Health Psychology
2018, Vol. 37, No. 3, 257–261

0278-6133/18/$12.00 http://dx.doi.org/10.1037/hea0000572

BRIEF REPORT

Interaction Between Self-Regulation, Intentions and Implicit Attitudes in the Prediction of Physical Activity Among Persons With Obesity

Guillaume Chevance
University of Montpellier and Les Cliniques du Souffle®, Groupe 5 Santé

Yannick Stephan
University of Montpellier

Nelly Héraud
Les Cliniques du Souffle®, Groupe 5 Santé

Julie Boiché
University of Montpellier

Objective: Both explicit and implicit motivational processes predict physical activity (PA); however, their respective contributions may depend on interindividual differences. This study examined the moderating role of trait impulsivity and executive functions in the associations between PA intentions, implicit attitudes toward sedentary behavior, and PA measured with accelerometers in persons with obesity. ***Methods:*** Participants ($N = 76$; $M_{age} = 56$ years, $SD = 11.9$; $M_{Body\ Mass\ Index} = 39.1$, $SD = 6.5$) completed baseline questionnaires measuring their PA intentions and trait impulsivity. They also performed 2 computerized tests measuring implicit attitudes toward sedentary behavior and executive functions. PA was assessed 4 months later with an accelerometer. ***Results:*** Implicit attitudes toward sedentary behavior and executive functions interacted to predict PA. Higher implicit attitudes were associated with significantly lower PA in participants with low and moderate executive functions but not high executive functions. ***Conclusions:*** These results support the role of implicit processes and cognitive factors in health-related behavior adoption through time. Practically, these variables may be useful to identify individuals at risk of abandoning PA after programs who thus may benefit from complementary interventions (e.g., provide feedback on implicit attitudes and develop self-regulatory skills).

Keywords: executive functions, impulsivity, automatic processes, cognitive factors, obesity

Supplemental materials: http://dx.doi.org/10.1037/hea0000572.supp

Although regular physical activity (PA) is a key component of obesity management, greater than 80% of persons with obesity fail to meet the current guidelines (Ekkekakis, Vazou, Bixby, & Georgiadis, 2016). Therefore, identifying the motivational factors associated with PA in these individuals is crucial. According to contemporary models like the Reflective-Impulsive Model (RIM, Hofmann, Friese, & Wiers, 2008), health-related behaviors are driven by both explicit and implicit motivational processes. Explicit processes refer to conscious regulatory processes, such as beliefs and deliberate intentions. By contrast, implicit processes are assumed to influence health behavior without the person perceiving that influence, thus in a less intentional and more efficient manner (Sheeran et al., 2016). In the PA context, studies have highlighted that both explicit and implicit processes were independently associated with PA behavior (Chevance, Caudroit, Romain, & Boiché, 2017; Conroy, Hyde, Doerksen, & Ribeiro, 2010); however, the respective influence of these two processes toward PA vary between individuals (Friese, Hofmann, & Schmitt, 2009). Explicit processes are theoretically stronger behavioral predictors in people with high self-regulatory dispositions, whereas implicit processes should be more strongly associated with behavior in people with low self-regulatory resources. For example, Hall, Fong, Epp, and Elias (2008) found that explicit processes (i.e., intentions) toward PA were more strongly—and positively—associated with self-reported PA at 1 week in students characterized by higher executive functions. Cheval, Sarrazin, Isoard-

Guillaume Chevance, Epsylon Laboratory, University of Montpellier and Les Cliniques du Souffle®, Groupe 5 Santé; Yannick Stephan, Euromov, University of Montpellier; Nelly Héraud, Les Cliniques du Souffle®, Groupe 5 Santé; Julie Boiché, Epsylon Laboratory, University of Montpellier.

Guillaume Chevance is funded by a grant from the French Agency for Research and Technology. This study has received financial support from the APARD Foundation and the region Occitanie.

It should be noted that this manuscript contains data that are part of a larger study, please see Chevance, Caudroit, Henry, et al. (2017). The sample of participants and the dependent variable (i.e., physical activity) are the same in the two studies.

