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CYCLE XXXIV

SELF-REGULATION OF PHYSICAL ACTIVITY BEHAVIOR

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School director: Prof. Giovanni Galfano

Supervisor: Prof. Marta Ghisi

Doctoral student: Ceren Gürdere

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OVERVIEW OF THE STUDIES

In the present thesis, it was aimed to investigate self-regulation of physical activity (PA) behavior with regard to reflective and automatic processes involved. The roles of trait self-control, PA intention, PA behavior automaticity, affective reactions during PA, and executive functions were investigated.

In order to assess trait self-control in the subsequent study, in the first study, it was aimed to validate Italian version of the Brief Self-Control Scale (BSCS; Tangney, Baumeister, & Boone, 2004) which is a widely used measure of trait self-control. Two hundred and sixty-two Italian university students completed BSCS along with measures of grit, impulsive behavior, self-esteem, resilience, and psychological distress. One hundred and forty-three of the first sample completed BSCS after three weeks again. Results indicated that the Italian version of the BSCS is one-dimensional as the original BSCS. Good internal consistency and test-retest stability were documented. Validity of the construct was established with the association between BSCS and measures of grit and impulsive behavior. Furthermore, results showed that BSCS was positively correlated with self-esteem and resilience, and negatively with psychological distress. In conclusion, findings indicated that the Italian BSCS is a reliable and valid instrument assessing trait self-control in Italian speaking populations.

In the second study, trait self-control, PA intention, affective reaction during PA, and automaticity were examined in relation to PA behavior, following a recent dual-process model of PA behavior (Physical Activity Adoption and Maintenance Model, Strobach et al., 2020). It was expected that trait self-control would moderate intention – PA behavior relationship, and automaticity would mediate the relationship between affective reaction and PA behavior. Fifty-three healthy adults participated to the study via online questionnaire including measures of PA behavior, intention, automaticity, affective reaction, and trait self-control. Results were in line with the model-driven expectations, and the study provided preliminary evidence for the model. Implications were discussed in relation to PA promotion programs.

In the third study, a systematic review and meta-analysis was conducted to investigate the predictive role of executive functions on PA behavior. Systematic searches were carried out and prospective studies which reported the relationship between baseline executive functions and later PA behavior were selected. Results of the random effects meta-analysis revealed a significant total effect size for executive functions on PA behavior. Effect size remained significant when accounted for publication bias. High heterogeneity was observed across studies. Due to the different measures used, executive function components could not be differentially tested. Despite limitations, the study provided evidence for executive functions' predictor role on PA behavior. More research is encouraged to inform PA promotion programs that are well-prepared for individual differences in executive functions.

GENERAL INTRODUCTION

Physical Activity, Physical Health, and Psychological Well-Being

PA behavior has long been investigated in relation to both physical and mental health, as well as psychological well-being and distress. Lack of PA and sedentary lifestyle constitute a high risk for poor health, whereas regular engagement in PA is associated with better physical and mental health. Studies showed that PA highly benefits cardiorespiratory fitness, which is a strong protector against cardiovascular diseases and all-cause mortality (Ellison et al., 2012; Wilson, Allison, & Cable, 2016). With regular PA, muscle and skeletal health improve (Gunter, Almstedt, & Janz, 2012) and risks of developing obesity, diabetes, hypertension, and some cancer types reduce (Lewis & Hennekens, 2016).

There is also compelling evidence supporting mental health and psychological well-being benefits of regular PA. These benefits include stress relieving, mood enhancing, self-esteem boosting, antidepressive, and anxiolytic effects (Scully et al., 1998). PA also prevents and limits normal physiological and pathological cognitive impairment (Rockwood & Middleton, 2007). It was suggested that PA behavior facilitates alterations in neurobiological systems relevant to mental health (Crewther et al., 2011). In general (e.g. community samples, school children, university students), high risk (e.g. prison inmates), and clinical populations (patients with major depression and anxiety disorders) consistent findings have been reported as the following, reductions in perceived stress, negative affect, depression and anxiety symptoms as well as improvements in mood, self-esteem, life satisfaction and optimism (Battaglia et al., 2015; Hassmèn, Koivula, & Uutela, 2000; Kim et al., 2017; Mikkelsen et al., 2017; Pavey, Burton, & Brown, 2015; Penedo & Dahn, 2005). Importantly, de Vries and colleagues (2017) showed that well-being benefits of regular exercising became visible after two to four weeks. Regular exercising at least two to three times a week was documented to be associated with less depression, anger, stress, and higher levels of sense of coherence than less

frequent or none exercising (Hassmen, Koivula, & Uutela, 2000). Consistent findings in the literature indicate that PA behavior is associated with increased psychological well-being.

Processes Involved in Self-Regulation of Physical Activity Behavior

Well-documented and far-reaching physical and mental health benefits of PA emphasize the importance of PA behavior, and the factors that are associated with adherence to PA. Even though individuals are well aware of the benefits of regular PA, and they intend to be physically active, most of the time they fail to engage in PA regularly, and maintain their activity (Hamilton et al., 2008). It is of great importance to tackle self-regulation of PA behavior in order to better understand the processes involved, to bridge the intention-behavior gap, and to inform PA promotion programs.

Earlier understanding of self-regulation of health behaviors was mostly influenced by social cognition approach (Hagger, 2016). Following the assumption of theory of planned behavior that behavior is predicted by intentions solely (Ajzen, 1991), this approach assumed that individuals engage in health behaviors through rational decision-making with the use of systematic and deliberate evaluations (Conner & Norman, 2005). However, it has been criticised and shown that this linear rational reasoning does not fully explain health behaviors (Gibbons, Houlihan, & Gerrard, 2009; Sheeran et al., 2013).

Dual-process theories on the other hand, postulated that self-regulation of health behaviors involves two types of information processing systems (Hoffmann, Friese, & Strack, 2009; Hoffmann, Friese, & Wiers, 2008; Strack & Deutsch, 2004). Reflective and automatic processes operate in parallel and interact with each other in self-regulation of behavior. Reflective processes (i.e., explicit) determine behavior through reflective decision-making, requiring working memory resources whereas automatic processes (i.e., implicit) capture automatic and effortless elicitation of behaviors without requiring much working memory resources.

In the context of PA behavior, there has been three prominent variables of reflective processes considered to be involved in self-regulation of PA behavior: Intentions, trait self-control, and executive functions. Intention refers to the decision to perform PA and to the degree of commitment to enact that decision (Rhodes & Rebar, 2017). Intention to engage in PA was documented to be positively associated with PA modestly (McEachan et al., 2011) and translation of intentions into behavior was suggested to demand self-regulatory forces' involvement (Chatzisarantis et al., 2019; Rhodes & de Bruijn, 2013; Sheeran & Webb, 2016). Trait self-control, referring to individuals' tendency and ability to exert control over behavior in favor of long-term goals versus instant gratifications, was considered crucial in that respect (Englert, 2016; Englert, Graham, & Bray, 2020; Englert & Rummel, 2016). Besides that, emerging evidence pointed out the important role of executive functions which refer to the goal-directed higher-level cognitive processing (Diamond, 2013), in intention-behavior gap and effective self-regulation of PA behavior (Best, Nagamatsu, & Liu-Ambrose, 2014; Hall et al., 2008; Pfeffer & Strobach, 2017). It was corroborated that; trait self-control and executive functions enable the actualization PA intentions (Strobach et al., 2020).

Research on automatic processes involved in PA behavior regulation capitalized on behavioral automaticity and affective states. It was suggested that self-control facilitates the formation of adaptive habits, and through increased automaticity, PA behavior is initiated with less effort gradually (Pfeffer & Strobach, 2018). Interlinked with automaticity, affective experience during PA was suggested to be another important automatic process involved (Ekkekakis, 2017; Haggar, 2020). Studies showed that perceived affective experiences during PA predicted later PA behavior significantly, where the more positive the affective experiences, the more frequent was the PA behavior in the future (Schneider, Dunn, & Cooper, 2009; Williams et al., 2008). Likewise, it was reported that negative affect during PA was associated with PA avoidance (Rhodes & Kates, 2015). Brand and Ekkekakis (2018) argued that momentary and anticipated affect along with more reflective processes, individuals maintain physically inactive. The Affective-Reflective Theory of Exercise and

Physical Inactivity (Brand & Ekkekakis, 2018) further postulated that repeated affective experiences in the context of exercise or PA generate an automatic affective valuation, which corresponds with impulses to approach or avoid. To illustrate, past unpleasant affective experiences from exercise may have led to the formation of a negative automatic affective valuation for the concept of exercise. Thus, ideation of exercise may trigger a negative visceral reaction and the urge to remain inactive. However, it is also suggested that if self-control resources are available, it is possible to override this by reflective processes, enabling the initiation to exercise.

Main Objectives

Despite growing body of research reporting reflective and automatic process variables that are responsible for self-regulation of PA behavior, more research is required in order to pinpoint the underlying mechanisms, and to document the complex relationship among these factors in the prediction of PA behavior. In the present thesis, trait self-control, PA intention, automaticity, affective reactions, and executive functions in association with PA behavior were investigated within a dual-process framework. It was aimed to contribute to the current literature providing evidence for and highlighting factors associated with effective self-regulation of PA behavior.

CHAPTER 1

Study 1. The Italian Validation of the Brief Self-Control Scale: Psychometric Properties and Correlates

1.1. Introduction

Trait self-control refers to one's capacity to override dominant responses in accordance with personal long-term goals (Baumeister & Heatherton, 1996). Exertion of self-control captures both action and inaction; engaging in goal-consistent behaviors, and also abstaining from goal-inconsistent behaviors and avoiding temptations (Hoyle & Davidson, 2016).

Individual differences in self-control capacity and its relation to important life outcomes have attracted much attention in the literature. High trait self-control has been associated with better academic performance (Duckworth & Seligman, 2005; King & Gaerlan, 2014), better psychological adjustment, higher levels of well-being, life satisfaction, and self-esteem (Bowlin & Baer, 2012; Hoffmann et al., 2014; Tangney et al. 2004) and less impulse control problems (Bergen et al. 2012; Verstuyf et al., 2013). In longitudinal studies (Fergusson et al., 2013; Moffitt et al., 2011), it was reported that while controlling for gender, family socioeconomic status, and intelligence, high self-control in childhood was associated with higher educational degree, occupational prestige, income, and savings behaviour. Moreover, it predicted physical and mental health, lack of substance dependence and criminal convictions. On the contrary, low self-control in childhood was associated with starting smoking, school dropouts, unplanned pregnancies in teenage years, as well as poor mental and physical health, worse personal finances, and criminal convictions in adulthood. Overall, it is well-documented that trait self-control and major life outcomes across a variety of domains such as school, work, interpersonal functioning, well-being, and adjustment are associated where the higher the trait self-control, the better the life outcomes tend to be (Ridder et al., 2012).

