The association between implicit attitudes toward physical activity and physical activity behavior: A systematic review and correlational meta-analysis

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Abstract:

As a result of recent calls to attend to the implicit processes that regulate health behaviors, the study of implicit attitudes and physical activity behavior has grown rapidly in the past decade. The aim of this study was to summarize existing evidence on the extent to which implicit attitudes toward physical activity are associated with physical activity behavior. A systematic literature review was performed to retrieve studies reporting both a measure of implicit attitudes and physical activity. For the meta-analysis, effect size (Pearson's r) were extracted from eligible studies or retrieved from authors. A total of 26 independent studies, and 55 effect sizes, were eligible. There was a small, significant, and positive correlation between implicit attitudes and physical activity, a finding replicated across multiple meta-analytical strategies with sensitivity analyses applied. This association was not significantly moderated by study design or objective, participants' age or other characteristics, or measures of implicit attitudes or physical activity. This meta-analysis provides evidence that implicit attitudes toward physical activity are positively associated with physical activity in adults to a small degree.

Key words: automatic evaluations; dual-processes; non-conscious; exercise; motivation

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Engaging in regular physical activity has been associated with reduced risk of 25 chronic health conditions (Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017). Indeed, people who engage in at least 150 min of moderate to vigorous physical activity per week are less likely to experience depression and anxiety symptoms (Rebar et al., 2015), develop Alzheimer’s disease (Reiner, Niermann, Jekauc, & Woll, 2013), cardiovascular diseases, type 2 diabetes, osteoporosis, and certain types of cancer (Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). Despite the health benefits of physical activity being quite well known, most people engage in none or far less physical activity than is recommended for optimal health benefits. Self-reported estimates indicate that 31% of adults worldwide are physically inactive, ranging from 43% in the Americas and 35% in Europe to 17% in Southeast Asia (Hallal et al., 2012). Accelerometer-based assessments are even more concerning, with approximately 70% of 18-39-year-old adults and 90% of 60-79-year-old adults not achieving the recommended 150 minutes of weekly moderate-to-vigorous physical activity (Statistics Canada, 2015). These low physical activity prevalence rates highlight the need for new approaches to understand determinants of physical activity behavior and inform the development of effective behavior change interventions (Sheeran, Klein, & Rothman, 2017).

To this point, most efforts to understand physical activity and develop interventions have taken on a social-cognitive approach, applying, for example, the social cognitive theory (Bandura, 1977), theory of planned behavior (Ajzen, 1991), or the health action process approach (Schwarzer, 2008). These models mainly focus on cognitive behavioral determinants such as outcome expectancies, confidence in one’s capacity to perform the behavior, rational formation of intentions and utilization of self-regulatory strategies (i.e., goals, planning; see Rhodes, 2017, and Rhodes, McEwan, & Rebar, 2019 for reviews).

Social cognitive theories are undoubtedly valuable for understanding physical activity. Social cognitive theory-based interventions have a significant impact on physical activity to the order of d = .31; however which specific social-cognitive theory is the basis of a physical activity intervention makes no difference in behavior change efficacy (Gourlan et al., 2016). This finding may, at least partially, be the result of the extensive amount of conceptual overlap of social cognitive theories (see Ekkekakis & Zenko, 2016; Gainforth, West, & Michie, 2015; Gourlan et al., 2016; Rhodes, 2017; Sheeran et al., 2017). That interventions derived from social cognitive theories explain only a small portion of physical activity behavior suggests that these are not comprehensive models of motivation. Relatively recently, new directions in the field have helped broaden perspectives on what types of processes impact physical activity behavior outside of social-cognitive constructs (Brand & Ekkekakis, 2018; Cheval et al., 2018; Conroy & Berry, 2017), with a major advancement being the distinction between “explicit” and “implicit” processes[1] (Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017; Sheeran et al., 2016).

Usually implicit processes are presented as being housed within ‘dual process models’ such as the Reflective Impulsive Model (RIM, Hofmann, Friese, & Wiers, 2008) or the Associative-Propositional Evaluation model (APE, Gawronski & Bodenhausen, 2006). Within these models, explicit processes are described as less efficient and more intentional, controllable and consciously regulated than implicit processes (Bargh, 1994). These processes refer to facets of social-cognitive theories such as beliefs, expectations, intentions and the self-regulation of intention implementation (Rhodes, 2017). Implicit processes, on the contrary, are considered relatively more automatic (Bargh, 1994), such that their behavioral influences are presented as being more efficient, unintentional, uncontrollable, and less conscious than explicit processes (for a critical view of the distinction proposed here see: De Houwer & Moors, 2012; Melnikoff & Bargh, 2018).

