variable scores by scoring observed variables rather than other aggregating methods; and (c) testing a model where a structure (e.g., covariances) could be imposed and assessed as to fit of the data (Novikova et al., 2013). The final strength of our study is its large sample size (287 participants), which provides good power to detect small effect size (i.e., power = .90 for $f^2 = .058$, power = .80 for $f^2 = .045$).

## Conclusion

Identifying the psychological determinants driving the reduction of the intention-behavior gap for health behaviors led us to investigate the role of executive functions as a predictor of individual differences in trait self-control and self-control resources. No evidence was found supporting executive functions as direct predictors of the four health behaviors considered. However, the current results support the role of self-control resources as a potential way to promote physical activity and reduce sedentary activity, and trait self-control as a likely determinant to increase adoption of a healthy diet and lower that of an unhealthy diet. In sum, we hypothesize that *cold* executive functions may not explain individual differences in self-control or health behaviors, and that the aspects of self-control (trait or state) that are effective in health behavior adoption depend on the behavioral domain. This study paves the way to longitudinal studies at the within-person level assessing the effects of *hot* “affective-related” executive functions on trait and self-control resources and health behaviors.

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**Supplementary Materials**

**Table S1. Descriptive statistics.**

| | **Self-control resources** | **Trait self-control** | **MVPA** (min/week) | **Sedentary activity** (min/week) | **Healthy diet** | **Unhealthy diet** | **SSRT Integration** (IC, ms) | **Mean correct letters** (WM) | **Reaction time switch cost** (CF, ms) |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 4.25 | 4.43 | 272.48 | 1876.31 | 5.16 | 2.77 | 231.92 | 2.86 | 352.43 |
| Median | 4.40 | 4.38 | 240.00 | 1800.00 | 5.25 | 2.75 | 233.94 | 2.92 | 346.94 |
| SD | 1.23 | 0.88 | 172.02 | 1240.43 | 0.92 | 0.94 | 63.83 | 0.21 | 108.09 |
| Min | 1.00 | 1.46 | 0.00 | 40.00 | 2.00 | 1.00 | 89.19 | 0.67 | 119.11 |
| Max | 7.00 | 6.92 | 705.00 | 5050.00 | 7.00 | 6.00 | 383.41 | 3.00 | 591.57 |
| Cronbach Alpha | 0.89 | 0.80 | - | - | 0.47 | 0.65 | - | - | - |
| McDonalds Omega | 0.92 | 0.83 | - | - | 0.51 | 0.68 | - | - | - |
| Skeweness | -0.29 | 0.01 | 0.56 | 0.45 | -0.44 | 0.45 | 0.08 | -3.89 | 0.04 |
| Kurtosis | 2.87 | 2.82 | 2.50 | 2.27 | 2.70 | 3.19 | 2.48 | 30.66 | 2.35 |

Note. MVPA = Moderate to Vigorous Physical Activity, SSRT = Stop-Signal Reaction Time, IC = Inhibitory Control, WM = Working Memory, CF = Cognitive Flexibility, min = minutes, ms = milliseconds

**Table S2. Correlations with confidence intervals.**

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. Self-control resources | | | | | | | | |
| 2. Trait self-control | **.20**** **[.09, .30]** | | | | | | | |
| 3. MVPA | **.17**** **[.06, .28]** | -.06 [-.17, .05] | | | | | | |
| 4. Sedentary activity | -.10 [-.21, .01] | .05 [-.07, .16] | -.00 [-.12, .11] | | | | | |
| 5. Healthy diet | .11 [-.01, .22] | **.19**** **[.08, .30]** | **.21**** **[.10, .32]** | .02 [-.09, .14] | | | | |
| 6. Unhealthy diet | **-.12*** **[-.23, -.01]** | **-.23**** **[-.33, -.12]** | **.13*** **[.02, .24]** | -.02 [-.13, .10] | .01 [-.11, .12] | | | |
| 7. SSRT Integration (IC) | -.02 [-.13, .10] | -.08 [-.19, .03] | .02 [-.09, .14] | **-.13*** **[-.24, -.02]** | -.11 [-.22, .00] | .00 [-.11, .12] | | |
| 8. Mean correct letters (WM) | .08 [-.03, .19] | .07 [-.04, .18] | .03 [-.09, .14] | -.01 [-.13, .10] | **.12*** **[.01, .23]** | -.04 [-.15, .07] | -.02 [-.13, .10] | |
| 9. Reaction time switch cost (CF) | -.10 [-.21, .01] | -.00 [-.11, .11] | -.08 [-.19, .03] | .02 [-.09, .14] | .03 [-.08, .14] | -.06 [-.17, .05] | -.08 [-.19, .04] | .03 [-.09, .14] |