1.1.1. Measurement of trait self-control

In the literature, the most widely used measure of trait self-control has been the Brief Self-Control Scale (BSCS; Tangney et al., 2004). The measure was tailored according to the strength model of self-control (Baumeister et al., 1994) capturing thought, emotion, impulse, and performance control. Self-Control Scale (SCS) is a 36-item scale, and the short form of it, the Brief Self-Control Scale (BSCS) consists of 13 of these items. It is a one-dimensional self-report questionnaire, where items are rated on a 5-point scale, from 1 *not at all like me* to 5 *very much like me*. Some items are reverse coded. One total score is computed for BSCS by summing items responses; higher scores indicate higher levels of trait self-control. The range of BSCS score is from 13 to 65. The psychometric properties of both SCS and BSCS were found satisfactory (Tangney et al., 2004). It was reported that BSCS have adequate internal reliability, alpha values reported were .83 and .85. Test-retest reliability with three-week interval was .87. Concordant with expectations, higher BSCS scores were associated with higher grade point average, less problems of binge eating and alcohol abuse, higher psychological adjustment, self-acceptance and self-esteem, better interpersonal relationships, more guilt feelings, and less shame feelings which were regarded as more beneficial emotional patterns.

BSCS has been adapted to German (Bertrams & Dickhäuser, 2009), Turkish (Nebioglu et al., 2012), French (Brevers et al., 2017), Russian (Gordeeva et al., 2017), and SCS to Chinese (Unger et al., 2016) and Polish (Pilarska & Baumeister, 2018) so far. In the German adaptation (Bertrams & Dickhäuser, 2009) it was reported that BSCS proved to be one-dimensional, reliable, and valid. In the Turkish adaptation (Nebioglu et al., 2012), BSCS was again reported to be reliable, and validity was supported in relation to measures of impulsiveness, negative body responses, anger management, and social skills. In this study however, two-factor structure was observed. French adaptation study (Brevers et al., 2017) also reported acceptable internal consistency, and showed test-retest stability. Exploratory factor analysis yielded one-factor as the original scale. Validity was supported with the

negative association between BSCS and impulsive behaviour measure. Russian adaptation study (Gordeeva et al., 2017) also documented satisfactory reliability and reported that total composite score of the scale was more meaningful, supporting one-dimensional structure, and correlations between BSCS and positive outcome variables of self-esteem, perspective taking, and shame-proneness were reported.

1.1.2. The current study

The main aim of the present study was to validate the Italian version of the BSCS for both research and clinical purposes in Italian-speaking populations, and also to enable cross-cultural research on self-control including Italian samples. We examined factor structure, internal consistency, temporal stability, and validity of the Italian BSCS. Exploratory factor analysis was carried out, Cronbach's alpha was employed for assessing internal consistency, and test-retest reliability with three-week interval was tested. Convergent validity was examined with the association between BSCS and grit consistent with the earlier theorizations and findings (Duckworth & Gross, 2014; Oriol et al., 2017), and divergent validity was examined with the association between BSCS and impulsivity as it was consistently documented to be negatively related (Brevers et al., 2017; Nebioglu et al., 2012). Furthermore, the relationship between trait self-control measured with BSCS and self-esteem, resilience, and general distress were explored in parallel to the well-documented findings in the aforementioned literature (Bowlin & Baer, 2012; Fergusson et al., 2013; Hoffmann et al., 2014; Tangney et al. 2004).

It was expected to document one-factor structure as the original scale, and to demonstrate good psychometric properties with regard to reliability and validity. For the examination of validity, BSCS scores were expected to be negatively associated with impulsivity and positively associated with grit. In addition, positive correlations between BSCS and self-esteem and resilience, and negative correlation between BSCS and psychological distress were expected.

1.2. Method

1.2.1. Participants and procedure

Participants were 262 University of Padova students recruited during university lessons on voluntary basis. Participants ranged in age from 18 to 31 years (M =22.87, SD =2.27), 81.3% were female, 18.3% were male, and .4% were other. Test-retest subgroup of the sample was 143 in size, age range was 21-29 years (M =22.76, SD =1.47), and 86% were female and 14% were male.

Participants received an online link in which they were asked to fill out the demographic information form (including questions on age, sex, and academic status), the Italian version of the SCS followed by the standardized measures of impulsivity, general distress, resilience, grit, and self-esteem. A subgroup of participants was asked to fill out the SCS twice after a three-week interval.

The study received formal approval by the Ethics Committee for Psychological Research at University of Padova. This research was conducted in accordance with the Declaration of Helsinki.

1.2.2. Measures

The Italian Version of the Brief Self-Control Scale was developed following the standard procedures in the psychology literature (Brislin, 1986). Firstly, the original version was translated from English to Italian by three researchers independently, and a common version was agreed upon. Secondly, a bilingual individual with comprehensive knowledge of the discipline of psychology back-translated the common Italian version to English. The back-translated version was nearly identical to the original one; few differences were resolved through discussion, and the final Italian version was adjusted according to the consensus. The items of the scale are presented in table 1.

Table 1. The Italian version of BSCS

			Per nulla simile a me — Moltissimo simile a me
	1.	Sono bravo/a a resistere alle tentazioni.	1--------2--------3--------4--------5
(R)	2.	Ho difficoltà a interrompere le cattive abitudini.	1--------2--------3--------4--------5
(R)	3.	Sono pigro/a.	1--------2--------3--------4--------5
(R)	4.	Dico cose inappropriate.	1--------2--------3--------4--------5
(R)	5.	Se sono divertenti, faccio alcune cose che sono dannose per me.	1--------2--------3--------4--------5
	6.	Rifiuto le cose che sono negative per me.	1--------2--------3--------4--------5
(R)	7.	Vorrei avere più autodisciplina.	1--------2--------3--------4--------5
	8.	Le persone potrebbero dire che ho un'auto-disciplina di ferro.	1--------2--------3--------4--------5
(R)	9.	Piacere e divertimento qualche volta mi impediscono di portare a termine il lavoro.	1--------2--------3--------4--------5
(R)	10.	Ho problemi a concentrarmi.	1--------2--------3--------4--------5
	11.	Sono capace di lavorare in modo efficace verso obiettivi a lungo termine.	1--------2--------3--------4--------5
(R)	12.	A volte non riesco a evitare di fare una cosa, anche se so che è sbagliata.	1--------2--------3--------4--------5
(R)	13.	Spesso agisco senza pensare a tutte le alternative.	1--------2--------3--------4--------5

Note. (R) refers to reverse coded items

The Short Grit Scale (Grit-S; Duckworth et al., 2009; Italian version by Sulla et al., 2018) is a 8-item scale that aims to measure trait level grit with the two subscales of perseverance of effort (e.g., "Setbacks don't discourage me") and consistency of interest (e.g. of a reversed item, "I often set a goal but later choose to pursue a different one"). Participants are asked to rate how much each of the items represents themselves on a 1 = *not like me at all* to 5 = *very much like me* -point scale. Higher scores correspond to higher level of grit. The psychometric properties of the Italian version were good; the subscales ant the whole scale demonstrated sufficient to good internal consistency (Cronbach's alpha ranged from .60 to .83), two factor model was supported, and predictive validity in relation to career changes and educational attainment while controlling for conscientiousness was evidenced. In the present study, observed internal consistency value for the whole scale was .82, and .70 and .79 for the subscales.

The Short Form of Impulsive Behavior Scale (S-UPPS-P; Billieux et al., 2012; Italian version by D'Orta et al., 2015) is a 20-item questionnaire with five subscales; positive urgency (e.g. "When I am really excited, I tend not to think on the consequences of my actions"), negative urgency (e.g. "When I am upset I often act without thinking"), lack of perseverance (e.g. of a reversed item, "I am a productive person who always gets the job done"), lack of premeditation (e.g. of a reversed item, "I usually make up my mind through careful reasoning"), and sensation seeking (e.g., "I sometimes like doing things that are a bit frightening") that evaluates facets of impulsivity. Each item is rated on a 1 = *agree strongly* to 4 = *disagree strongly* -point scale. Higher scores indicate higher impulsive behavior tendency. The Italian version showed good psychometric properties; the subscales demonstrated good internal consistency (Cronbach's alpha ranged from .73 to .84), five factor model and construct validity was supported. In the present study, the observed internal consistency values for subscales were .83, .75, .93, .88, and .81 respectively.

The Depression Anxiety and Stress Scales-21 (DASS-21; Lovibond & Lovibond, 1995; Italian version by Bottesi et al., 2015) is a 21-item measure of general distress consisting of three subscales

of depression (e.g., “I couldn’t seem to experience any positive feeling at all”), anxiety (e.g., “I was aware of dryness of my month”), and stress (e.g., “I found it hard to wind down”). Participants are asked to rate to what extent each of the items applied to them considering the last week on a 0 = *did not apply to me at all* to 3 = *applied to me very much, or most of the time* -point scale. Higher total scores indicate higher general distress. The Italian version had good psychometric properties. The Cronbach’s alpha coefficients of the three subscales and the whole scale in both community and clinical samples were good to excellent (ranged from .74 to .92), where the alpha values were the highest for the whole scale. Test-retest reliability was good and construct validity was established with large correlations to other measures of anxiety, depression, and stress, and further support was documented with regard to its use as a measure of general distress. The observed internal consistency value in the present sample was .95 for the whole scale.

The Resilience Scale for Adults (RSA; Hjemdal et al., 2001; Italian version by Bonfiglio et al., 2016) is a 33-item measure of resilience protective factors with six subscales of perception of self (e.g., belief in myself), planned future (e.g., clear future goals), social competence (e.g., enjoy relations with other), structured style (e.g., organize my time), family cohesion (e.g., family do things together), and social resources (e.g., strong bonds with friends). Each item is rated on a 5-point scale anchored with opposing semantic answers. Higher scores indicate higher level of resilience. The Italian version showed good psychometric properties; the subscales demonstrated sufficient to good internal consistency (Cronbach’s alpha ranged from .66 to .87), six factor model was supported, test-retest reliability was adequate, and construct validity was documented with medium-to-large correlation coefficients. In the present sample, internal consistency values were .77, .81, .71, .85, .88, and .85 respectively.

The Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965; Italian version by Prezza et al., 1997) is a 10-item (e.g., “On the whole, I am satisfied with myself”) unidimensional measure of global self-esteem. Each item is rated on a 1= *strongly disagree* to 4 = *strongly agree*-point scale. Higher scores

indicate higher levels of self-esteem. The Italian version of the scale demonstrated good internal consistency (Cronbach's alpha = .84) and 15-days test-retest reliability (r = .76). In the present sample, observed internal consistency value was .91.

1.2.3. Data analysis

Statistical analyses were performed with the software Statistical Package for the Social Sciences (SPSS) version 27. Exploratory Factor Analysis (EFA) was performed with principal components analysis (PCA). The number of factors identified was based on an examination of eigenvalues greater than one and on the scree plot. Internal consistency was assessed by Cronbach's α coefficient computation where $\alpha \geq .90$ = excellent; $.90 > \alpha \geq .80$ = good, and $.80 > \alpha \geq .70$ = acceptable (Cronbach, 1951). Relationship between BSCS and other related measures were examined with Pearson correlation coefficients.

1.3. Results

1.3.1. Descriptive statistics and factor structure

The observed mean score of BSCS in the sample ($n = 259$) was 44.93 with a standard deviation of 7.99, where the range of scores were from 21 to 60. The skewness and kurtosis were calculated for each of the 13 items. The results showed that the skewness ranged from -.86 to .06 and kurtosis from -1.00 to .22. There was no evidence of strong deviation from normality. Results from the PCA indicated one-factor solution (see Figure 1), and this factor explained 29.8% of the variance. Item-loadings ranged from .31 to .67 for Factor 1, which were higher than the factor loading cut-off of .30 (Kline, 2005).