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While there is no empirical support yet toward a real distinction amongst the implicit processes described in the literature, some authors have proposed a tripartite classification and labeled implicit processes as either *cognitive*, *affective*, or *motivational* *(Sheeran et al., 2016; Sheeran, Gollwitzer, & Bargh, 2013)*. These authors have proposed that cognitive, affective, and motivational implicit processes refer respectively to distinct constructs such as *attentional bias*, *implicit attitudes* and *impulsive approach-avoidance tendencies*. Among these implicit processes, the construct of implicit attitudes has arguably received much more theoretical and empirical attention than the others in the physical activity literature (Conroy & Berry, 2017; Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017).

Implicit attitudes were originally defined as "*a manifest as actions or judgments that are under the control of automatically activated evaluation, without the performer's awareness of that causation*" (Greenwald, McGhee, & Schwartz, 1998, *p. 1464*). Greenwald and Banaji (1995) acknowledged that this definition was based on previous ones that already included automaticity notions, like the Doob's (1947) definition, which describes attitudes as "…*an implicit, drive-producing response… (p. 136)*". Methodologically, the development of a new class of computerized implicit assessment tools in the mid-1990s marked a burgeoning in the study of implicit attitudes (Gawronski & Brannon, 2018). Unlike explicit attitudes, which are almost exclusively assessed via self-report, the automatic nature of implicit attitudes infers they may not be accessible via introspective reflective and therefore cannot be captured through self-report, so are rather assessed through implicit (or indirect) measures. The main characteristic of implicit measures is that reflections of the targeted construct (e.g., implicit attitudes toward physical activity) are inferred, most of the time through response times and accuracy of performance on categorization tasks (usually computer-based). The most prominent instrument used to this point is the Implicit Association Test (IAT; Greenwald, McGhee, &

Schwartz, 1998) or variations thereof (e.g., Single-Category IAT, Karpinski & Steinman, 2006; for a review of implicit measures see Gawronski & De Houwer, 2014).

In the physical activity literature, implicit attitudes correspond to the expression of *automatic evaluations of physical activity*, which are the affective experiences that arise rapidly and involuntarily when the concept of physical activity is activated in a person's mind (Conroy & Berry, 2017). The more positive a person's implicit attitude toward physical activity (i.e., positive automatic evaluations toward physical activity), the more she/he will be physically active. In theory, implicit attitudes are likely to be associated with physical activity behavior directly and indirectly, through other implicit processes or explicit processes (Gawronski & Bodenhausen, 2006; Hofmann et al., 2008; Perugini, Richetin, & Zogmaister, 2010). To this point, studies have demonstrated that implicit attitudes are directly associated with the amount of physical activity people engage in, both self-reported or measured with accelerometers, even after controlling for the variability explained by explicit processes (see Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017, for reviews). Indeed, several studies found that implicit and explicit attitudes toward physical activity are mostly unrelated (e.g., Brand & Antoniewicz, 2016; Hyde, Doerksen, Ribeiro, & Conroy, 2010) and independently associated with physical activity behavior (e.g., Calitri et al., 2009; Chevance, Caudroit et al., 2017; Padin et al., 2017). However, to the best of our knowledge, there is no evidence yet of indirect associations between implicit attitudes and physical activity through interactions with explicit processes (see for example Muschalik, Elfeddali, Candel, & de Vries, 2018; Chevance, Caudroit et al., 2018), or other implicit processes (e.g., attentional bias, approach-avoidance tendencies, see Oliver & Kemps, 2018).

The Present Study

From an initial study conducted more than 10 years ago testing the role of implicit attitudes toward physical activity behavior (Eves, Scott, Hoppé, & French, 2007), multiple studies have been conducted investigating links between these two variables (see (Cheval, Sarrazin, & Radel, 2016; Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017). Amidst their systematic reviews with broader aims of understanding links between implicit processes and physical activity behavior, Cheval et al. (2016) and Rebar et al. (2016) reviewed studies testing associations between physical activity and implicit attitudes, concluding that the evidence at that point was largely correlational. Schinkoeth and Antoniewicz (2017) systematically reviewed studies testing implicit attitudes and exercise behavior associations, concluding that most studies found small-to-medium effects, and noting great heterogeneity between studies. Although the state of the literature is such that aggregative reviews are being conducted and theoretical advancements established (e.g., Conroy & Berry, 2017; Rebar, 2017), there has yet to be a quantitative synthesis of the direction and magnitude of the relationship between implicit attitudes and physical activity behavior. This estimation will provide evidence to ensure that future correlational studies are appropriately powered and evidence-based theoretical propositions about the existence and size of the link between implicit attitudes and behavior.

As highlighted by previous reviews, there is some interesting heterogeneity in the literature: the measurement of implicit attitudes varies across studies, as does the measurement and quantification of physical activity behaviors (Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017). Additionally, there is heterogeneity in the timing and samples of the tested correlations; retrospective, cross-sectional and prospective associations have been tested; and studies have involved a variety of populations including university students, adults from the general population, exercisers, or people living with chronic diseases. All these divergences between studies may impact the magnitude of the association between implicit attitudes and physical activity, but have not been tested through a meta-analysis.