*Note.* Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$, ** indicates $p < .01$. IC = Inhibitory Control, WM = Working Memory, CF = Cognitive Flexibility

***Physical Activity and Sedentary Activity Measurement Model***

The first physical activity and sedentary activity CFA included two latent variables (trait self-control and self-control resources). The latent variable “trait self-control” was specified with the 13 items of the brief self-control scale; the latent variable “self-control resources” was specified with the five items of the subjective vitality scale. Results showed satisfactory loadings to the latent variables, except for three items from the Brief Self-Control Scale (i.e., items 1, 6 and 11), with loadings below .40 being removed (Hair et al., 2013). According to modification indices, theoretically meaningful covariances between variables were added to improve the model fit (Whittaker, 2012). Precisely, we only included covariances between items from the same scale and stopped when an additional covariance did not improve model fit to keep the most parsimonious model. Measurement model with covariances showed good model-fit indices ($\chi^2$ (105) = 84.731, RMSEA = 0.03, 90% CI [0.00, 0.05], CFI = 0.99, TLI = 0.99).

***Healthy And Unhealthy Diet Measurement Model***

The first healthy and unhealthy diet CFA included four latent variables (trait self-control, self-control resources, healthy diet score, and unhealthy diet score). The latent variable representing trait self-control and self-control resources was specified with the same items as for the previous CFA (i.e., 10 items for trait self-control, 5 items for self-control resources). The latent variable representing healthy and unhealthy diet was respectively specified with the four items of the Healthy Eating Behavior Scale (HEBS) representing healthy food consumption, and the four items representing unhealthy food consumption. Results showed satisfactory loadings to the latent variables, except for one item from the HEBS, healthy diet dimension (item 4), and two items from the HEBS, unhealthy diet dimension (items 3 and 4), with loadings below .40 being removed (Hair et al., 2013). Compared with the physical activity and sedentary activity CFA, modification indices did not suggest new additional important covariances to consider. The measurement model with covariances showed good model-fit indices ($\chi^2$ (143) = 162.44, RMSEA = 0.02, 90% CI [0.00, 0.04], CFI = 0.99, TLI = 0.99).