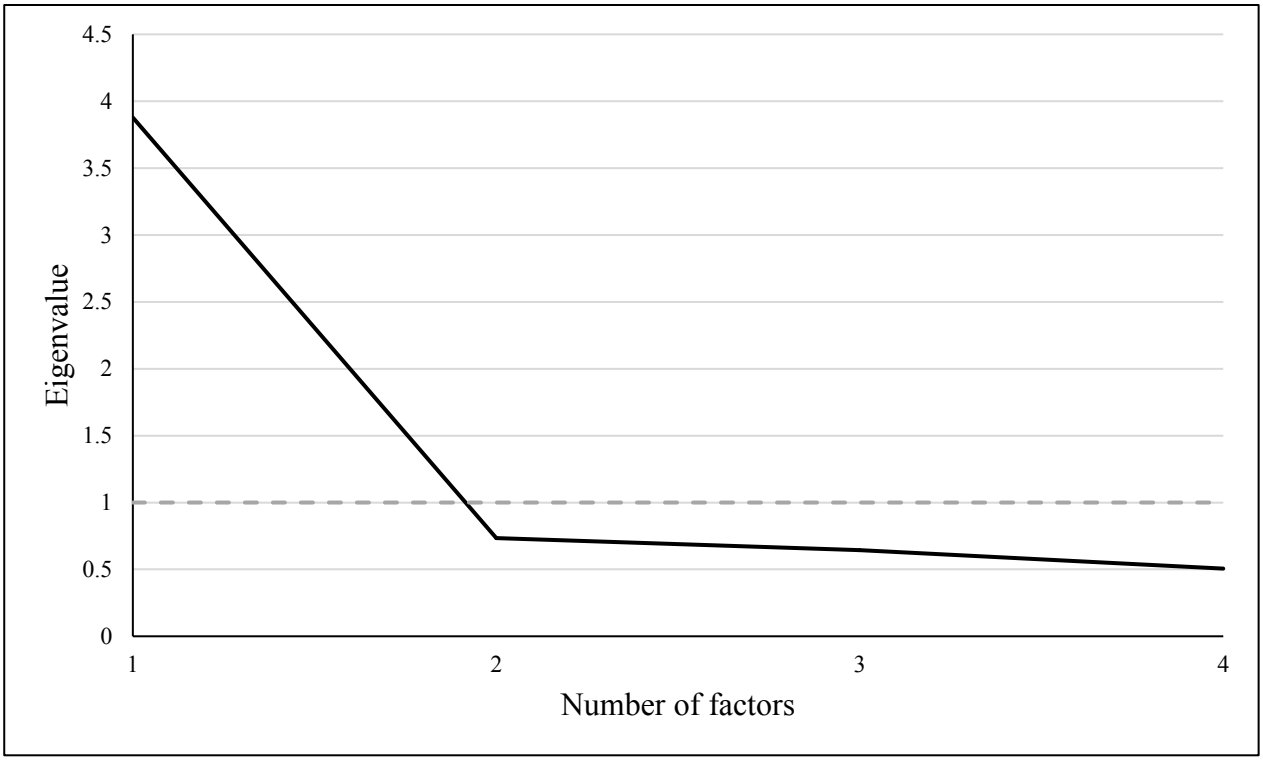

Figure 1. Scree plot

1.3.2. Internal consistency and test-retest reliability

Internal consistency analysis revealed a Cronbach's α coefficient of .83 indicating good internal consistency. For the subsample, who was re-administered BSCS after three weeks, Pearson correlation analysis showed a good test-retest reliability (r = .84, p < .001).

1.3.3. Associations with demographic variables

There was no significant difference in BSCS scores (t(249) = -1.21, p = .23) between male (M =42.68, SD =7.92) and female participants (M =45.40, SD =7.95), and there was not a significant relationship between BSCS and age (r = -.09; p = .131).

1.3.4. Validity

Convergent validity examination revealed that BSCS was positively correlated with total Grit-S ($r = .73$, $p < .001$), and the two subscales perseverance of effort ($r = .67$, $p < .001$) and consistency of interest ($r = .62$, $p < .001$) significantly.

Divergent validity examination showed BSCS was negatively correlated with all S-UPPS-P subscales; positive urgency ($r = -.35$, $p < .001$), negative urgency ($r = -.31$, $p < .001$), lack of perseverance ($r = -.37$, $p < .001$), lack of premeditation ($r = -.33$, $p < .001$), and sensation seeking ($r = -.22$, $p < .001$) significantly.

1.3.5. Correlations with other measures

The correlations between BSCS and other measures are presented in Table 2. BSCS was negatively correlated with DASS-21 significantly, whereas it was positively correlated with all RSA subscales of perception of self, planned future, structured style, social competence, family cohesion, and social resources and RSES significantly.

Table 2. Correlations of BSCS with measures of DASS-21, RSA, and RSES

	Brief Self-Control Scale
Depression Anxiety and Stress Scales-21	-.45***
Resilience Scale for Adults	
Perception of self	.39***
Planned future	.36***
Structured style	.24***
Social competence	.59***
Family cohesion	.36***
Social resources	.32***
Rosenberg Self-Esteem Scale	.84***

Note. *** $p < .001$

1.4. Discussion

The present study aimed to provide the Italian version of the BSCS and evaluate its' psychometric properties. With respect to the factor structure of the scale, consistent with the original BSCS, exploratory factor analysis revealed the best factor solution is a one factor model in parallel to other validation studies (Bertrams & Dickhäuser, 2009; Brevers et al., 2017; Gordeeva et al., 2017) except two-factor resolution was supported in Turkish version (Nebioglu et al., 2012). Maloney et al. (2011) also reported two factor structure for the original scale named as self-discipline and impulsivity. However, it was argued in the Polish adaptation of the SCS that seemingly two factors were due to the presence of the regular and reverse-coded items.

The Italian BSCS showed very good reliability. Internal consistency value and three-week temporal stability were both good. With regard to convergent validity, the Italian BSCS was

positively correlated with grit, and with regard to divergent validity, it was negatively correlated with impulsive behavior as expected (Bergen et al., 2012; Verstuyf et al., 2013).

When other correlates were assessed, it was revealed that BSCS was positively correlated with self-esteem and resilience, and was negatively correlated with psychological distress in line with the expectations (Bowlin & Baer, 2012; Hoffmann et al., 2014; Tangney et al. 2004). These findings provided further support for the relationship between trait self-control and psychological well-being where higher level of trait self-control is associated with better psychological well-being.

Several shortcomings of the present study should be noted. The sample size was relatively small and, therefore, did not allow to test confirmatory factor analysis. Secondly, the sample consisted of university students, and most of the participants were females, which limit the generalizability of the results. Therefore, it is encouraged for future studies to test the Italian BSCS in larger and more representative samples.

In conclusion, despite the above-mentioned limitations, present study provided the Italian version of the BSCS demonstrating good reliability and validity. We hope that this tool will be useful for researchers investigating trait self-control in Italian speaking samples and for clinical purposes.

CHAPTER 2

Study 2. The Roles of Physical Activity Intention, Trait Self-Control, Affective Reaction, and Automaticity in the Prediction of Physical Activity Behavior: A Test of Physical Activity Adoption and Maintenance Model

2.1. Introduction

Building on dual-process theories of self-regulation (Brand & Ekkekakis, 2018; Hoffmann, Friese, & Strack, 2009), a recent theoretical model, the Physical Activity Adoption and Maintenance model (PAAM model; Strobach et al., 2020) provided an elaborate understanding of explicit and implicit processes in the self-regulation of PA behavior. In this model, explicit processes included PA intention, trait self-regulation, and executive functions while implicit processes included habit formation and affective reactions. It was depicted how explicit and implicit processes interact simultaneously in the adoption and maintenance of PA. It was suggested that PA intention is one of the main predictors of PA which is moderated by executive functions and trait self-regulation. In other words, executive functions and trait self-regulation as processes involved in self-regulation, are considered significant in the translation of intention to behavior. Another main predictor of PA was suggested to be habit strength, where PA behavior shifts from effortful to effortless gradually. It was further postulated positive affective states during PA has a facilitating effect on the habit formation.

2.1.1. The current study

In the present study, it was aimed to test the PAAM model (Strobach et al., 2020) for the first time, and specifically examine the relationship between PA behavior and trait self-regulation, affective reaction during PA, PA intention, and PA habit strength. Model driven hypotheses were; (1) intention and PA habit strength would be positively associated with MVPA, (2) trait self-regulation would moderate the relationship between intention and PA where higher levels of trait self-regulation

would amplify the association between intention and behavior, (3) PA habit strength would mediate the relationship between affective reaction during PA and PA.

2.2. Method

2.2.1. Participants and procedure

Participants were adults who were at least 18 years old and without any physical health condition that constitutes medical contradiction to engaging in exercise such as injuries, heart condition, or any other constraint. In the consent from, participants were informed about the criteria. Participation was on voluntary basis. Data was collected with online questionnaires prepared in Unipark software. The sample of the current study was part of a project *A multi-national study on self-regulation of physical activity: Examination of the Physical Activity Adoption and Maintenance Model* (Pfeffer, Englert, Gürdere, Ghisi, Bottesi, Bray, & Graham, 2021). For this study, the sample from Italy was extracted. The sample consisted of 53 participants. The mean age of the sample was 25.68 (*SD* =7.13) and the ages ranged from 21 to 51. 88.7% were female and 11.3% were male. 49 of the participants reported their nationality as Italian, 1 Ukrainian, 1 Turkish, 1 Romanian, and 1 Chilean. All of the participants confirmed their fluency in Italian language. The mean years of education was 17.64 (*SD* =2.25) with a range of 14-26. The study received formal approval by the Ethics Committee at Medical School Hamburg. This research was conducted in accordance with the Declaration of Helsinki.

2.2.2. Measures

Demographic information form consisted of age, sex, nationality, fluency in Italian language, and years of education.

Trait self-regulation was measured with the Brief Self-Control Scale (BSCS; Tangney et al., 2004; Italian version by Gürdere et al., submitted). It is a one-dimensional 13-item scale. The items are rated on a 5-point scale. Higher scores indicate higher levels of trait self-control. The psychometric properties of the Italian BSCS were good. The scale showed good internal consistency (Cronbach's alpha = .83) and good 3-weeks test-retest reliability (r = .84). One-dimensional model was supported.

Physical activity behavior was measured with the four items derived from the short form of the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003; Italian version by Mannocci et al., 2010). The psychometric properties of the Italian IPAQ short version were reported acceptable (Mannocci et al., 2010). The Cronbach's alpha was .60 on items about PA for the short version. Firstly, information on moderate and vigorous PAs was provided to the participants as the following "Moderate physical activities refer to exercises that take moderate physical effort, make you sweat a little and make you breathe somewhat harder than normal (such as brisk walking, dancing, brisk cycling, and fitness course). Vigorous physical activities refer to exercises that take hard physical effort, where you sweat hard and where you breathe much more than normal (such as running, fast cycling, fast swimming, circuit training, and competitive sports)". Participants were asked to indicate how many times they perform moderate PAs and vigorous PAs in a week, and for how long (in minutes) on average per occasion. The frequency values were multiplied with average duration per occasion for moderate and vigorous PAs. The final moderate-to-vigorous physical activity (MVPA) score was calculated by their sum.