The aim of this study is to summarize existing evidence on the extent to which implicit attitudes toward physical activity are directly associated with physical activity behavior. According to the correlations observed in the health psychology literature (Rooke, Hine, & Thorsteinsson, 2008), effect size in the small-to-medium range (Cohen, 1992) is expected. No a priori hypotheses were formulated regarding moderator analyses.

Methods

The systematic review and meta-analysis were conducted in accordance with the PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009, see supplemental materials), principles of the Meta-Analysis Reporting Methods (MARS, American Psychological Association, 2008), and recommendations provided by Quintana (2015), as well as Lakens, Hilgard, & Staaks (2016). The study protocol was uploaded on the *Open Science Framework* (OSF) prior to data collection and analyses (available at https://osf.io/mgv82/) all the study materials and data are provided in supplemental materials and on OSF). Differences between the protocol, the initial pre-print of this study and peer-reviewed version are also detailed in supplemental materials.

Search Strategy

A systematic review of the literature was performed to retrieve studies reporting both a measure of implicit attitudes toward physical activity and physical activity behavior. The search was conducted using the databases PubMed, PsycARTICLES, PsycINFO, SPORTDiscus, and Open Grey (Conn, Valentine, Cooper, & Rantz, 2003). Studies were also sourced from three relevant systematic reviews (Cheval et al., 2016; Rebar et al., 2016; Schinkoeth & Antoniewicz, 2017). Articles published in peer-review journals in French or English, up to December 2018, were included. The following combination of terms was used: ("implicit attitudes" OR "automatic evaluations" OR "dual-processes" OR "non-conscious") AND ("Exercise" OR "Exercising" OR "Exerciser" OR "Physical activity" OR “Walking”). The inclusion screening was based on article abstracts and titles. Two independent coders (GC, PB; GC, AR) conducted searches and screening; any discrepancies were identified and resolved (see https://osf.io/mgv82/). To reduce the risk of publication bias, authors of eligible studies were contacted and asked to provide any relevant unpublished data.

Criteria for Study Inclusion

Studies reporting both measures of implicit attitudes toward physical activity and physical activity behavior were included. Implicit attitudes were defined as automatic evaluations reflecting “*the affective experiences that arise rapidly and involuntarily when the concept of physical activity is activated”* (Conroy & Berry, 2017). For this study, a valid measure of implicit attitudes was defined through the utilization of (*i*) a validated implicit measurement procedure (for a review, see Gawronski & De Houwer, 2014), and (*ii*) physical activity or exercise stimuli combined with positive or negative stimuli. This second criterion excluded studies assessing only other implicit processes such as attentional bias (e.g., Berry, 2006), implicit identity (e.g., Banting, Dimmock, & Lay, 2009), approach/avoidance tendencies (e.g., Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2015), or implicit attitudes toward specific object such as a physical activity promotion program (e.g., Yun & Berry, 2018) or toward sedentary behavior (e.g., Chevance, Caudroit, et al., 2018), as the measure stimuli were not exclusive to positive, negative and physical activity/exercise.

Physical activity was defined, “*bodily of movement that results in a substantial increase over the resting energy expenditure*” (Caspersen, Powell, & Christenson, 1985). This broad definition allowed for inclusion of different types and intensity of physical activity (e.g., moderate to vigorous, light, total), expressed in different units (e.g., metabolic equivalents, number of steps per day or week, mean time per day or week), and measured through self-reported questionnaires, as well as pedometers or accelerometers.

Cross-sectional (i.e., implicit attitudes and physical activity measured during the same session), retrospective (i.e., physical activity measured before implicit attitudes) and prospective (i.e., physical activity measured after implicit attitudes) studies were included. Studies adopting an experimental, quasi-experimental or interventional design were included, but only data of implicit attitudes and physical activity done before any intervention/experimental manipulation were retained for the meta-analysis. Studies involving adults (>18 years old) were included without a maximum age limitation.

Data Extraction and Management

Effect sizes were extracted from eligible studies or retrieved post hoc from the authors when not reported in the article. An a priori data extraction form was developed and data were coded from each paper by three coders (GC, PEC, AR). Discrepancies were identified and resolved by re-referencing the articles. The following information was extracted: first author's name and publication year, characteristics of the participants, study design, the implicit attitudes measure and scoring procedures, the physical activity measure, the correlation (*r*) between implicit attitudes and physical activity and sample size. When available, we also extracted the associations between implicit attitudes and physical activity after controlling for the variance explained by other explicit processes (e.g., explicit attitudes, intentions), to investigate an additive correlational pattern (Perugini, Richetin, & Zogmaister, 2010).