**Table S3. Physical Activity and Sedentary Activity Full Structural Equation Model.**

| Independent variable | Dependent variable | Estimate | Estimate 95%CI [LL, UL] | Std. Err. | z | p | $R^2$ |
|---|---|---|---|---|---|---|---|
| *Factor Loadings* | | | | | | | |
| SV.1 | Self-control resources | 1.00+ | [1.00, 1.00] | | | | |
| SV.2 | | 1.06*** | [0.98, 1.13] | 0.04 | 26.93 | .000 | |
| SV.3 | | 0.48*** | [0.35, 0.61] | 0.07 | 7.15 | .000 | |
| SV.4 | | 1.03*** | [0.92, 1.13] | 0.05 | 19.26 | .000 | |
| SV.5 | | 1.06*** | [0.95, 1.16] | 0.05 | 20.07 | .000 | |
| BSCS.2 | Trait self-control | 1.00+ | [1.00, 1.00] | | | | |
| BSCS.3 | | 1.42*** | [0.90, 1.95] | 0.27 | 5.31 | .000 | |
| BSCS.4 | | 0.82*** | [0.44, 1.91] | 0.19 | 4.28 | .000 | |
| BSCS.5 | | 0.89*** | [0.47, 1.31] | 0.21 | 4.14 | .000 | |
| BSCS.7 | | 1.30*** | [0.80, 1.81] | 0.26 | 5.03 | .000 | |
| BSCS.8 | | 1.47*** | [0.92, 2.01] | 0.28 | 5.29 | .000 | |
| BSCS.9 | | 0.93*** | [0.48, 1.37] | 0.23 | 4.08 | .000 | |
| BSCS.10 | | 1.37*** | [0.85, 1.89] | 0.27 | 5.14 | .000 | |
| BSCS.12 | | 0.84*** | [0.46, 1.21] | 0.19 | 4.36 | .000 | |
| BSCS.13 | | 0.90*** | [0.51, 1.29] | 0.20 | 4.55 | .000 | |
| *Regression Slopes* | | | | | | | |
| SSRT integration (IC) | Self-control resources | -0.04 | [-0.14, 0.07] | 0.05 | -0.70 | .484 | .02 |
| Mean correct letters (WM) | | 0.08 | [-0.02, 0.19] | 0.05 | 1.62 | .106 | |
| RT switch cost (CF) | | -0.09 | [-0.19, 0.02] | 0.05 | -1.64 | .100 | |
| SSRT integration (IC) | Trait self-control | -0.02 | [-0.08, 0.04] | 0.03 | -0.67 | .500 | .01 |
| Mean correct letters (WM) | | 0.03 | [-0.03, 0.09] | 0.03 | 0.91 | .365 | |
| RT switch cost (CF) | | 0.00 | [-0.06, 0.06] | 0.03 | 0.00 | .998 | |
| SSRT integration (IC) | MVPA | 0.02 | [-0.09, 0.14] | 0.06 | 0.40 | .687 | .04 |
| Mean correct letters (WM) | | 0.06 | [-0.05, 0.17] | 0.06 | 1.01 | .311 | |
| RT switch cost (CF) | | -0.04 | [-0.16, 0.07] | 0.06 | -0.74 | .459 | |
| Self-control resources | | 0.20** | [0.06, 0.35] | 0.07 | 2.77 | .006 | |
| Trait self-control | | -0.11 | | 0.16 | -0.69 | .491 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SSRT integration (IC) | | -0.17** | [-0.28, -0.05] | 0.06 | -2.89 | .004 | |
| Mean correct letters (WM) | | -0.02 | [-0.14, 0.09] | 0.06 | -0.42 | .676 | |
| RT switch cost (CF) | Sedentary activity | -0.01 | [-0.12, 0.11] | 0.06 | -0.15 | .881 | .04 |
| Self-control resources | | -0.15* | [-0.29, 0.00] | 0.07 | -2.00 | .046 | |
| Trait self-control | | 0.08 | [-0.24, 0.40] | 0.16 | 0.51 | .611 | |
| | | *Residual Variances* | | | | | |
| SV.1 | | 0.27*** | | 0.03 | 8.70 | .000 | |
| SV.2 | | 0.18*** | | 0.02 | 7.32 | .000 | |
| SV.3 | | 0.83*** | | 0.07 | 11.75 | .000 | |
| SV.4 | | 0.22*** | | 0.03 | 8.63 | .000 | |
| SV.5 | | 0.18*** | | 0.02 | 7.42 | .000 | |
| BSCS.2 | | 0.81*** | | 0.08 | 10.49 | .000 | |
| BSCS.3 | | 0.62*** | | 0.07 | 9.20 | .000 | |
| BSCS.4 | | 0.87*** | | 0.08 | 11.24 | .000 | |
| BSCS.5 | | 0.85*** | | 0.08 | 10.97 | .000 | |
| BSCS.7 | | 0.69*** | | 0.07 | 9.52 | .000 | |
| BSCS.8 | | 0.59*** | | 0.07 | 8.53 | .000 | |