Correspondence concerning this article should be addressed to Guillaume Chevance, Laboratoire Epsylon, 4 Boulevard Henri IV, 34000 Montpellier. E-mail: guillaumechevance@hotmail.fr

Gautheur, Radel, and Friese, (2016) found that implicit processes (i.e., impulsive approach tendencies) toward sedentary behavior were more strongly—and negatively—associated with PA measured with accelerometers at 1 week in adults with higher levels of impulsivity. Yet, despite these reports, these assumptions have never been examined simultaneously in the same study, which limits comparison of the respective roles of these two moderators.

According to the RIM, health-related problems can be framed in terms of a motivational conflict between unfavorable impulses, favorable reasoned intentions, and self-regulation implicated in the management of this conflict (Hofmann et al., 2008). Thus, drawing upon the RIM and past research (Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2016; Hall, Fong, Epp, & Elias, 2008), the present study sought to examine the moderating role of both impulsivity and executive functions in the associations between PA intentions, implicit attitudes toward sedentary behavior, and PA measured with accelerometers in persons with obesity. It was expected that (a) impulsivity would weaken the positive association between PA intentions and PA behavior but strengthen the negative association between implicit attitudes toward sedentary behavior and PA behavior; and (b) executive functions would strengthen the positive association between PA intentions and PA behavior but weaken the negative association between implicit attitudes toward sedentary behavior and PA behavior. Given that no study has conducted a follow-up over a period longer than 1 week, a 4-month prospective design was adopted to test these hypotheses.

Method

Participants and Procedure

Participants were recruited during a weight-management program. They were eligible for study enrollment if they were between 18 and 75 years old and had a body mass index $\geq$30 kg/m^2. They were not included in the study if they had a medical contraindication to exercise (e.g., serious osteoarticular pain) or were unable to respond to paper-based questionnaires or perform computerized tests. No financial incentives were provided for this study. Procedures were in accordance with the principles of the 1975 Declaration of Helsinki, as revised in 2000, and approved by the Ethics Committee of the Group *5* Santé. All participants provided written informed consent. PA intentions, implicit attitudes toward sedentary behavior, impulsivity and executive functions were measured at the end of a weight-management program (Time 1), during an individual meeting with an experimenter; PA behavior was measured using accelerometers 4 months later (Time 2). The motivational variables (computerized tests were performed with the Inquisit Millisecond 3.0 software, Seattle) were measured at the end of the program to examine PA maintenance after the intervention. A total of 100 participants provided complete baseline measures. Of this sample, 76 provided a valid measure of PA (i.e., $\geq$10 hr/day for at least 1 weekend day and 2 week days) at follow-up (Time 2). No significant differences were found between those who participated at Time 2 and those who did not (see attrition analyses in supplemental materials).

Measures

Physical activity intentions. Three items measuring intentions were formulated following current recommendations (Rhodes & Horne, 2013). Participants were first reminded of the definition of regular PA according to the French national plan for nutrition and health (i.e., doing at least 30 min per day of moderate to vigorous PA, 5 days per week). Following this definition, three items were proposed with a 7-point Likert scale ranging from 1 (*do not agree at all*) to 7 (*totally agree*). Those items were: "I intend to practice a regular physical activity after my weight management program; "Even if I am tired, alone, or sick, I have set the objective of practicing a regular physical activity after my weight management program"; "Even if I have other demands on my time, I will practice a regular physical activity after my weight management program" (Cronbach's alpha = .86). The answers were totaled, with higher scores indicating stronger intentions to practice regular PA.

Implicit attitudes toward sedentary behavior. Implicit attitudes were estimated through the computerized Single Category Implicit Association Test (Karpinski & Steinman, 2006). During the Single Category Implicit Association Test, participants are required to sort stimuli representing three categories with only two response keys, each assigned to two of the three categories (e.g., positive + sedentary behavior vs. negative; positive vs. negative + sedentary behavior; the words used in this study are provided in the supplemental materials). If two categories are highly associated cognitively, the sorting task is expected to be easier when they share the same response key than when they do not. Hence, ease of sorting was estimated with RTs (Richetin, Costantini, Perugini, & Schönbrodt, 2015). Scores were computed using a winsorizing process with R statistical software and the IAT.Score package (this method has provided better support regarding reliability compared with others; see Chevance, Héraud, Guerrieri, Rebar, & Boiché, 2017; Richetin et al., 2015). Scores ranged between −2 and +2, with positive scores revealing more favorable implicit attitudes toward sedentary behavior. Internal consistency (i.e., split-half reliability), calculated using the function SplitHalf from Richetin et al. (2015), was high (r = .88).