Quality Assessment

Following the method of Molloy, O'Carroll, and Ferguson (2014), a custom tool of five criteria were used to assess study quality including the: (*i*) study design (prospective study = 1, cross-sectional or retrospective study = 0): (*ii*) measure of physical activity (utilization of pedometers or accelerometers = 1, other = 0); (*iii*) sample size (more than 85 participants = 1, less than 85 = 0; *N* = 85 was chosen as the appropriate cut-off because it is the minimum number required to have 80% power to detect a medium effect size using *r* and an alpha of 0.05; Cohen, 1992); (*iv*) validity of physical activity assessment (validated measure = 1, non-validated measure = 0); and (*v*) information regarding the reliability (e.g., Cronbach's alpha or split-half reliability) of the implicit measure (reliability reported = 1, not provided = 0). The score was computed for each reported effect size and then averaged, leading to a study score between 0 and 1, with higher score interpretable as higher study quality. For sensitivity analyses, the study quality scores were split into a 'high' ($\geq$ .08), 'medium' (.02 > score < .08) or 'low' ($\leq$ .02) categorical variable.

Moderator Coding

Ten potential moderators were tested: (*i*) participants' mean age (i.e., treated as a continuous moderator); (*ii*) type of population (i.e., nominal moderator: people with chronic diseases *versus* participants from the general population *versus* University students); (*iii*) study design (i.e., nominal moderator: cross-sectional *versus* retrospective *versus* prospective); (*iv*, *v*) physical activity measure (i.e., nominal moderator: self-reported [this also included interview-based questionnaires and frequency of physical activity participation retrieved from someone other than the participant] *versus* accelerometers and pedometers); physical activity type (i.e., moderate to vigorous physical activity score *versus* other scores, including total physical activity, light intensity physical activity or incidental physical activity); (*vi*, *vii*) implicit attitudes assessment (i.e., nominal moderator: classification tasks *versus* priming tasks; IAT and relative tasks *versus* others tasks; (*viii*) study quality (i.e., treated as a continuous moderator). Two moderators were added post-registration of the protocol: (*ix*) given that most studies were conducted by a small set of research laboratories, one moderator corresponding to the research teams was proposed (i.e., categorical moderator: Berry et al., *versus* Brand et al., *versus* Boiché et al., *versus* Conroy et al., *versus* others), and it was explored if effect size varied according to the study's main objective (i.e., categorical moderator: studies which aimed to explore the correlation between implicit attitudes and physical activity *versus* studies with other main aims [e.g., examining change in implicit attitudes]).

Statistical Analyses

Pearson's r was used as effect size, and Fisher's r-to-z transformation was performed (Borenstein et al., 2009). For one study (Bluemke, Brand, Schweizer, & Kahlert, 2010), Spearman's correlations were converted to Pearson's correlations before Fisher's r-to-z transformation according to Gilpin (1993). After the calculation, Fisher's *z* was converted back to Pearson's *r* for reporting the average correlation and 95% confidence interval (CI). Magnitude of effect sizes (*r*) were interpreted as small > .1, medium > .3, and large > .5 (Cohen, 1992). The meta-analysis employed a robust variance estimation to account for dependencies of having multiple effect sizes come from each study. Statistical dependency is very common in psychology (Moeyaert et al., 2016), especially dependency in the sampling errors that occurs if multiple measures of the variables are performed within a same study (e.g., physical activity measured with both a questionnaire and an accelerometer).

Robust variance estimation accounts for dependent effect sizes by estimating an overall effect size across studies as a weighted mean of the observed effect sizes (see Hedges et al., 2010, Tanner-Smith & Tipton, 2014; Tipton, 2015). This method allows simultaneous analysis of multiple effect sizes per study with accurate estimates and standard errors, even when information on the covariance of these effect sizes is unavailable. If needed, the robust variance estimation method could also be adjusted for "small" meta-analyses containing fewer than 40 studies (Tipton, 2015; this correction was applied in the present study).

There are three advised options for managing with dependent effect sizes in meta-analyses. Researchers can choose to aggregate effect sizes within-study, perform a multi-level meta-analysis, or utilize robust variance estimation. Recently, Moeyaert et al. (2016) conducted a simulation study to compare the statistical performance of these three different approaches. They concluded that each of these options results in unbiased estimates; however, in scenarios in which there are a limited number of studies for analyses (N = 25), they recommend that the robust variance estimation method should be applied. To ensure we applied the most robust and conservative approach, we used the robust variance estimation method as the main meta-analytic approach. An aggregated meta-analysis and multi-level meta-analysis were also performed as sensitivity analyses (see below).

Traditional influence or publication bias analyses (e.g., Egger's regression test, multivariate outliers' diagnostics) are not implemented in the statistical package used to perform the robust variance estimation. To overcome this limitation, we followed the method used by Zelinsky and Shadish (2016). First, univariate outliers were inspected with the Grubbs test on all effect sizes (two iterations were performed). Then, we conducted influence and publication bias analyses using the aggregated method (one aggregated effect size per study). Within this aggregated analysis, Baujat Plot (Baujat, Mahé, Pignon, & Hill, 2002) and residual cook's distances were used to identify multivariate outliers (Viechtbauer & Cheung, 2010, see in supplemental results). Univariate and multivariate outliers detected with these methods were compared and referenced to inform the sensitivity analyses. Contour enhanced and traditional funnel plots were also performed within the aggregated meta-analyses and are provided as supplemental results.