| BSCS.9 | | 0.84*** | | 0.08 | 10.37 | .000 | |
| BSCS.10 | | 0.65*** | | 0.07 | 9.18 | .000 | |
| BSCS.12 | | 0.86*** | | 0.08 | 11.16 | .000 | |
| BSCS.13 | | 0.85*** | | 0.08 | 11.07 | .000 | |
| MVPA | | 0.96*** | | 0.08 | 11.90 | .000 | |
| Sedentary activity | | 0.96*** | | 0.08 | 11.92 | .000 | |
| SSRT integration (IC) | | 0.99*** | | 0.08 | 11.94 | .000 | |
| Mean correct letters (WM) | | 1.00*** | | 0.08 | 11.94 | .000 | |
| RT switch cost (CF) | | 0.99*** | | 0.08 | 11.94 | .000 | |
| | | *Residual Covariances* | | | | | |
| SV.1 | SV.2 | 0.09*** | [0.05, 0.14] | 0.02 | 3.96 | .000 | |
| BSCS.4 | BSCS.5 | 0.23*** | [0.12, 0.34] | 0.06 | 4.14 | .000 | |
| BSCS.5 | BSCS.12 | 0.24*** | [0.13, 0.34] | 0.05 | 4.41 | .000 | |
| BSCS.12 | BSCS.13 | 0.21*** | [0.10, 0.32] | 0.06 | 3.71 | .000 | |
| BSCS.9 | BSCS.10 | 0.24*** | [0.13, 0.35] | 0.06 | 4.27 | .000 | |
| BSCS.4 | BSCS.13 | 0.17** | [0.06, 0.27] | 0.06 | 2.99 | .003 | |
| BSCS.2 | BSCS.12 | 0.13* | [0.03, 0.24] | 0.05 | 2.54 | .011 | |
| BSCS.5 | BSCS.8 | 0.07 | [-0.02, 0.17] | 0.05 | 1.51 | .131 | |
| BSCS.10 | BSCS.12 | 0.10* | [0.01, 0.19] | 0.05 | 2.18 | .029 | |
| BSCS.9 | BSCS.13 | 0.13** | [0.04, 0.23] | 0.05 | 2.76 | .006 | |
| BSCS.3 | BSCS.9 | 0.13** | [0.03, 0.23] | 0.05 | 2.60 | .009 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| BSCS.7 | BSCS.9 | 0.14** | [0.04, 0.25] | 0.05 | 2.61 | .009 |
| BSCS.7 | BSCS.10 | 0.09 | [-0.02, 0.19] | 0.05 | 1.67 | .095 |
| BSCS.2 | BSCS.8 | -0.07 | [-0.17, 0.02] | 0.05 | -1.51 | .131 |
| BSCS.9 | BSCS.12 | 0.08 | [-0.01, 0.18] | 0.05 | 1.68 | .092 |
| BSCS.5 | BSCS.13 | 0.07 | [-0.03, 0.18] | 0.05 | 1.35 | .176 |
| BSCS.4 | BSCS.12 | 0.08 | [-0.02, 0.19] | 0.05 | 1.56 | .119 |
| BSCS.2 | BSCS.4 | 0.09 | [-0.02, 0.19] | 0.05 | 1.67 | .096 |
| BSCS.2 | BSCS.13 | 0.08 | [-0.03, 0.19] | 0.06 | 1.49 | .137 |
| BSCS.2 | BSCS.9 | 0.06 | [-0.04, 0.16] | 0.05 | 1.24 | .215 |
| SV.1 | SV.3 | 0.03 | [-0.02, 0.08] | 0.03 | 1.06 | .287 |
| SSRT integration (IC) | RT switch cost (CF) | -0.08 | [-0.20, 0.03] | 0.06 | -1.43 | .152 |
| SSRT integration (IC) | Mean correct letters (WM) | -0.01 | [-0.13, 0.10] | 0.06 | -0.21 | .830 |
| Mean correct letters (WM) | RT switch cost (CF) | 0.00 | [-0.11, 0.12] | 0.06 | 0.02 | .984 |
| MVPA | Sedentary activity | 0.02 | [-0.09, 0.13] | 0.06 | 0.41 | .685 |
| *Latent Variances* | | | | | | |
| Self-control resources | | 0.72*** | | 0.08 | 8.80 | .000 |
| Trait self-control | | 0.19** | | 0.06 | 3.05 | .002 |
| *Latent Covariances* | | | | | | |
| Self-control resources | Trait self-control | 0.07* | [0.02, 0.13] | 0.03 | 2.54 | .011 |
| *Fit Indices* | | | | | | |
| $\chi^2$ | | 152.17 | | | | |
| $\chi^2$_df | | 133.00 | | | | |
| p_$\chi^2$ | | 0.12 | | | | |
| p_Baseline | | 0.00 | | | | |
| GFI | | 0.95 | | | | |
| AGFI | | 0.92 | | | | |
| NFI | | 0.92 | | | | |
| NNFI | | 0.98 | | | | |
| CFI | | 0.99 | | | | |
| TLI | | 0.98 | | | | |
| RMSEA | | 0.02 | [0.00, 0.04] | | | |
| p_RMSEA | | 1.00 | | | | |
| Loglikelihood | | 7211.93 | | | | |
| AIC | | 14577.86 | | | | |
| BIC | | 14859.10 | | | | |
| BIC (adj.) | | 14614.93 | | | | |