Impulsivity. Trait impulsivity was estimated at baseline with a French version of the UPPS-P Impulsive Behavior Scale (Billieux et al., 2012). This questionnaire is a 20-item scale, with all items scored on a 4-point Likert scale. Given that trait impulsivity is not a unitary construct (Sharma, Markon, & Clark, 2014), we computed a score of *lack of conscientiousness* (eight items, Cronbach's alpha = .86), following the recommendations of Billieux et al. (2012). Higher scores indicated higher trait impulsivity.

Executive functions. Executive functions were estimated through a computerized short form of the Wisconsin Card Sorting Test (Greve, 2001). This task is a global task that mainly reflects the shifting component of executive functions and, to a lesser extent, inhibition (Miyake et al., 2000). It requires matching a series of 64 cards presented in the middle of the screen with one of four cards presented on the top of the screen, according to one of three attributes (color, number of elements, shape of elements). The sorting criterion remained the same until the participant correctly sorted eight cards. The percentage of correct responses was used as a performance indicator, with a higher percentage indicat-

ing higher executive functions (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991).

Physical activity. At follow-up, participants were asked to wear an ActiGraph GT3X+ accelerometer (ActiGraph, Pensacola, FL) on their nondominant wrist 24 hr/day for an entire week. Accelerometer data in raw format were processed with R using the GGIR package (van Hees et al., 2014), and the default parameters of the g.shell.GGIR function. Participants with valid data (≥10 hr/day) for at least 1 weekend day ($M = 1.9$, $SD = .27$) and 2 week days ($M = 4.6$, $SD = 1$) were included in the analyses. To qualify as Moderate to Vigorous PA, ≥ 80% of the activity needed to be ≥100 milligravity units, for at least a period (bout) of 1 min, using moving 10-min windows. For each participant, duration in moderate-to-vigorous PA was calculated and reported in mean minutes per day.

Data Analysis

Multiple regression analyses were conducted to examine the moderating role of impulsivity and executive functions in the relationships between PA intentions, implicit attitudes toward sedentary behavior, and PA behavior. In the first model (Model 1), intentions, implicit attitudes, impulsivity, and their interaction terms (i.e., impulsivity*intentions, impulsivity*implicit attitudes) were entered as independent variables and PA behavior as the dependent variable. In the second model (Model 2), PA behavior was regressed on intentions, implicit attitudes, executive functions, and their interaction terms (i.e., executive functions*intentions, executive functions*implicit attitudes). Before running these analyses, outliers were checked and all the independent variables were standardized. Given that PA behavior was positively skewed, we performed a logarithmic transformation.

Results

Descriptive statistics (i.e., means, standard deviations, and Pearson's correlations) are presented as supplemental materials. Results of the regression analyses are displayed in Table 1. No predictors were significantly associated with PA behavior in Model 1. Regarding Model 2, implicit attitudes toward sedentary behavior ($\beta = -.26$, $p = .03$) as well as executive functions ($\beta = .26$, $p = .02$) were significantly associated with PA behavior. Moreover, the analysis revealed a significant interaction between implicit attitudes and executive functions ($\beta = .31$, $p < .01$). Simple slope analyses showed that implicit attitudes more favorable to sedentary behavior were associated with lower PA in participants with low ($b = -.75$, $t = -3.11$, $p = .003$) and moderate executive functions ($b = -.34$, $t = -2.29$, $p = .025$) but not in those with high executive functions ($b = .07$, $t = .38$, $p = .705$; see Figure 1).