Heterogeneity was quantified with I^2 for the robust variance estimation meta-analysis. An I^2 value of 25 was interpreted as having a low dispersal, 50 as moderate, and 75 as high dispersal (Higgins, Thompson, Deeks, & Altman, 2003). Moderator analyses using robust variance estimation and correction for small sample size were performed following Tipton (2015). Significant moderator effects were discussed only when the df < 4 and p

$< .01$ to prevent potential Type I error.

Sensitivity analyses

As recommended by Greenhouse and Iyengar (2009), a set of sensitivity analyses were carried out to verify the robustness of ours estimated effect sizes. First, results from the robust variance estimation meta-analysis were compared with the aggregated (one effect size retained per study), and multi-level meta-analyses (Assink & Wibbelink, 2016). Then, combining results from the univariate and multivariate outliers' detection, the three models were computed a second time after removing the influent effect sizes. Finally, the three meta-analyses models were performed omitting effect sizes from low quality studies (i.e., quality score $\leq .02$).

All analyses were carried out in R 3.2 (R Core Team, 2016) using the *robumeta* package (Fisher & Tipton, 2015) for the robust variance estimation meta-analysis, the *metaphor* package (Viechtbauer, 2010) for the multi-level meta-analysis, and the *MAc* package (Del Re & Hoyt, 2012) for the study aggregation. Analyses were performed by GC and independently replicated by PB. The dataset and script to perform the analyses are available as supplemental materials and on the OSF page of the project *(https://osf.io/mgv82/)*.

Results

Systematic Review

As depicted in the flow diagram (see Figure 1), a first iteration resulted in a total of 112 extracted articles, with 2 additional included studies published after the last systematic review iteration, 3 additional included datasets from unpublished manuscripts, and one thesis identified in the grey literature. After removing duplicates and screening titles and abstract, 40 articles were extracted for full-text screening, which resulted in 26 eligible articles and 58 associations. Of the 7 authors contacted for additional data from their published studies, 2 were unable to provide it, leading to a total of 55 effect sizes for use in the meta-analysis.

[Insert Figure 1 about here]

Sample sizes range from $N = 44$ to $N = 340$, the majority ($k = 15/26$ studies) included a University student sample, used a questionnaire to estimate physical activity ($k = 44/58$ effect sizes), and an IAT or adapted task (i.e., SC-IAT; B-IAT) to measure implicit attitudes ($k = 43/58$ effect sizes). Among the 58 associations found, 21 were obtained from a cross-sectional design, 19 from a retrospective design, and 18 from a prospective design. Regarding physical activity type, half of the included effect sizes were representative of a moderate to vigorous physical activity measure ($k = 34/58$ effect sizes), whereas the others used total physical activity (i.e., planned exercise, as well as household, work, or commuting activity), the number of steps per day, or average activity counts measured with accelerometers.

Among the 26 independent studies, 10 examined an additive correlational pattern between implicit attitudes and physical activity after controlling the variance explained by social-cognitive constructs. Regression analyses included constructs such as intentions (controlled in 6 studies of 10), explicit attitudes (5/10), or self-belief measures such as self-efficacy or perceived behavioral control (3/10). Of these 10 studies, 6 reported positive and significant associations between implicit attitudes and physical activity after controlling for one (or more) social-cognitive construct (studies number 8, 9, 11, 12, 13, 22 in the Table 1), 5 reported non-significant associations (studies number 11, 14, 15, 20, 22), and one study reported a significant but negative correlation between implicit attitudes and physical activity (study number 21). An overview of these studies is provided in Table 1.

[Insert Table 1 about here]

Association between Implicit Attitudes and Physical Activity

The robust variance meta-analysis corrected for small sample size revealed that there was a positive correlation between implicit attitudes toward physical activity and physical activity behavior [r = .11, 95% CI (.05, .17), p < .001; see Figure 2]. There was a moderate level of heterogeneity (I^2 = 51%). Two univariate outliers (Oliver & Kemps, 2018; Berry et al., 2011) were identified with the Grubbs tests performed on the 55 available effect sizes. In the aggregated analysis, one multivariate outlier (Oliver & Kemps, 2018) was identified (see in supplemental results). Robust variance estimation analyses omitting outlier effect sizes lead to comparable estimates [without Oliver & Kemps, 2018: r = .11, 95% CI (.05, .17), p < .001; without Oliver & Kemps, 2018 and Berry et al., 2011: r = .10, 95% CI (.04, .16), p < .001].

[Insert Figure 2 about here]

Sensitivity analyses

Sensitivity analyses were conducted to test the difference between the three meta-analysis models (i.e., robust variance estimation with correction for small sample size, aggregated and multi-level meta-analyses), compare models that included and excluded potential outliers, and studies with low quality ratings. Among these 12 models (see Figure 3), the lowest estimate was obtained with the multi-level meta-analysis, excluding low quality studies [k = 47 effect sizes, r = .07, 95% CI (.02, .13), p < .01]. The greatest estimate was obtained with aggregated meta-analysis excluding Oliver and Kemps's study [k = 24 effect sizes, r = .12, 95% CI (.08, .17), p < .001]. All these 12 estimates were statistically significantly different from zero.