Note. +Fixed parameter $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$. MVPA = Moderate to Vigorous Physical Activity, SSRT = Stop-Signal Reaction Time, IC = Inhibitory Control, WM = Working Memory, CF = Cognitive Flexibility.

**Table S4. Healthy and Unhealthy Diet Full Structural Equation Model.**

| Independent variable | Dependent variable | Estimate | Estimate 95%CI [LL, UL] | Std. Err. | z | p | $R^2$ |
|---|---|---|---|---|---|---|---|
| *Factor Loadings* | | | | | | | |
| SV.1 | Self-control resources | 1.00+ | [1.00, 1.00] | | | | |
| SV.2 | | 1.06*** | [0.98, 1.13] | 0.04 | 26.93 | .000 | |
| SV.3 | | 0.48*** | [0.35, 0.61] | 0.07 | 7.15 | .000 | |
| SV.4 | | 1.03*** | [0.92, 1.13] | 0.05 | 19.26 | .000 | |
| SV.5 | | 1.06*** | [0.95, 1.16] | 0.05 | 20.07 | .000 | |
| BSCS.2 | Trait self-control | 1.00+ | [1.00, 1.00] | | | | |
| BSCS.3 | | 1.42*** | [0.90, 1.95] | 0.27 | 5.31 | .000 | |
| BSCS.4 | | 0.82*** | [0.44, 1.91] | 0.19 | 4.28 | .000 | |
| BSCS.5 | | 0.89*** | [0.47, 1.31] | 0.21 | 4.14 | .000 | |
| BSCS.7 | | 1.30*** | [0.80, 1.81] | 0.26 | 5.03 | .000 | |
| BSCS.8 | | 1.47*** | [0.92, 2.01] | 0.28 | 5.29 | .000 | |
| BSCS.9 | | 0.93*** | [0.48, 1.37] | 0.23 | 4.08 | .000 | |
| BSCS.10 | | 1.37*** | [0.85, 1.89] | 0.27 | 5.14 | .000 | |
| BSCS.12 | | 0.84*** | [0.46, 1.21] | 0.19 | 4.36 | .000 | |
| BSCS.13 | | 0.90*** | [0.51, 1.29] | 0.20 | 4.55 | .000 | |
| *Regression Slopes* | | | | | | | |
| SSRT integration (IC) | Self-control resources | -0.04 | [-0.14, 0.07] | 0.05 | -0.70 | .484 | .02 |
| Mean correct letters (WM) | | 0.08 | [-0.02, 0.19] | 0.05 | 1.62 | .106 | |
| RT switch cost (CF) | | -0.09 | [-0.19, 0.02] | 0.05 | -1.64 | .100 | |
| SSRT integration (IC) | Trait self-control | -0.02 | [-0.08, 0.04] | 0.03 | -0.67 | .500 | .01 |
| Mean correct letters (WM) | | 0.03 | [-0.03, 0.09] | 0.03 | 0.91 | .365 | |
| RT switch cost (CF) | | 0.00 | [-0.06, 0.06] | 0.03 | 0.00 | .998 | |
| SSRT integration (IC) | Healthy diet | -0.09 | [-0.18, 0.01] | 0.05 | -1.80 | .072 | .11 |
| Mean correct letters (WM) | | 0.07 | [-0.02, 0.16] | 0.05 | 1.53 | .125 | |
| RT switch cost (CF) | | 0.02 | [-0.07, 0.12] | 0.05 | 0.53 | .596 | |
| Self-control resources | | 0.06 | [-0.05, 0.17] | 0.06 | 1.04 | .298 | |
| Trait self-control | | 0.35* | [0.08, 0.62] | 0.14 | 2.57 | .010 | |
| SSRT integration (IC) | Unhealthy diet | 0.00 | [-0.04, 0.05] | 0.02 | 0.19 | .852 | |