Discussion

This study found that implicit attitudes toward sedentary behavior interact with executive functions in the prediction of PA measured with accelerometers. To our knowledge, this study is the first to report an interaction between implicit motivational processes and executive functions in the PA literature. Specifically, holding positive implicit attitudes toward sedentary behavior significantly impeded PA levels in persons with obesity with low and moderate executive functions but not in those with high executive functions. This result confirms the specific hypothesis of the RIM, indicating that individuals with high dispositional resources manage automatically activated impulses better than those with low resources (Friese, Hofmann, & Schmitt, 2009).

Theoretically, executive functions are a set of cognitive processes that are interconnected with reward centers and could explain, in part, the capacity to forgo immediate pleasure in the interests of more long-term benefits (Hall & Marteau, 2014). In the PA context, the management of immediate impulses in favor of long-term benefits is central. Indeed, although regular PA over months will likely lead to many benefits, the initiation of each PA bout may require forgoing more immediate pleasurable activities, such as sedentary behavior. In this regard, the results from this study provide some empirical support for an interaction between implicit motivational influence and executive functions in the prediction of PA.

Practically, this finding offers at least two interventional perspectives. Future research can target either implicit processes to reduce the automatic positive valence of sedentary behaviors, or it can target the enhancement of executive functions to better manage implicit processes. The literature concerning the effectiveness of training executive functions is currently under debate, with recent evidence suggesting that training programs alone are not

Table 1
Multiple Regression Analyses With Prospective Physical Activity as Dependent Variable (N = 76)

Physical activity (Model 1)				Physical activity (Model 2)			
Predictors	β (*SE*)	*P*	R^2	Predictors	β (*SE*)	*p*	R^2
PA intentions	.04 (.17)	.783	.02	PA intentions	.02 (.15)	.889	.16
SB implicit attitudes	−.20 (.16)	.118		SB implicit attitudes	−.26 (.15)	.026	
Impulsivity	.00 (.19)	.951		Executive functions	.26 (.15)	.018	
Impulsivity ∗ PA intentions	.12 (.17)	.388		Executive functions ∗ PA intentions	.06 (.15)	.580	
Impulsivity ∗ SB implicit attitudes	.05 (.13)	.728		Executive functions ∗ SB implicit attitudes	.31 (.15)	.009	

Note. PA = physical activity; SB = sedentary behavior; R^2 = *adjusted* R^2; β = standardized β; ∗ = interaction terms. Results of the interactions remained similar when age, or body mass index, or past PA (i.e., one item asking participants to report habitual frequency of PA per week) or implicit attitudes toward PA measured at Time 1 were entered independently in each model (see the adjusted models in supplemental material). The three-way interactions between intentions, implicit attitudes, and impulsivity in Model 1 (i.e., impulsivity ∗ intention ∗ implicit attitudes) and executive functions in Model 2 (i.e., executive functions ∗ intentions ∗ implicit attitudes) were also examined. In both cases these interaction terms were not significantly associated with PA (see supplemental materials).

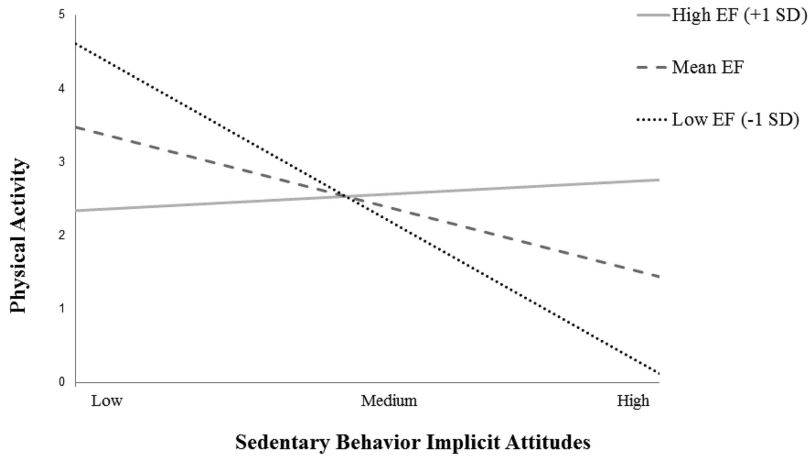

Figure 1. Interaction between implicit attitudes toward sedentary behavior and executive functions. EF = executive functions.

effective to improve self-regulation (Miles et al., 2016). On the other hand, experimental manipulations of implicit processes are scarce in the PA literature, but recent studies have shown encouraging results (Berry, 2016). Combining these two approaches, for example by helping people to identify their implicit attitudes and develop self-regulatory skills, could improve future PA promotion programs for persons with obesity.