[Insert Figure 3 about here]

Moderator Analyses

Ten potential moderators were tested using robust variance estimation: participants' age, characteristics, study design, physical activity measure (2 moderators), implicit attitudes measure (2 moderators), study laboratory, study quality and study objective. Results revealed that none of them were statistically significant (Table 2).

[Insert Table 2 about here]

Discussion

Our aim was to provide a systematic review and meta-analysis of the direct correlation between implicit attitudes toward physical activity and physical activity behavior. To our knowledge, this is the first meta-analysis of this emerging area of research interest. Implicit attitudes toward physical activity were significantly correlated with physical activity behavior, with a small effect size [r = .11, 95% CI (.05, .17)], and the association was robust over the different models and sensitivity analyses performed. This finding aligns with relatively newly introduced theory to physical activity research that physical activity behavior is partially regulated by automatic processes (Brand & Ekkekakis, 2018; Cheval et al., 2018; Conroy and Berry, 2017). Across other fields of health psychology, Rooke, Hine, & Thorsteinsson (2008) found a slightly stronger correlation of r = .27 [95% CI (.21, .31)] between implicit attitudes and substance use (i.e., alcohol, cigarettes, cocaine, marijuana). Greenwald et al. (2009) reported a sub-group summary correlation of .22 [95% CI (.15, .29)] between implicit attitudes and alcohol and drug use. Taken together (see Figure 4), the findings of the present meta-analysis suggest that implicit attitudes have a smaller association with physical activity behavior (around r = .10) than those of substance use. It may be that the association is smaller because physical activity encompasses more than just a single behavior which may be goal-driven or incidental; whereas drug and alcohol use describes precise actions.

Comparatively, the correlation between implicit attitudes and physical activity seems much smaller than those observed for other motivational determinants of physical activity. Indeed, McEachan et al. (2011) found a mean *r* of .45 between intentions toward physical activity and physical activity behavior; Rhodes, Fiala, and Conner (2009) found a summary *r* of .42 between affective judgments and physical activity. Gardner, de Bruijn, and Lally (2011) reported a mean *r* of .46 between scores of the self-reported habit index and physical activity behavior. It may be that implicit attitudes truly are less associated with physical activity than these motivational processes; however, conclusions should be tempered with consideration for alternative explanations of the size of these effects.

One potential methodological rationale that may explain this discrepancy in effect sizes is the principle of correspondence (Ajzen & Fishbein, 1977; Perugini, Richetin, & Zogmaister, 2010), in that the more a construct measure shares relevant features with a behavioral measure, the stronger their correlation. In previous meta-analyses (Gardner, de Bruijn, & Lally, 2011; McEachan et al., 2011; Rhodes, Fiala, & Conner, 2009), both the motivational variable and physical activity were typically assessed via self-report questionnaires (181 of the 197 studies include in these meta-analyses used a self-report measure of physical activity). On the contrary, the present findings are based on response timed implicit measurement and either monitor or self-report based measures of behavior. Therefore, it is not necessarily surprising that the correspondence between such disparate measures (i.e., self-reported *versus* reaction time-based measure) are lower than those assessed with more convergent measures.

A second reason that might explain the small correlation between implicit attitudes and physical activity behavior is that implicit attitudes are associated with physical activity only in some conditions, for some people, and regarding specific behaviors. Indeed, associations between implicit attitudes (and more broadly other implicit processes) and physical activity are likely to vary depending on several situational, dispositional and behavioral moderators (Friese, Hofmann, & Schmitt, 2008). Situational moderators refer to state variables that are likely to vary in short temporal scales (i.e., minutes, hours, days) or due to environmental features such as stress, mood, or social desirability. Dispositional moderators mainly refer to more trait-like variables such has personality (i.e., impulsivity) or cognitive abilities (i.e., self-regulation) which are presumably more stable over time. Behavioral moderators correspond to the features of the specific behavior under scrutiny, such as the difference between a planned and incidental behavior. In theory, the less a behavior is under cognitive control, the stronger implicit processes' role should be in predicting that behavior. Given that only a few studies among those included in the present systematic review included moderator analyses (4 of 26 studies), it is clear that more work is needed to understand the specific conditions under which implicit attitudes are, and or are not, associated with physical activity behavior.