| Mean correct letters (WM) | | -0.05 | [-0.12, 0.01] | 0.03 | -1.66 | .097 | |
| RT switch cost (CF) | | 0.04 | [-0.01, 0.10] | 0.03 | 1.50 | .135 | |
| Self-control resources | | 0.05 | [-0.02, 0.12] | 0.04 | 1.44 | .151 | |
| Trait self-control | | -0.26* | [-0.53, 0.00] | 0.13 | -1.96 | .050 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Residual Variances* | | | | | | |
| SV.1 | | 0.27*** | | 0.03 | 8.70 | .000 |
| SV.2 | | 0.18*** | | 0.02 | 7.32 | .000 |
| SV.3 | | 0.83*** | | 0.07 | 11.75 | .000 |
| SV.4 | | 0.22*** | | 0.03 | 8.63 | .000 |
| SV.5 | | 0.18*** | | 0.02 | 7.42 | .000 |
| BSCS.2 | | 0.81*** | | 0.08 | 10.49 | .000 |
| BSCS.3 | | 0.62*** | | 0.07 | 9.20 | .000 |
| BSCS.4 | | 0.87*** | | 0.08 | 11.24 | .000 |
| BSCS.5 | | 0.85*** | | 0.08 | 10.97 | .000 |
| BSCS.7 | | 0.69*** | | 0.07 | 9.52 | .000 |
| BSCS.8 | | 0.59*** | | 0.07 | 8.53 | .000 |
| BSCS.9 | | 0.84*** | | 0.08 | 10.37 | .000 |
| BSCS.10 | | 0.65*** | | 0.07 | 9.18 | .000 |
| BSCS.12 | | 0.86*** | | 0.08 | 11.16 | .000 |
| BSCS.13 | | 0.85*** | | 0.08 | 11.07 | .000 |
| HBES.1 | | 0.54*** | | 0.07 | 7.18 | .000 |
| HBES.2 | | 0.70*** | | 0.07 | 9.84 | .000 |
| HBES.5 | | 0.46*** | | 0.08 | 5.74 | .000 |
| HBES.6 | | 0.89*** | | 0.09 | 10.06 | .000 |
| HBES.8 | | 0.31 | | 0.31 | 1.01 | .314 |
| SSRT integration (IC) | | 0.99*** | | 0.08 | 11.94 | .000 |
| Mean correct letters (WM) | | 1.00*** | | 0.08 | 11.94 | .000 |
| RT switch cost (CF) | | 0.99*** | | 0.08 | 11.94 | .000 |
| *Residual Covariances* | | | | | | |
| SV.1 | SV.2 | 0.09*** | [0.05, 0.14] | 0.02 | 3.96 | .000 |
| BSCS.4 | BSCS.5 | 0.23*** | [0.12, 0.34] | 0.06 | 4.14 | .000 |
| BSCS.5 | BSCS.12 | 0.24*** | [0.13, 0.34] | 0.05 | 4.41 | .000 |
| BSCS.12 | BSCS.13 | 0.21*** | [0.10, 0.32] | 0.06 | 3.71 | .000 |
| BSCS.9 | BSCS.10 | 0.24*** | [0.13, 0.35] | 0.06 | 4.27 | .000 |
| BSCS.4 | BSCS.13 | 0.17** | [0.06, 0.27] | 0.06 | 2.99 | .003 |
| BSCS.2 | BSCS.12 | 0.13* | [0.03, 0.24] | 0.05 | 2.54 | .011 |
| BSCS.5 | BSCS.8 | 0.07 | [-0.02, 0.17] | 0.05 | 1.51 | .131 |
| BSCS.10 | BSCS.12 | 0.10* | [0.01, 0.19] | 0.05 | 2.18 | .029 |
| BSCS.9 | BSCS.13 | 0.13** | [0.04, 0.23] | 0.05 | 2.76 | .006 |
| BSCS.3 | BSCS.9 | 0.13** | [0.03, 0.23] | 0.05 | 2.60 | .009 |
| BSCS.7 | BSCS.9 | 0.14** | [0.04, 0.25] | 0.05 | 2.61 | .009 |
| BSCS.7 | BSCS.10 | 0.09 | [-0.02, 0.19] | 0.05 | 1.67 | .095 |