Physical activity intention was assessed with Italian translation of the three items (Ajzen, 1991; Pfeffer, Englert, & Müller-Alcazar, 2020); "I intend to engage physical activity for at least 30 min per day with MVPA intensity," "I plan to be . . .," and "I am determined to be . . ." (see Appendix A for Italian items). Each item is rated on a 6-point Likert scale from 1 (strongly disagree) to 6 (strongly agree). PA intention score is calculated by the sum of the three item responses. Higher scores reflect

stronger intention. Internal consistency for the Italian intention scale was α = .89 indicating good reliability.

Physical activity habit strength was measured with the Italian translation of the four-item subscale named Self-Report Behavioural Automaticity Index of the Self-Report Habit Index (SRHI; Gardner et al., 2012). Items assess how automatically respondent engages in PA (see Appendix B for Italian items). Each item is rated on a 1 (disagree) to 5 (agree) Likert type scale. Behavioral automaticity score is obtained by the sum of four item responses. The four-item automaticity subscale was found to be reliable (Gardner et al., 2012), in the present study internal consistency for the Italian translated version was α = .92 indicating very good reliability.

Affective reaction during physical activity was measured with Italian translation of one item on the pleasantness of the feeling (the Feeling Scale; Hardy and Rejeski, 1989). Participants were asked to rate their affect during physical exercises from very bad (-5) to very good (+5). The item score was recoded from 1 to 11, higher scores indicating more positive affective reaction (see Appendix C for Italian item).

2.2.3. Data analysis

The software Statistical Package for the Social Sciences (SPSS) version 27 was used for data screening and analyses. Internal consistencies of the translated scales were assessed by Cronbach's α coefficient. Relationships among study variables were examined with Pearson correlation coefficients. To test the hypotheses, a hierarchical multiple regression analysis was conducted. Because of the different scaling, continuous variables were centered, and dichotomous variables were dummy coded prior to calculating the two-way interaction terms. PROCESS macro for SPSS (Hayes, 2017) was utilized for moderation and mediation analyses.

2.3. Results

2.3.1. Descriptive statistics and correlations

In Table 1, descriptive statistics of and correlations among study variables are presented. In our sample, the mean MVPA engagement for a week was 233.94 minutes (*SD* = 7.13). MVPA was positively correlated with PA intention, behavioral automaticity, and pleasantness of the affective reaction during PA. Trait self-control was positively associated with PA intention significantly. MVPA, intention, automaticity, and affective reaction were all significantly positively correlated with each other. The correlations between age and other study variables were not significant.

Table 1. Means, Standard Deviations and Correlations (N = 53)

	1	2	3	4	5	6
Age (1)	-	-.26	-.26	-.11	-.01	.01
Trait self-control (2)		-	.30*	.10	.05	.13
Intention (3)			-	.54**	.38**	.43**
Automaticity (4)				-	.47**	.64**
Affective reaction (5)					-	.43**
MVPA (6)						-
M	25.68	45.89	9.87	9.28	8.47	233.4
SD	7.13	6.77	5.05	4.77	2.17	185.21

Notes. * $p < .05$; ** $p < .01$

2.3.2. Hierarchical Regression Analysis

A hierarchical regression analysis was conducted to examine the predictors of MVPA controlling for sex and age. In Table 2 the results of the analysis are presented.

Table 2. Hierarchical Regression Analyses Results (N = 53).

	Step 1			Step 2			Step 3		
	β	R^2	*F*	*β*	R^2	*F*	*β*	R^2	*F*
		.08	3.31*		.48	8.86***		.52	7.98***
Sex	-.35*			-.32*			-.31*		
Age	-.03			.08			.07		
Intention				.15			.15		
Trait self-control				.08			-.03		
Affective reaction				.18			.11		
Automaticity				.44**			.40**		
Int x TSC							.26*		
Int x AR							.07		

Notes. * p < .05; ** p < .01; *** p < .001; Int = Intention; TSC = Trait self-control; AR = Affective reaction

Basic demographic variables sex and age were entered in the first step as control variables. Sex was a significant predictor of MVPA (β = -.35, p = .01) while age was not. In step 1, regression model was significant (R^2 = .08, $F(2,50)$ = 3.31, p = .04), and the explained variance in MVPA was 8%.

In step 2, intention, trait-self-control, affective reaction, and automaticity independent variables were added into the regression equation. Sex stayed as a significant predictor (β = -.32, p = .04). Automaticity was also a significant predictor of MVPA (β = .44, p = .002), but trait self-control,

affective reaction, and intention were not. In this step, regression model was significant (R^2 = .48, $F(6,46) = 8.86$, $p < .001$), the change in explained variance was significant (ΔR^2 = .42, $\Delta F(6,46)$ = 10.39, $p < .001$) and the variables explained 48% of the variance in MVPA.

In step 3, two-way interaction terms were added into the regression equation, which were intention x trait self-control and intention x affective reaction. Sex (β = -.31, p = .04) and automaticity (β = .4, p = .003) stayed as significant predictors. Also, intention x trait self-control interaction was significant (β = .26, p = .04) in the prediction of MVPA. In this last step, the increase in explained variance was not significant, however the regression model was significant (R^2 = .52, $F(8,44) = 7.98$, $p < .001$). Overall, 52% of the variance in MVPA was explained by the model, including control variables of age and sex, independent variables of intention, trait self-control, affective reaction, and automaticity, and interactions of intention x trait self-control and intention x affective reaction.

2.3.3. Sex difference in MVPA

As sex was a significant predictor of MVPA at each step, independent samples t-test showed that on average males (M = 408.3, SD =258.32) reported to be more physically active than females (M = 211.06, SD =164.39) significantly (t (51) = 2.59, p = .01).

2.3.4. Moderation Analysis

Since intention and trait self-control interaction was significant in the hierarchical regression analysis, a subsequent moderation analysis was carried out. In this model, predictors were trait self-control, intention, their interaction, and the outcome variable was MVPA. The overall model was significant ($F(3,49) = 8.6$, $p < .001$) and explained 35% of the variance in MVPA. Intention significantly predicted MVPA (b = 12.33, $t(49) = 2.71$, p = .01) whereas trait self-control did not (b = -3.22, $t(49) = -.93$, p = .35), and the interaction was significant (b = 2.64, $t(49) = 3.51$, $p < .001$).

Furthermore, simple slopes for intention predicting MVPA at different levels of trait self-control showed that for low trait self-control, there was no relationship between intention and MVPA (b = -4.19, $t(49)$ = -.58, p = .56). For average trait self-control (b = 15.27, $t(49)$ = 3.43, p < .001) and for high trait self-control (b = 31.14, $t(49)$ = 4.96, p < .001), intention positively predicted MVPA significantly. To simply summarize, the association between intention and MVPA was stronger, when trait self-control scores were higher compared to lower (see Figure 1).

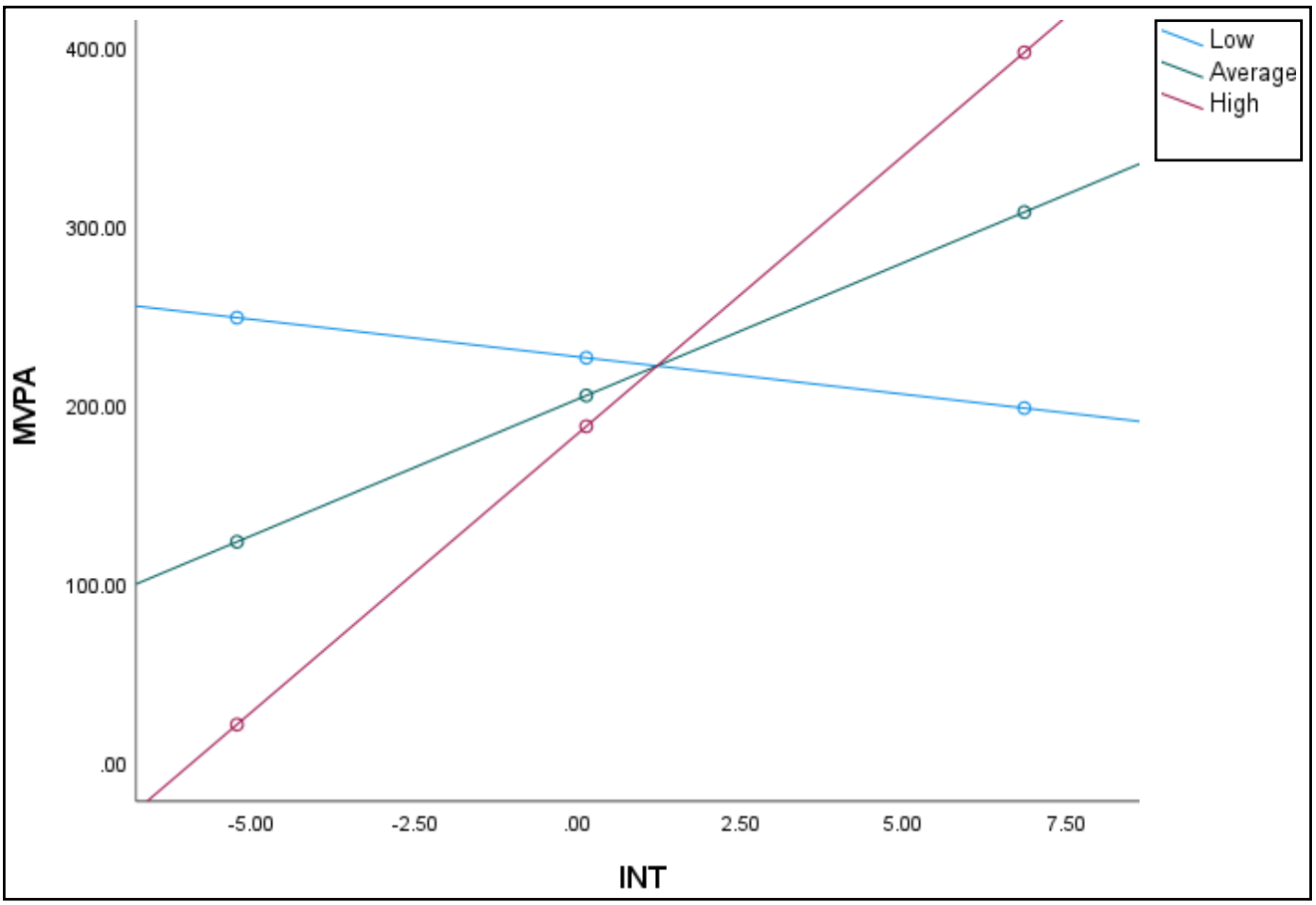

Figure 1. The relationship between intention and MVPA minutes per week for lower, average and higher levels of trait self-control (*INT* = *Intention*)

2.3.5. Mediation Analysis

A mediation model was tested to examine whether automaticity mediates the relationship between affective reaction and MVPA (see figure 2). Results firstly showed that affective reaction significantly predicted MVPA (R^2 = .18, F(1,51) = 11.31, p < .001), namely path c was significant (b = 36.34, t(51) = 3.36, p < .001). Secondly, affective reaction significantly predicted automaticity (R^2 = .22, F(1,51) = 14.37, p < .001), namely path a was significant (b = 1.03, t(51) = 3.79, p < .001). Thirdly, affective reaction and automaticity were included into the regression equation predicting MVPA. The regression model was significant (R^2 = .42, F(1,51) = 18.42, p < .001). Automaticity was a significant predictor of MVPA controlling for affective reaction (b = 21.63, t(51) = 4.59, p < .001), which indicated that path b was significant. In this case, affective reaction was no longer a significant predictor of MVPA (b = 14.03, t(51) = 1.35, p = .18) which constituted c' path and confirmed full mediation (c - c' was different from 0). In other words, the indirect effect of affective reaction on MVPA through automaticity was significant.