To illustrate, two studies indicate that the relationship between implicit attitudes and physical activity could be moderated by dispositional variables. Padin et al. (2017) found that implicit attitudes toward exercise were associated to physical activity among students with low, but not high, effortful control (one aspect of self-regulation). It may be that individuals with higher capacity for self-regulation relied less on implicit attitudes toward physical activity to guide behavior than those with lower self-regulation. In a similar fashion, Chevance, Stephan et al. (2018) showed that implicit attitudes favorable to sedentary behaviors were prospectively associated with significantly less physical activity in obese adults with low and moderate, but not high, executive functions. It may be that people with high executive functioning may be able to overcome the influence of negative implicit attitudes toward physical activity (or resist influence from positive implicit attitudes toward sedentary behavior). To our knowledge, situational or behavioral moderators of the relationship between implicit attitudes and physical activity have not been investigated yet. Other studies investigating the conditions in which implicit attitudes are specifically associated with physical activity are thus needed, and this includes studies investigating the moderating effects of other implicit and explicit processes (see for example Muschalik et al., 2018; Oliver & Kemps, 2018).

The study-level moderators explored in this study were not found to significantly impact the correlation between implicit attitudes and physical activity. However, given the presumed low statistical power of our moderator analyses, this does not constitute strong evidence for null effects (Hedges & Pigott, 2004). Other studies are clearly needed to understand how study features such as measures of implicit attitudes (i.e., type of tasks, stimuli, and scoring algorithms) impact the correlation between implicit measures and physical activity (see Chevance et al., 2017b; Rebar et al., 2015; Zenko & Ekkekkakis, 2019 for methodological studies). For example, reliability of implicit measures is often not reported in the literature (only 9 studies of 26 in the present study). Researchers are thus encouraged to systematically compute the internal consistency of their implicit measures, using preferentially standardized methods (see Richetin, Costantini, Perugini, & Schönbrodt, 2015) and take appropriate steps to account for poor reliability if necessary. Although the moderator analysis of study quality rating was not statistically significant, the sensitivity analysis excluding low quality studies reported systematically lower correlations between implicit attitudes and physical activity (see Figure 4). This suggests that the implicit attitudes-physical activity correlation could be overestimated due to methodological weaknesses (i.e., self-reported measure of physical activity, cross-sectional design, limited sample size, validity/reliability of physical activity and implicit attitudes measures). Future multi-lab investigations could be beneficial for producing more powerful, replicable, and rigorous studies in the field (see for example, Lai et al., 2016).

Complementary Perspectives

The present review brought to light many unresolved issues that should be addressed as the field advances. Firstly, in comparison with traditional socio-cognitive models (e.g., the Theory of Planned Behavior, Ajzen, 1991) or more contemporary inclusive models (e.g., The Multi-Process Action Control Approach, Rhodes, 2017), dual-process models describe overarching heuristics hypotheses without specifying precise pathways between underlying theoretical constructs (Deutsch, Gawronski & Hofmann, 2017). For example, the Theory of Planned Behavior (Ajzen, 1991) describes both specific processes (e.g., explicit attitudes, intentions) and related hypotheses (e.g., intentions mediate the relationship between explicit attitudes and behavior). On the contrary, dual-process models put forth claims about the types of influences that are present (e.g., behaviors can be framed in terms of conflict between implicit and explicit processes) without specifying the constructs or the nature of the links between constructs (Hofmann, Friese, & Wiers, 2008; Gawronski & Bodenhausen, 2006). Several proposals are made below to solve this question.

In this paper we chose to align with the classification proposed by Sheeran, Gollwitzer and Bargh (2013) that specify three different categories of implicit processes: cognitive (e.g., attentional bias), affective (e.g., implicit attitudes), and motivational constructs (e.g., non-conscious goal pursuit). In future, it would be interesting to empirically test this classification, how these different implicit constructs, and whether their relative measures, are (or are not) associated, and to what extent they independently contribute to explain physical activity behavior (see Oliver & Kemps, 2018). For example, it could be interesting to explore whether different measures developed to reflect implicit attitudes share variability that is not shared with measures of other constructs (i.e., attentional bias), accounting for method and random residual error (see Bar-Anan & Vianello, 2018). More specific hypotheses, such as the mediating role of impulsive approach-avoidance tendencies in the relationship between implicit attitudes and physical activity could also be explored (see Chen & Bargh, 1999; Rotteveel et al., 2015). Such studies might help to understand the mechanisms that relates implicit attitudes to physical activity behaviors.

Additionally, there is no evidence yet determining whether implicit attitudes interact with other explicit motivational constructs to influence physical activity. For example, the Temporal Self-regulation Theory (Hall & Fong, 2007) proposes that intention-behavior gap (i.e., the variability in behavior left unexplained by intentions) could be partially explained by unfavorable implicit processes (see Cheval et al., 2015). To our knowledge, this hypothesis has been tested at least twice in prospective designs, both showing non-significant moderation effects of implicit attitudes on intention-behavior associations (Chevance, Caudroit et al., 2018; Muschalik et al., 2018). Recently, Oliver and Kemps (2018) also reported non-significant moderation effects of implicit attitudes on associations of physical activity behavior with controlled and autonomous forms of motivation (motivation constructs based on self-determination theory). Other studies are thus needed to understand the process by which implicit attitudes and explicit processes interact to explain physical activity variability. In the same vein, measuring the discrepancy between explicit and implicit attitudes measures (see Brand & Antoniewicz, 2016) could also help to understand how these two processes conjointly influence physical activity within individuals.