| | | | | | | |
|---|---|---|---|---|---|---|
| BSCS.2 | BSCS.8 | -0.07 | [-0.17, 0.02] | 0.05 | -1.51 | .131 |
| BSCS.9 | BSCS.12 | 0.08 | [-0.01, 0.18] | 0.05 | 1.68 | .092 |
| BSCS.5 | BSCS.13 | 0.07 | [-0.03, 0.18] | 0.05 | 1.35 | .176 |
| BSCS.4 | BSCS.12 | 0.08 | [-0.02, 0.19] | 0.05 | 1.56 | .119 |
| BSCS.2 | BSCS.4 | 0.09 | [-0.02, 0.19] | 0.05 | 1.67 | .096 |
| BSCS.2 | BSCS.13 | 0.08 | [-0.03, 0.19] | 0.06 | 1.49 | .137 |
| BSCS.2 | BSCS.9 | 0.06 | [-0.04, 0.16] | 0.05 | 1.24 | .215 |
| SV.1 | SV.3 | 0.03 | [-0.02, 0.08] | 0.03 | 1.06 | .287 |
| SSRT integration (IC) | RT switch cost (CF) | -0.08 | [-0.20, 0.03] | 0.06 | -1.43 | .152 |
| SSRT integration (IC) | Mean correct letters (WM) | -0.01 | [-0.13, 0.10] | 0.06 | -0.21 | .830 |
| Mean correct letters (WM) | RT switch cost (CF) | 0.00 | [-0.11, 0.12] | 0.06 | 0.02 | .984 |
| | | *Latent Variances* | | | | |
| Self-control resources | | 0.72*** | | 0.08 | 8.80 | .000 |
| Trait self-control | | 0.19** | | 0.06 | 3.05 | .002 |
| | | *Latent Covariances* | | | | |
| Self-control resources | Trait self-control | 0.07* | [0.02, 0.13] | 0.03 | 2.54 | .011 |
| Healthy diet | Unhealthy diet | -0.01 | [-0.05, 0.02] | 0.02 | -0.78 | .436 |
| | | *Fit Indices* | | | | |
| $\chi^2$ | | 214.39 | | | | |
| $\chi^2$_df | | 191.00 | | | | |
| p_$\chi^2$ | | 0.12 | | | | |
| p_Baseline | | 0.00 | | | | |
| GFI | | 0.93 | | | | |
| AGFI | | 0.90 | | | | |
| NFI | | 0.90 | | | | |
| NNFI | | 0.98 | | | | |
| CFI | | 0.99 | | | | |
| TLI | | 0.98 | | | | |
| RMSEA | | 0.02 | [0.00, 0.03] | | | |
| p_RMSEA | | 1.00 | | | | |
| Loglikelihood | | 7116.89 | | | | |
| AIC | | 14391.77 | | | | |
| BIC | | 14680.32 | | | | |
| BIC (adj.) | | 14429.81 | | | | |

Note. +Fixed parameter *p<0.05, **p<0.01, ***p<0.001. MVPA = Moderate to Vigorous Physical Activity, SSRT = Stop-Signal Reaction Time, IC = Inhibitory Control, WM = Working Memory, CF = Cognitive Flexibility.