In the present study, executive functions did not interact with intentions in the prediction of PA, which does not confirm previous results from the literature (Hall, Fong, Epp, & Elias, 2008). Moreover, trait impulsivity did not moderate the relationships between implicit/explicit processes and PA behavior, as was shown in past research (Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2016). However, these previous studies were conducted with young adults over short periods, whereas the current study considered a longer time interval in the context of a weight-management program. These differences may well explain the discrepancies in the results. Other studies are thus needed to further explore these effects and determine the conditions in which they are verified.

This research has several strengths: the study of both explicit and implicit motivational constructs and their interactions with two conceptually different moderators, its prospective design, and the assessment of PA with accelerometers. It also presents several limitations. First, it was conducted within the context of a specific weight-management program, and other associations might be expected in different contexts, with different time intervals, and among a larger sample less likely to be biased by power issues. Second, executive functions are not a unitary construct, and other patterns of results might have been obtained with different facets of this variable (i.e., inhibition, updating, shifting). Third, the effect sizes reported in this study were small; thus, the clinical relevance of the results should be tempered. Despite these limitations, this study is the first to provide evidence that implicit attitudes toward sedentary behavior and executive functions interact to predict PA in persons with obesity.

References

Berry, T. R. (2016). Changes in implicit and explicit exercise-related attitudes after reading targeted exercise-related information. *Psychology of Sport and Exercise, 22,* 273–278. http://dx.doi.org/10.1016/j.psychsport.2015.09.001

Billieux, J., Rochat, L., Ceschi, G., Carré, A., Offerlin-Meyer, I., Defeldre, A.-C., . . . Van der Linden, M. (2012). Validation of a short French version of the UPPS-P Impulsive Behavior Scale. *Comprehensive Psychiatry, 53,* 609–615. http://dx.doi.org/10.1016/j.comppsych.2011.09.001

Cheval, B., Sarrazin, P., Isoard-Gautheur, S., Radel, R., & Friese, M. (2016). How impulsivity shapes the interplay of impulsive and reflective processes involved in objective physical activity. *Personality and Individual Differences, 96,* 132–137. http://dx.doi.org/10.1016/j.paid.2016.02.067

Chevance, G., Caudroit, J., Henry, T., Guerin, P., Boiché, J., & Héraud, N. (2017). Do implicit attitudes toward physical activity and sedentary behavior prospectively predict objective physical activity among persons with obesity? *Journal of Behavioral Medicine, 41,* 31–42. http://dx.doi.org/10.1007/s10865-017-9881-8

Chevance, G., Caudroit, J., Romain, A. J., & Boiché, J. (2017). The adoption of physical activity and eating behaviors among persons with obesity and in the general population: The role of implicit attitudes within the Theory of Planned Behavior. *Psychology Health and Medicine, 22,* 319–324. http://dx.doi.org/10.1080/13548506.2016.1159705

Chevance, G., Héraud, N., Guerrieri, A., Rebar, A., & Boiché, J. (2017). Measuring implicit attitudes toward physical activity and sedentary behaviors: Test-retest reliability of three scoring algorithms of the Implicit Association Test and Single Category-Implicit Association Test. *Psychology of Sport and Exercise, 31,* 70–78. http://dx.doi.org/10.1016/j.psychsport.2017.04.007

Conroy, D. E., Hyde, A. L., Doerksen, S. E., & Ribeiro, N. F. (2010). Implicit attitudes and explicit motivation prospectively predict physical activity. *Annals of Behavioral Medicine, 39,* 112–118. http://dx.doi.org/10.1007/s12160-010-9161-0