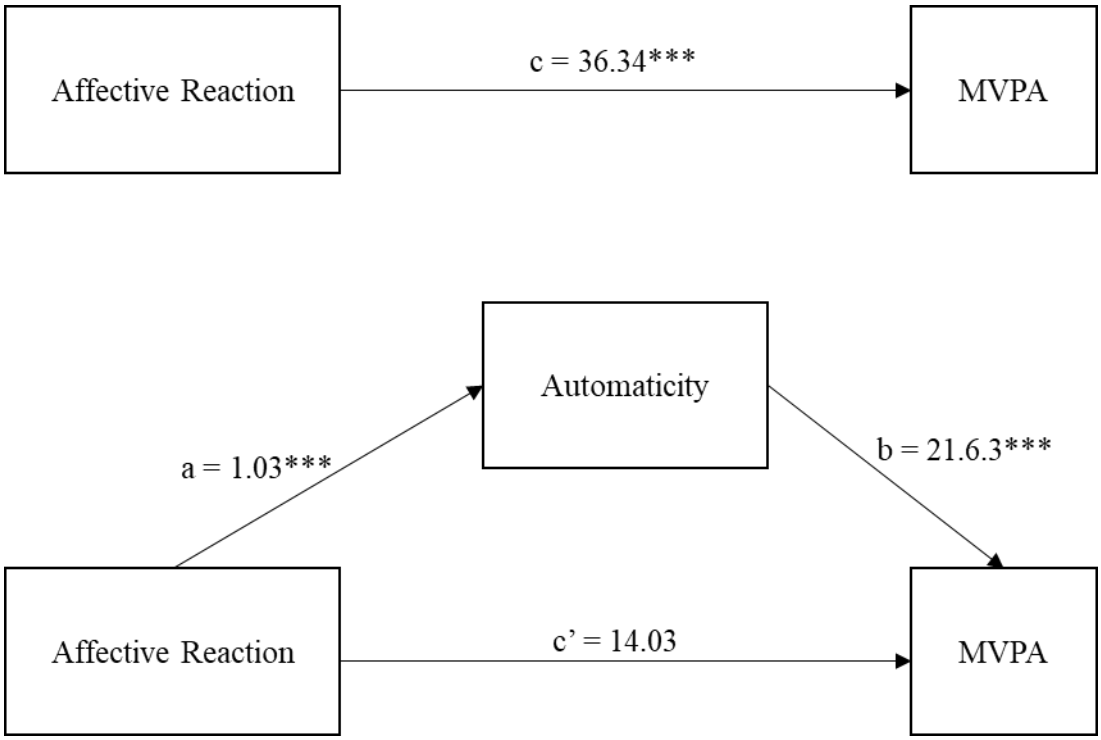

Figure 2. Regression coefficients of the mediation model

Notes. * p < .05; ** p < .01; *** p < .001

2.4. Discussion

The results of the present study showed that intention, automaticity, affective reaction, and MVPA were all positively correlated with each other significantly. There was a significant difference between men and women in MVPA amount. Hierarchical regression analysis revealed that automaticity and the intention x trait self-control interaction were significant predictors of MVPA. Subsequent moderation analysis showed that for higher levels of trait self-control, intention significantly predicted MVPA but not for lower levels of trait self-control. Higher trait self- control strengthened the relationship between intention and behavior. Furthermore, in the mediation analysis it was documented that automaticity mediated the relationship between affective reaction and MVPA.

With regard to dual-process theories (e.g. Hoffmann, Friese, & Strack, 2009), it can be concluded that the examined variables in this study; intention, trait self-control, affective reaction, and automaticity appear to be relevant automatic and reflective aspects of physical activity regulation, which was particularly shown in the interaction effect and mediation. It can be argued that in the prediction of MVPA, interactive effects of automatic and reflective processes should be explored rather than examining these variables in an additive pattern with direct effects only (Pfeffer, Brand,& Strobach, submitted).

Our results were in line with the PAAM model (Strobach et al., 2020) driven expectations and consistent with current literature. The documented moderating role of trait self-control on intention and behavior relationship was in line with the literature suggesting that adherence to physical exercise routines requires self-control strength (Englert, 2016; Hagger et al., 2010) where intention to engage in PA does not necessarily translate into behavior (Rhodes & Bruijn, 2013). Higher trait self-control predicts a smaller intention-behavior gap (Pfeffer & Strobach, 2017), and individuals with higher trait self-control tend to actualize PA intentions programs more efficiently (Finne, Englert, & Jekauc, 2019). Moreover, the reported mediating role of automaticity on affective reaction and MVPA relationship supported that positive affective reactions during PAs could facilitate formation of habits

and building up of automaticity, which in turn predicts PA behavior (Strobach et al., 2020). Lastly, in our study, males reported to engage in MVPA more than females on average consistent with the earlier findings (Azevedo et al., 2007; Hamrik et al., 2014). It was argued that although there is not a significant difference in general PA between sexes, men are more likely to practice sports and exercise, while women tend to perform daily walking and biking more (Abel et al. 2001).

Several limitations of the present study should be mentioned. Executive functions being one of the PAAM model implicit process variables were not investigated in the present study. Although executive functions were measured in the multi-national project, Italian sample's executive functions test results were not processed and available in the database yet since data collection is still ongoing in Italian population. Secondly, the current sample size was relatively small and consisted of mostly young adult female university students, which may have impacted the statistical power. Considering that much less number of males participated to the present study, especially reported sex differences may not be generalizable. Also, considering that BSCS was validated exclusively in university student sample as presented in Chapter 1, although the sample of the current study consisted of young adults mostly, there was also middle-aged adults participated, for whom reliability and validity of the BSCS might be questionable. More importantly, the study design was cross-sectional, therefore causal interpretations should be explored in experimental and prospective studies in order to document the effects of the factors relevant to implicit and expilict processes on PA behavior. However, despite the limitations, the present study provided a preliminary test and support for the PAAM model.

To elaborate on the implications of the present study, it should be noted that in the literature, interventions to increase PA intentions has documented to be substantially effective (see Silva et al., 2018 for a review). On the other hand, the idea of increasing trait self-control is rather argumentative. However, it has been corroborated that self-control practices over time, could have the potential to increase general self-control skills not only within the sphere of the practice but across different spheres (Oaten and Cheng, 2006a; 2006b; 2007). It was supported that self-control as a core ability

can be enhanced through continuous practice over time (Finkel et al., 2009; Galliot et al., 2007). Importantly, it was documented that there was a bidirectional link between self-control skills and regular PA. Evidence from several studies suggests that regular physical exercise over a period of time is associated with increments in self-control strength (Denson et al., 2011; Muraven, 2010). As the baseline self-control skills predicted commitment to PA program, in parallel, PA engagement predicted significant increments in self-control skills (Howard, Vella, & Cliff, 2018; Lakes & Hoyt, 2004; Shachar et al., 2016). In conclusion, to promote PA behavior, interventions to increase PA intentions and self-control skills as well as fostering PA habit formation and more positive affective reactions towards PA should be considered. Furthermore, interventions promoting PA should take sex differences into account.

CHAPTER 3

Study 3. Executive Functions Predict Physical Activity Behavior – A Systematic Review and Meta-Analysis

3.1. Introduction

PA is one of the most important health behaviors for the prevention and the therapy of widespread non-communicable chronic diseases such as coronary heart disease, stroke, diabetes mellitus, back pain, and mental disorders (Powell, Paluch, & Blair, 2011; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017). Despite extensive evidence documenting the positive effects of PA on physical and mental health, too many people in western industrialized countries are still not sufficiently physically active to reach and maintain these health benefits (Guthold, Stevens, Riley, & Bull, 2018, 2020; Hallal et al., 2012; Sallis et al., 2016). This insufficient activity status emphasizes the importance for a sound knowledge about relevant factors that might facilitate or hinder PA behavior, as these factors should inform the development of effective PA promotion programs. In the context of dual-process models and their implicit and explicit processes, researchers however became increasingly interested in the role of executive functions (EFs) as a determinant of PA behavior only recently (Buckley, Cohen, Kramer, McAuley, & Mullen, 2014; Strobach, Englert, Jekauc, & Pfeffer, 2020).

3.1.1. Executive functions and the self-regulation of health behavior

EFs are cognitive operations that refer to goal-directed as well as higher-level cognitive processing, enabling effortful top-down control of behavior over lower-level cognitive processes. These functions' combination is a multifaceted construct comprised of several higher-order control processes that subserve the capacity to self-regulate. Importantly, individual differences in these processes may predict health behaviors and the translation of intentions into action, such as PA (Hofmann, Schmeichel, & Baddeley, 2012). In their unity/diversity framework, Miyake and

colleagues (Miyake & Friedman, 2012; Miyake et al., 2000) systematized the complexity of different situations and processes involving the EF construct primarily in three domains: inhibition, updating, and shifting. *Inhibition* is related to deliberate overriding of dominant or prepotent responses, *updating* refers to monitoring and manipulating working memory contents, and *shifting* is associated with switching flexibly between different tasks or mental sets (i.e., cognitive flexibility). The unity/diversity framework states that although the executive domains tap some common variability (i.e., the unity component), they also show separability (i.e., the diversity component). This common variability and separability is assessed by analyzing behavioral performance in EF tests.

It is assumed that EFs support the self-regulation of goal-directed behavior in process-oriented terms by organizing information and behavior to effortfully overcome short-term gratifications not in line with the attainment of long-term goals. Self-regulation entails 1) a standard or a goal that individuals endorse, mentally represent, and monitor, 2) sufficient motivation to invest effort into reducing discrepancies between standards and actual states, and 3) sufficient capacity to achieve the goal or the standard by reducing the discrepancy despite temptations and barriers that might arise (Baumeister & Heatherton, 1996). In detail, one main aspect of successful self-regulation is the ability to actively inhibit or to override behavioral responses (such as [unhealthy] habits and impulses) that are incompatible with one's (healthy) goals (Hofmann et al., 2012). In experimental lab contexts, this inhibition component was assessed by the go/no-go task (Logan, Cowan, & Davis, 1984) and the Stroop task (Loong, 1989). The go/no-go task requires the inhibition of responses on one set of stimuli while there are speeded responses on other stimuli. Alternatively, in the Stroop task, participants are instructed to respond to the ink of color words; these color words are congruent (e.g., GREEN in green ink) or incongruent (e.g., GREEN in red ink). Typically, reaction times in incongruent trials are larger than in congruent trials (i.e., the Stroop effect), indicating the requirement to inhibit or to override the tendency to produce a more dominant or automatic response on naming the color word in this task. Studies have shown that participants with low levels of inhibition in these experimental inhibition tasks (i.e., large Stroop effects in the Stroop task or high RTs in the go/no-go tasks) are less

successful at adhering to regular exercise classes (McAuley et al., 2011) or at translating their PA intentions into action (Allan, Johnston, & Campbell, 2011; Hall, Fong, Epp, & Elias, 2008).

However, in behavior beyond PA, several other researchers have struggled to replicate the finding of an association between inhibition and behavior or the intention–behavior gap (Allan et al., 2011; Allom & Mullan, 2014; Collins & Mullan, 2011), i.e. the difficulties to translate PA intentions into action. Furthermore, it is discussed that behavioral inhibition might play a less important role in positive health behaviors compared with the role in negative or risky behaviors, whereas updating might be more important for the initiation of positive health behaviors compared to negative health behaviors (Allom & Mullan, 2014; Pfeffer & Strobach, 2017). It is suggested that higher updating ability is associated with smaller PA intention-behavior gap (Pfeffer & Strobach, 2017). Through the updating function, mental representations of positive health behavior goals and means of goal achievement can be kept active and available for systematic processing (Hofmann et al., 2012). Furthermore, updating might facilitate regulation of affect that is incongruent with goal achievement. On the other hand, the shifting function might benefit self-regulation through flexibly adapting behavior in response to changing circumstances, instead of trying to follow rigid plans or means for goal attainment and by seizing new opportunities as they arise. Although there is an integration of inhibition with the domains updating and shifting in the unity/diversity framework (Miyake & Friedman, 2012), there are investigations needed that associate all of these domains with PA behavior and the intention-behavior gap in a systematic and elaborative way.

3.1.2. Recent reviews and meta-analyses on EF and PA behaviour

Several meta-analyses provided evidence for a substantial relationship between PA behavior and EFs (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Diamond & Ling, 2019; Hillman, Erickson, & Kramer, 2008; Kramer & Erickson, 2007; Tomporowski, McCullick, Pendleton, & Pesce, 2015). However, these meta-analyses mainly focused on the question, if acute bouts or regular PA can improve cognitive functions (such as EFs). To date, much fewer studies and

reviews scrutinized the question, if EFs might also support the execution of PA via self-regulatory processes (Buckley et al., 2014). Even though there is convincing theoretical overlap between EFs and self-regulatory processes, empirical evidence for this direct relationship between EFs and PA behavior or the moderating effect of EFs on the intention-behavior relationship is still scarce. For instance, the longitudinal study of Daly, McMinn, and Allan (2014) found the contribution of EFs to PA behavior to be over 50% larger than the contribution of PA to changes in EF, which highlights the importance to consider the (causal) effect of EFs on PA in future studies.

The meta-analysis of Gray-Burrows et al. (2019) was the first that synthesized existing studies that examined this relationship in healthy adults for different health behaviors, differentiating between health-protective (e.g., fruit/vegetable consumption, PA, sleep) and health-damaging (e.g., addictive behaviors, alcohol consumption, smoking, snack consumption) behaviors. Six studies examining PA behavior were included. The overall effect size for the association between EFs and PA behavior was calculated at $r = 0.085$. However, this meta-analysis included both cross-sectional and prospective studies. Cross-sectional studies are the least suitable design to make statements about the direction of the relationship, as they cannot address the temporal relationship between the predictor (e.g., EFs) and a behavior (e.g., PA behavior). Knowledge about causal relationship is however required to inform about the development of effective PA promotion programs to increase this activity and to reach and maintain health benefits. Thus, an elaborated analysis of the causal relation between EFs and PA from a general perspective of a systematic reviews and a meta-analysis is lacking.

3.1.3. The present study

The current systematic review and meta-analysis aimed to examine the impact of EFs on PA behavior. To address this research question, we refrained from including cross-sectional studies, as these studies do not allow to draw conclusion about the direction of the relationship of EFs and behavior. Instead, we focused on only prospective study designs where baseline EFs and PA behavior

at a later point were assessed, including longitudinal studies, interventions, and RCTs. It was aimed to explore whether EFs predict PA behavior.

3.2. Method

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) Statement (Moher et al., 2015).

3.2.1. Search Strategy

Systematic searches were performed with (physical activity OR exercise OR sport) AND executive function* keywords in PsycInfo, MEDLINE, and SPORTDiscus electronic databases from earliest record to April 2021. Also, forward backward tracking was carried out, the reference lists of relevant and selected studies were screened for other eligible studies.

3.2.2. Study Selection and Eligibility

At the first step, the database search yielded 4673 results, and among them 79 potentially eligible studies were selected by reviewing their titles and abstracts. Then the full texts of these studies were examined according to the following inclusion and exclusion criteria by three independent reviewers.

Inclusion criteria

1. Healthy population
2. Prospective study design
3. Measuring EF

4. Measuring PA behavior
5. Examination of the direct relationship between baseline EF and later PA behavior
6. Written in English language

Exclusion criteria

1. Cross-sectional study design
2. Physical health condition that constitutes medical contradiction to engaging in PA (e.g. post-surgery patients, post-stroke patients, heart condition, physical injury etc.)
3. Sample of special populations (e.g., any psychological disorder, cognitive impairment)

Since the focus of the study was EFs and PA, it was considered necessary to hold criteria on physical and mental health condition which might influence engagement in PA behavior, and absence of cognitive impairment with regard to EF performance. Studies were selected if the study was conducted in healthy population, design was prospective, baseline EF and subsequent PA behavior were measured, and their direct relationship was reported. Authors were contacted to request the direct correlational relationship result where it was not present. The issues raised by the reviewers were discussed and reached a consensus. From among 79 studies, a total of 8 studies were considered eligible. More than half of those 79 studies investigated improvements in EFs with PA. And the second most common exclusion reason was the absence of reporting EF-PA direct relationship. The flow diagram of the study selection is presented in detail in Figure 1.

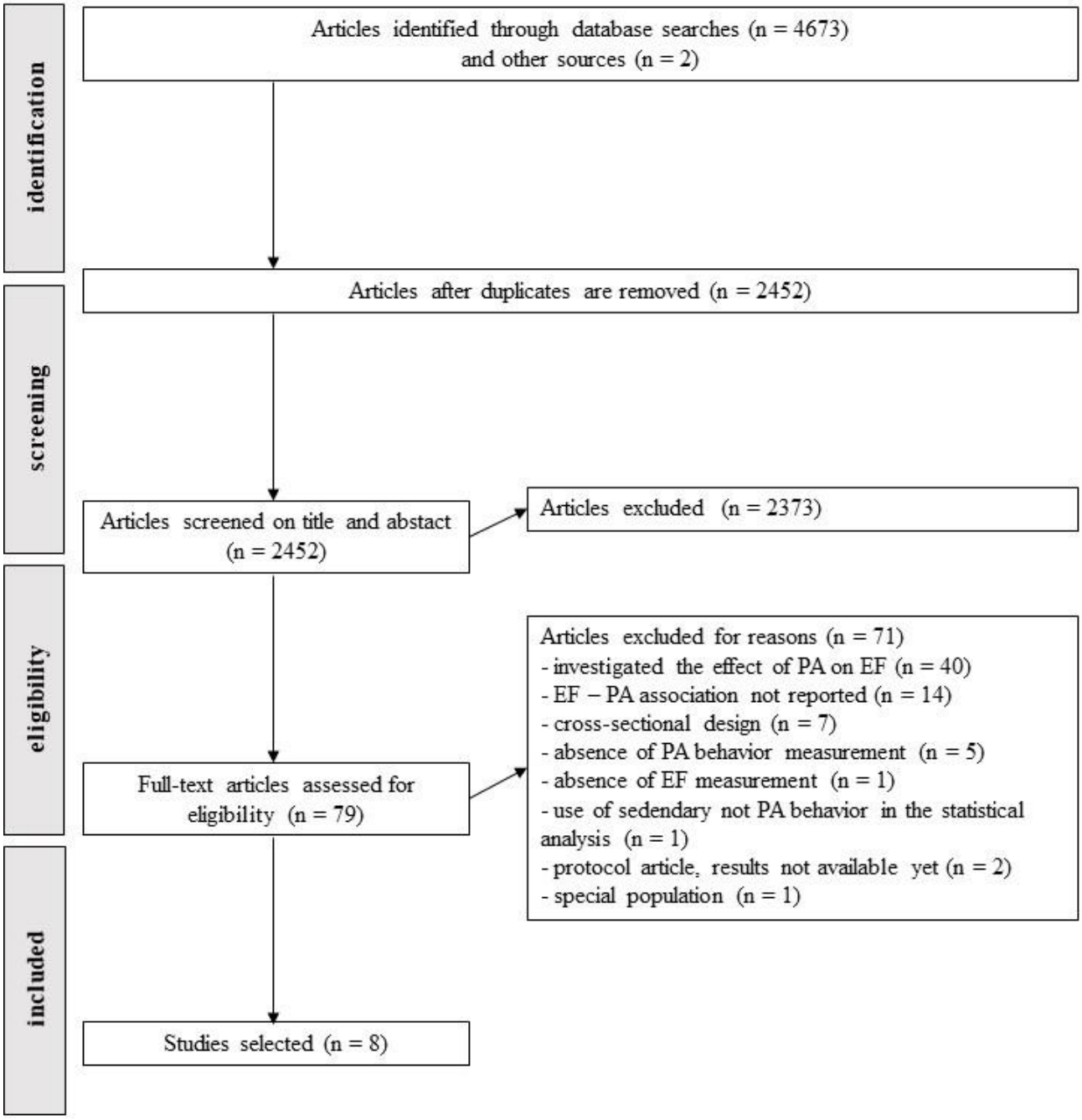

Figure 1. Flow diagram of the study selection process

3.2.3. Statistical analyses

Data analyses were conducted with the Metafor package (Viechtbauer, 2010) in R statistical software (R Core Team, 2020). For the EF scores where lower scores indicated higher performance, the Pearson correlation coefficients between EF score and PA behavior were reversed to quantify EF

performance and PA relationship. Random-effects model was utilized for meta-analysis. We examined the heterogeneity across studies with *Q* statistic, where a significant *Q* value indicates significant heterogeneity of results among studies (Crocetti, 2016). Next, the magnitude of the heterogeneity was obtained with I^2 index (Huedo-Medina et al., 2006). I^2 estimates the proportion of observed variance that reflects differences in effect sizes (Higgins et al., 2003). High I^2 index value reflects different results across studies due to such as different designs, different constructs whereas low I^2 index value points to similar results across studies. I^2 index values below 50% is considered low, 50-75% moderate, above 75% high. Lastly, publication bias was assessed with the "trim and fill" funnel plot method (Duval, 2005; Rothstein et al., 2006).