Ekkekakis, P., Vazou, S., Bixby, W. R., & Georgiadis, E. (2016). The mysterious case of the public health guideline that is (almost) entirely ignored: Call for a research agenda on the causes of the extreme avoidance of physical activity in obesity. *Obesity Reviews, 17,* 313–329. http://dx.doi.org/10.1111/obr.12369

Friese, M., Hofmann, W., & Schmitt, M. (2009). When and why do implicit measures predict behaviour? Empirical evidence for the moderating role of opportunity, motivation, and process reliance. *European Review of Social Psychology, 19,* 285–338. http://dx.doi.org/10.1080/10463280802556958

Greve, K. W. (2001). The WCST-64: A standardized short-form of the Wisconsin Card Sorting Test. *Clinical Neuropsychologist, 15,* 228–234. http://dx.doi.org/10.1076/clin.15.2.228.1901

Hall, P. A., Fong, G. T., Epp, L. J., & Elias, L. J. (2008). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology & Health, 23,* 309–326. http://dx.doi.org/10.1080/14768320701212099

Hall, P. A., & Marteau, T. M. (2014). Executive function in the context of chronic disease prevention: Theory, research and practice. *Preventive Medicine, 68,* 44–50. http://dx.doi.org/10.1016/j.ypmed.2014.07.008

Hofmann, W., Friese, M., & Wiers, R. W. (2008). Impulsive versus reflective influences on health behavior: A theoretical framework and empirical review. *Health Psychology Review, 2,* 111–137. http://dx.doi.org/10.1080/17437190802617668

Karpinski, A., & Steinman, R. B. (2006). The single category implicit association test as a measure of implicit social cognition. *Journal of Personality and Social Psychology, 91,* 16–32. http://dx.doi.org/10.1037/0022-3514.91.1.16

Miles, E., Sheeran, P., Baird, H., Macdonald, I., Webb, T. L., & Harris, P. R. (2016). Does self-control improve with practice? Evidence from a six-week training program. *Journal of Experimental Psychology: General, 145,* 1075–1091. http://dx.doi.org/10.1037/xge0000185

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Ahearn, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: A neuropsychological approach. *Neuropsychology Review, 2,* 109–145. http://dx.doi.org/10.1007/BF01109051

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49–100. http://dx.doi.org/10.1006/cogp.1999.0734

Rhodes, R. E., & Horne, L. (2013). Deepening the measurement of motivation in the physical activity domain: Introducing behavioural resolve. *Psychology of Sport and Exercise, 14,* 455–460. http://dx.doi.org/10.1016/j.psychsport.2012.12.010

Richetin, J., Costantini, G., Perugini, M., & Schönbrodt, F. (2015). Should we stop looking for a better scoring algorithm for handling Implicit Association Test data? Test of the role of errors, extreme latencies treatment, scoring formula, and practice trials on reliability and validity. *PLoS One, 10,* e0129601. http://dx.doi.org/10.1371/journal.pone.0129601

Sharma, L., Markon, K. E., & Clark, L. A. (2014). Toward a theory of distinct types of "impulsive" behaviors: A meta-analysis of self-report and behavioral measures. *Psychological Bulletin, 140,* 374–408. http://dx.doi.org/10.1037/a0034418

Sheeran, P., Bosch, J. A., Crombez, G., Hall, P. A., Harris, J. L., Papies, E. K., & Wiers, R. W. (2016). Implicit processes in health psychology: Diversity and promise. *Health Psychology, 35,* 761–766. http://dx.doi.org/10.1037/hea0000409

van Hees, V. T., Fang, Z., Langford, J., Assah, F., Mohammad, A., da Silva, I. C., . . . Brage, S. (2014). Autocalibration of accelerometer data for free-living physical activity assessment using local gravity and temperature: An evaluation on four continents. *Journal of Applied Physiology, 117,* 738–744. http://dx.doi.org/10.1152/japplphysiol.00421.2014

Received May 16, 2017
Revision received August 24, 2017
Accepted August 28, 2017 ■