3.3. Results

Characteristics of the studies included in the meta-analysis regarding design details, sample size, mean and range of age at baseline, EF and PA measures are presented in Table 1. As noted, most of the studies were observational (**1-6**), one was RCT (**7**), and one was intervention (**8**). Samples consisted of young adults (**1**, **4**, **5, 6, 7**), mixed aged adults (**3**) with an overall age range of 18-89, older adults (**8**), and children (**2**). Sample sizes ranged from 32 to 6069, and the duration of the study from 1 week to 6 years. Almost all of the studies employed performance tests of EFs (**2-8**), except one (**1**) which used a self-report measure. For PA behavior, half of the studies used self-report measures (**1**, **4**, **6**, **7**), some acceloremeter derived data (**2** and **3**), one both (**5**), and one (**8**) attendance record.

Each of the studies were assessed for their quality using a quality assessment tool (see Appandix D) adapted from Favieri et al. (2019) and Tooth et al. (2005). Two reviewers independently evaluated each study, the agreement rate was 84.6%, and disagreements were resolved through discussion. None of the eight studies were assessed as poor quality. The mean agreed quality rating (0 = poor, 1 = fair, 2 = good) for the eight studies ranged from 1.3 to 1.8.

Table 1. Summary of study characteristics

Study	Design	Sample	EF measurement	PA measurement
1. Frye & Shapiro, 2020	Prospective observational T: 1 week	N: 220 M_{age}:19.4 R_{age}: 18-25	Barkley Deficits in Executive Functioning Scale	Self-reported PA with International Physical Activity Questionnaire
2. Stautz et al., 2016	Prospective observational T: 6 years	N: 6069 M_{age}: 7	Stop signal, counting span, opposite world and sky search tasks	Average daily minutes of MVPA recorded using actigraph monitors
3. Hall et al., 2014	Prospective observational T: 1 week	N: 208 M_{age}: 45.2 R_{age}: 18-89	Stroop and go/no-go tasks	Average daily PA recorded by accelerometer
4. Hall et al., 2008	Prospective observational T: 1 week	N: 64 M_{age}: 19	Go/no-go task	Self-reported number of hours spent in vigorous PA over the past week
5. Loprinzi et l., 2020	Prospective observational T: 1 week	N: 32 M_{age}: 21.1 R_{age}: 18-45	Tower of London, operation span, stroop. letter-number, and switching tasks	Physical Activity Vital Signs Questionnaire Godin Leisure-Time Questionnaire Accelerometer-derived light PA
6. Pfeffer & Strobach, 2017	Prospective observational T: 1 week	N: 118 M_{age}: 23.2 R_{age}: 18-30	Go/no-go, stop-signal, visual memory, n-back, cueing, and alternating runs tasks	Self-reported number of hours engaged in vigorous PA
7. Pfeffer & Strobach, 2020	Prospective RCT T: 1 week	N: 191 M_{age}: 22.7 R_{age}: 18-34	Go/no-go, stop-signal, visual memory, n-back, cueing, and alternating runs tasks	Self-reported number of hours engaged in vigorous PA
8. McAuley et al., 2011	Prospective intervention T: 12 months	N: 177 M_{age}: 66.5 R_{age}: 58-81	Dual, stroop, flanker, Wisconsin card-sorting, and switching tasks	Exercise class attendance

Notes. RCT = Randomized controlled trial, T = Time frame/duration of the study, N = Sample size, M = Mean, R = Range

As studies used multiple indexes for EFs, for each study there were multiple effect sizes. Consequently, the actual number of effect sizes used in the analysis was 35. Pearson correlation coefficients were transformed into the effect size measure of Fisher's *z*. The total effect size was obtained with random-effects model. The random effect analysis showed a small but significant mean effect size, $z = .06$, 95% *CI* (.02–.10), $p = .0012$, indicating that baseline EF was positively associated with later PA behavior. Forest plot for the effect sizes for each study and the total effect size are presented in Figure 2. The test of heterogeneity was significant, $\chi 2\ (34) = 118.93$, $p < .001$, $I^2 = 85.99\%$, revealing a high variance across studies.

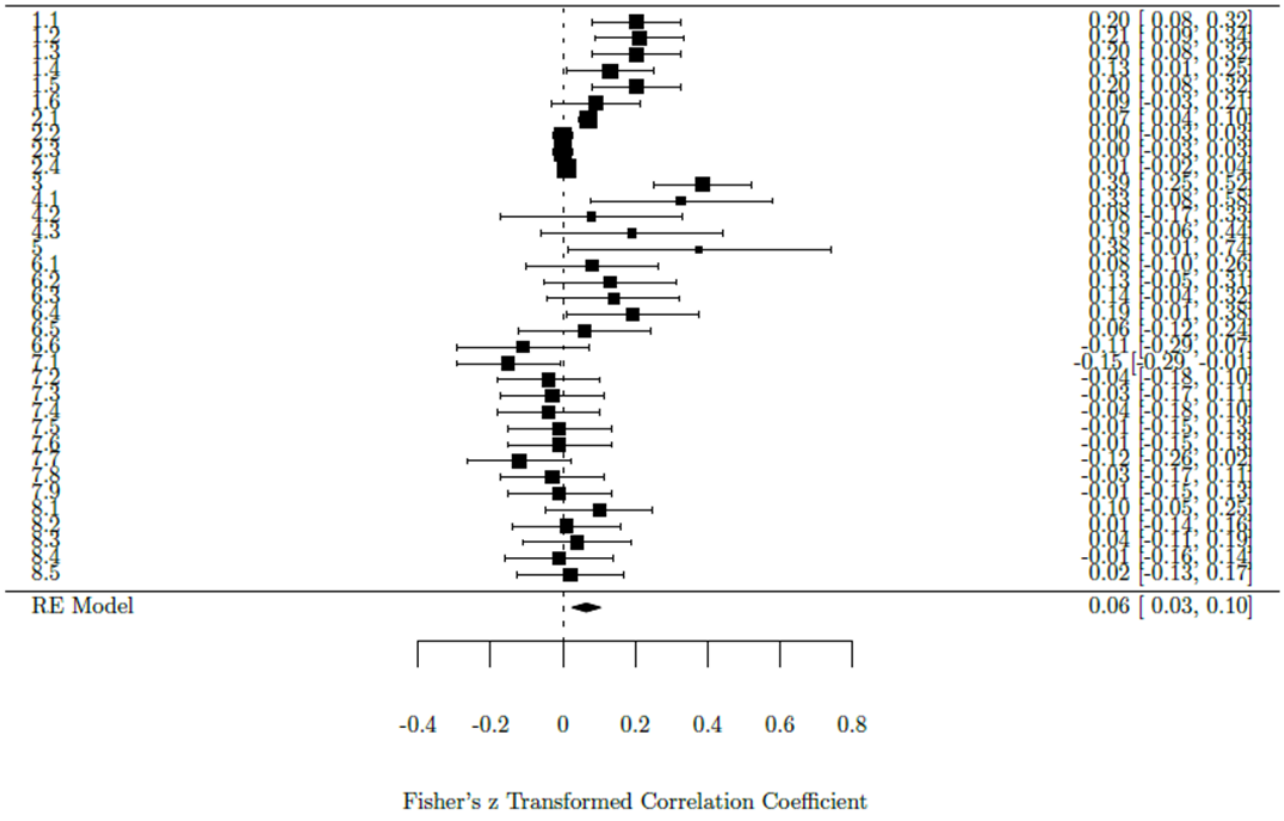

Figure 2. The forest plot of effect sizes

Notes. Each square represents the effect size of the study result with 95% confidence interval. The size of the symbol is proportional to the sample size of the study. On the left, in the first digit the study number is presented (1-8), and reported results are enumerated if more than one result is available.

Publication bias was also assessed, the funnel plot with trim and fill added two hypothetical missing studies (see Figure 3). Including these two studies decreased the total effect size but it remained significant, z = .05, 95% *CI* (.009–.096), p = .0169.

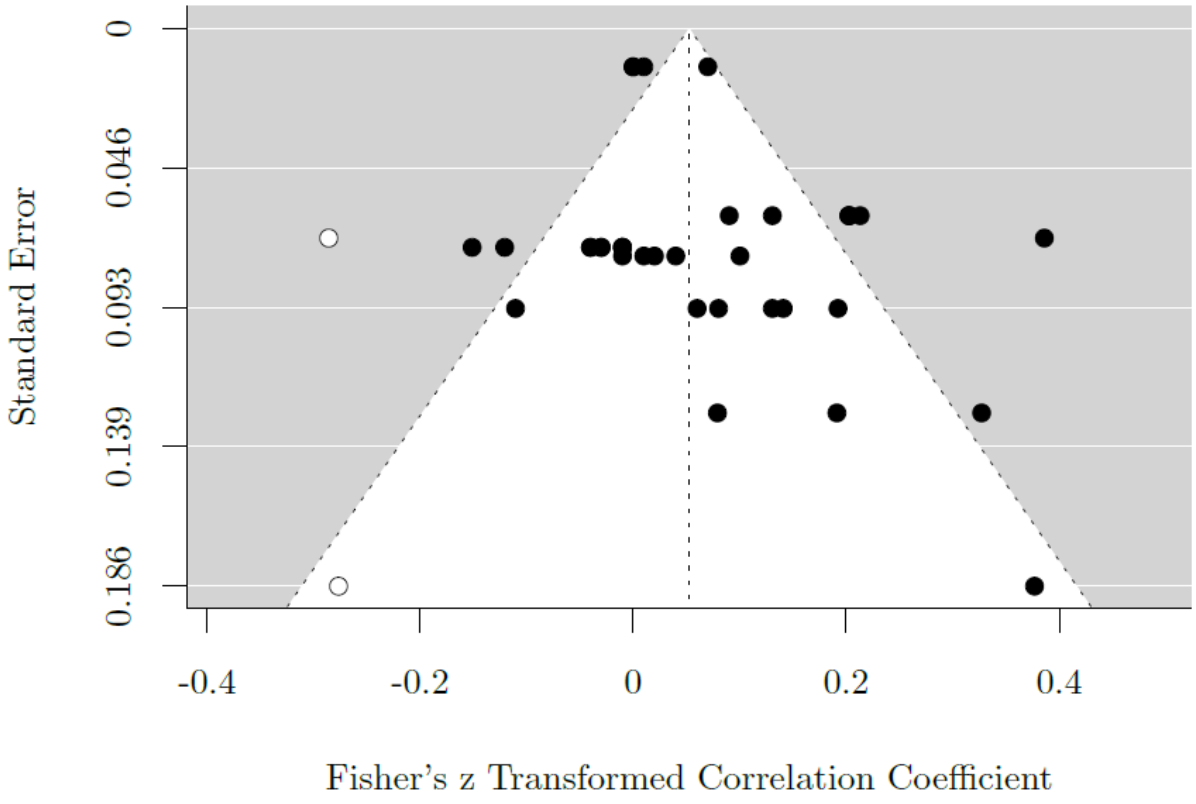

Figure 3. The funnel plot

Notes. Each black dot represents one study result that included in the meta-analysis. White dots represent the effect size of hypothetical unpublished results.

3.4. Discussion

The present meta-analysis was conducted to examine the relationship between EFs and PA behavior with a specific focus on the direction of the relationship. In the literature, there has been a large interest in exploring beneficial effects of acute or regular PA on EFs (Diamond & Ling, 2016; Herald et al., 2019; Moreau & Chou, 2019; Morris et al. 2019). However, despite some promising

results, there has been inconsistent findings where more critical approaches appear to be necessary (Van Waelvelde et al., 2019). On the other hand, in our opinion the role of EFs as part of self-regulatory processes, on PA behavior should be highlighted. For this purpose, systematic searches have been carried out, and prospective studies where the direct relationship between baseline EF and later PA behavior was assessed in healthy populations of any age were selected. Eight studies were found eligible, and the results of the meta-analysis showed that the total effect size for the relationship between EF and PA behavior was small but significant. When publication bias was accounted for, the effect size remained significant. In other words, when results across studies were synthesized quantitatively, it was revealed that baseline EFs predicted later PA behavior significantly. Our results supported the point of view that EFs should be considered as one of the potential determinants of PA behavior.

High heterogeneity was observed across studies that might have resulted from different study design characteristics, varying time intervals between t_0 and t_1, age groups of the study samples, and the heterogeneous measurement methods used for EFs and PA behavior. Some studies used self-report measures while others used objective measures. Especially, large variance of EF measures employed across studies created a challenge to explore further EFs and PA relationship differentiating for EF component (inhibition, updating, shifting). It was considered that mostly it was not completely clear which component was measured with the specific tasks, and that some tasks might tap more than one EF component to varying degrees and sometimes even all components. In addition, tasks differ in the way how much they tap on particular EFs and also how much they tap on cognitive domains beyond EFs (the task-impurity problem, Miyake & Friedman, 2012). There is a necessity for the development of domain specific EF tests, and standardization of EFs' measurement in order to be able to compare results across studies and to differentiate for EF domains.

It must be pointed out that the number of studies analyzed was limited which constituted both weakness and strength of the present meta-analysis. As relatively very few studies investigated the

impact of EFs on PA behavior, rather than the opposite, it was possible to include only eight studies, which was also the starting point of the present study to highlight EF as an important factor in PA behavior. Another weakness of the present study was although the direction of the EF-PA relationship was established with timeline, as the studies did not manipulate EFs, it is not possible to draw causal inferences with confidence. Despite limitations, the present meta-analysis showed that baseline EFs were positively associated with later PA behavior significantly.

For future research, it is highly encouraged to take into account the potential bidirectional relationship between EFs and PA behavior and notably to clarify the role of EFs for the self-regulation of PA, differentiating for components of EFs. Large-scale longitudinal studies and RCTs are needed in order to reach this goal. Furthermore, as some of the studies included in the present meta-analysis documented support, moderator role of EFs on the intention-PA behavior relationship should not be omitted (**1**, **4**, **6**, **7**). It is reasonable to argue that EFs and self-regulatory processes are only relevant when there is PA goal and thus intention, which might also explain the reported significant but small overall effect size for EFs and PA relationship. Therefore, it could be suggested that the effect of EFs as a moderator of the intention-behavior relationship might be more relevant than the direct effect of EFs on PA behavior (Hall et al., 2008; Pfeffer & Strobach, 2017). Future studies should address the moderator role of EFs in relation to PA behavior.

Moreover, it could be suggested for PA promotion programs to target improvement of EFs as well as PA intentions, and to implement efficient strategies by which EF component deficits could be compensated for. Pfeffer and Strobach (2020) reported that for people with lower to average updating performance, planning significantly predicted PA behavior. It was shown that planning could compensate for poor updating abilities especially when intentions are high. In a similar vein, Kelly and Updegraff (2017) documented that activity substitution mediated the relationship between cognitive flexibility (i.e., shifting) and PA, where participants recorded if they engaged in the planned PA, an alternate activity for substitution, or none. As in this study, mediator variables in EFs-PA

relationship should be explored, and further investigated for the purposes of translating these findings into effective strategies to implement in interventions designed to improve PA behavior, taking into consideration individual differences in EF components.

GENERAL DISCUSSION

To summarize, the aim of the present thesis was to investigate self-regulation of PA behavior with the three studies conducted, and specifically to shed light on determinants of PA behavior. At first, BSCS (Tangney et al., 2004), a frequently used measure of trait self-control was validated and adapted to Italian. Results supported that the Italian BSCS is a valid and reliable measure of trait self-control. In the second study, it was aimed to subject PAAM model (Strobach et al., 2020) to an experimental investigation for the first time. Results were in line with the model-driven assumptions and showed that trait self-control moderated the relationship between PA intention and behavior while automaticity mediated the relationship between affective reaction and PA behavior. Thirdly, a systematic review and meta-analysis was carried out to synthesize findings on the impact of EFs on PA behavior, contrary to the vast majority of studies in the literature focused on. Results revealed a significant total effect size indicating EFs predicted PA behavior significantly.

With the three studies, self-regulation of PA behavior was investigated from a dual-process systems approach in line with the current state of art (Brand & Ekkekakis, 2018; Strobach et al., 2020). Findings suggested that trait self-control facilitated intention's translation into behavior consistent with earlier studies (Finne, Englert, & Jekauc, 2019; Pfeffer & Strobach, 2017). The effect of affective reaction on PA through automaticity resonated with the amplification of the habit formation via positive affective experiences during PA (Ekkekakis, 2017; Rhodes & Kates, 2015). Moreover, documenting the predictive role of EFs on PA behavior provided support for the significance of EFs in adherence to PA (Daly, McMinn, & Allan 2014; Hall et al., 2014).

Implications

To elaborate on the implications of the three studies conducted in the present thesis, firstly the evidence supporting the Italian version of the BSCS as a valid and reliable instrument, suggested that

it could be used in clinical practice to measure trait self-control. As large body of research showed that trait self-control predicted important life outcomes and psychological well-being (e.g. Bowlin & Baer, 2012; Ridder et al., 2012), assessment of trait self-control could be beneficial to evaluate to which extent the individuals are struggling in self-control strength.

The results of the second study showed that intention itself was not a significant predictor of PA behavior but the interaction of intention and trait self-control was. Trait self-control enabled individuals to actualize their PA intentions into behavior, which suggests that to reach intended goals, self-control appears to be trivial as documented consistently earlier (e.g. Sheeran & Webb, 2016). Furthermore, automaticity being a strong predictor of PA behavior which was facilitated by positive affective experiences during PA, habit formation process seems to be central for the engagement in PA behavior. Overall practical implications emerge as PA promotion programs should target firstly developing intentions, self-control abilities, facilitation of positive affective experiences during PA, and formation of habits. Third study adding EFs' predictive role on PA behavior indicated that higher EF performance is favourable for adherence to PA, and therefore should be targeted for increasing PA behavior.

Limitations and Suggestions for Future Research

The sample of the validation study was limited in regard to age range and sex distribution. It is highly encouraged for future studies to test the Italian BSCS in other populations. Furthermore, considering the correlational nature of the second study and the studies included in the third meta-analysis study, causal interpretations with confidence were not possible. Experimental manipulation of automatic and reflective process variables as well as macro longitudinal studies are needed. Notably, future research should investigate efficient strategies to compensate for lower levels of trait self-control and lower performances on EF components in order to overcome barriers to initiate and maintain PA as well as ways to improve trait self-control and EFs.

Conclusions

Despite limitations, the present thesis documented that trait self-control coupled with PA intention and EFs are important determinants of PA behavior as part of self-regulatory processes. In addition, it was shown that positive affective reactions during PA predicted PA behavior through behavioural automaticity. Considering the earlier well-established mental and physical health benefits of PA (e.g. Battaglia et al., 2015), in light of the findings of the present theisis, evidence-based PA promotion programs are highly encouraged, targeting to improve PA intention, trait self-control, EFs, and positive affective experiences during PA.

APPENDIX

APPENDIX A: Intention- Intenzione

Cortesemente indica in che misura le seguenti affermazioni sono per te applicabili nelle prossime quattro settimane da 1 (fortemente in disaccordo) a 6 (fortemente d'accordo).

1. Intendo fare esercizio fisico almeno 30 minuti al giorno con intensità moderata-vigorosa.

2. Pianifico di fare esercizio fisico almeno 30 minuti al giorno con intensità moderata-vigorosa.

3. Sono determinato a fare esercizio fisico almeno 30 minuti al giorno con intensità moderata-vigorosa.

APPENDIX B: Behavioral automaticity - Automaticità comportamentale

l'esercizio fisico è qualcosa… (1: In disaccordo - 5: D'accordo)

1. che faccio automaticamente.

2. che faccio senza doverla consapevolmente ricordare.

3. che faccio senza pensare.

4. che inizio a fare prima di rendermi conto che lo sto facendo.

APPENDIX C: Affective reactions - Reazioni affettive

Durante l'esercizio fisico è abbastanza comune che l'umore cambi. Alcune persone trovano l'esercizio fisico piacevole, mentre altre lo trovano spiacevole. Cortesemente valuta come ti senti generalmente durante l'esercizio fisico.

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
molto male		male		abbastanza male	neutrale	abbastanza bene		bene		molto bene

APPENDIX D: Quality Assessment Tool

Items:	Answering options:
1. Are the objectives and hypotheses of the study clearly stated (EFs as predictors of PA)?	Yes (2); Partly (1); No (0); not stated/unclear (?)
2. Are eligibility criteria for the participants stated?	Yes (2); Partly (1); No (0); not stated/unclear (?)
3. Is the number of participants justified?	Yes, based on a priori sample size estimation (2); Yes, but not based on a priori sample size estimation (e.g., discussion of power in the discussion section) (1); No/not stated (0)
4. Was the independent variable (EFs) accurately assessed to minimize bias?	Yes, Objectively / reaction times /computer tasks (2); Yes, but Subjectively/self-reported /Questionnaire (1); No (0); Not stated (?)
5. Do the measurements of EFs truly reflect what you want them to (have they been validated)?	Yes, validation studies and values (e.g., construct or criterion validity) and references are presented (2); Yes, but only based on content validity and references (1); No (0); Not stated (?)
6. Was the outcome (PA) accurately measured to minimize bias?	Yes, Objectively/Step count/Accelerometer (2); Yes, but Subjectively/self-report/Questionnaire (1); No/Not stated/unclear (0/?)
7. Do the measures of PA truly reflect what you want them to (have they been validated)?	Yes, validation studies and values (e.g., construct or criterion validity) and references are presented (2); Yes, but only based on content validity and references (1); No (0); Not stated (?)
8. Is the reliability of the PA measures acceptable?	Yes, reliability studies and values and references are presented (2); Yes, but only based on references (1); No (0); Not stated (?)

9. Was PA as well as age and sex at t1 included as control variables in the analyses?	Yes (2); Partly (1); No (stated but not adequate) (0); Not stated/unclear (?)
10. Was the type of analyses conducted stated and adequate?	Good: ≥ 80% (2); Fair: 51-80% (1); Poor: ≤ 50% (0); Not stated/unclear (?)
11. Quality of results description (about executive variables and PA).	Executive functioning is included in the results (2); Executive functioning is partially included in the results (1); Executive functioning is not included in the results (0)
12. Quality of discussion and conclusion (about executive variables and PA).	Executive functioning is included in the results (2); Executive functioning is partially included in the results (1); Executive functioning is not included in the results (0)
13. Overall rating of the study	Good (2); Fair (1); Poor (0)

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