Beyond teasing apart the mechanism by which implicit attitudes are associated with behavior, bi-directional relationships between implicit attitudes and physical activity could also be hypothesized. For example, a recent retrospective study showed that childhood memories of physical education are associated with explicit attitudes toward physical activity and sedentary behaviors in adulthood (Ladwig, Vazou, & Ekkekakis, 2018). Moreover, studies indicate that affective responses to short bouts of exercise are subsequently associated with affective judgments about physical activity and, possibly, physical activity behavior directly (Ekkekakis & Dafermos, 2012; Rhodes & Kates, 2015). As implicit attitudes are malleable over time (Hyde et al., 2012), it may be that implicit attitudes toward physical activity vary, in both short and long term, as a consequence of past experiences with exercise and physical activity, and these changes may ultimately impact subsequent physical activity (see Brand & Ekkekakis, 2018; Hyde et al., 2012). More broadly, the origins, development and determinants of implicit attitudes have not been yet studied in the physical activity context. In future, it could be interesting to explore how implicit attitudes toward physical activity evolve during childhood (Dunham, Baron, & Banaji, 2008), how parents' and peers' implicit attitudes are shared in the social environment (see Guidetti, Conner, Prestwich, & Cavazza, 2012; Sherman, Chassin, Presson, Seo, & Macy, 2009), and what factors are prospectively associated with implicit attitudes development and change over time.

The field is advancing such that it is becoming increasingly clearer that motivation needs to account for competing alternative behavioral options to physical activity, and literature is emerging on the role of implicit attitudes toward conflicting behaviors such as sedentary behavior (i.e., time spend sitting, Tremblay et al., 2017) in the prediction of physical activity (sometimes this behavioral choice is incorporated as a relative choice in implicit measures of relative preferences such as the IAT). Indeed, recent theoretical reviews have suggested that "behaviors minimizing energetic cost", such as sedentary behaviors or physical inactivity, could be rewarding and imped physical activity participation (Cheval et al., 2018; Brand & Ekkekakis, 2018). In line with these hypotheses, Chevance, Caudroit et al. (2018) found a trending negative association (p = .06) between implicit attitudes toward sedentary behaviors (i.e., automatic evaluation of sedentary behaviors stimuli as pleasant or unpleasant) and physical activity measured four months later with accelerometers, after controlling for implicit attitudes toward physical activity and additional covariates. Hence, investigating how implicit processes toward alternative choice behaviors could negatively be associated with physical activity may extend our understanding of original dual-process model-based hypotheses of conflict between explicit and implicit processes (Hofmann, Friese, & Wiers, 2008).

Finally, two frameworks were recently developed to guide the experimental manipulation of implicit processes (see Hollands, Marteau, & Fletcher, 2016; Papies, 2016). Papies (2016) pointed out that these interventions might change the features of the environment to influence the activation of implicit processes in specific time and place (i.e., *cueing interventions*) and/or directly change the implicit processes that drive behaviors (i.e., *training interventions*). To date, a handful of studies have started exploring training interventions in the physical activity context. Retraining approach-avoidance tendencies (Cheval, Sarrazin, Pelletier, & Friese, 2016), evaluative conditioning (Antoniewicz & Brand, 2016b), delivering tailored exercise-related messages (Berry, 2016), and mental imagery (Markland, Hall, Duncan, & Simatovic, 2015) have all shown promise in modifying implicit processes. However, these studies have been conducted with students in a laboratory context, and the next step would be to examine their relevance in more ecologically valid settings (see Chevance et al., 2019 for a null findings).

Limitations

Conclusions from the present meta-analysis should be tempered by a number of limitations. First, the majority of the study included (15/26) were conducted among students which impact the generalizability and transferability of the findings. Future research should include more heterogeneous population samples. Second, it would have been interesting to estimate the contribution of implicit attitudes toward physical activity behavior after controlling for key explicit processes (i.e., incremental validity), as it has been done in some individual studies (e.g., Chevance et al., 2017; Conroy et al., 2010). While there is some evidence in the field that implicit attitudes are independently associated with physical activity behavior after controlling different traditional socio-cognitive constructs (5 to 7 studies of 10 in the present systematic review), lower effect sizes could be expected between implicit attitudes and physical activity after controlling for those “explicit” processes. In the same manner, controlling for past physical activity could have added important insight into how implicit attitudes are associated with behavior change. Incorporating past behavior into other meta-analyses has shown mitigating effects of the link between psychological determinants of physical activity (i.e., intentions) and physical activity behavior (Hagger, Chatzisarantis, & Biddle, 2001). This intriguing question could not be tested in the present study given multiple physical activity behavioral measures were rare in the included studies. The role of other motivational variables and past physical activity in the link between implicit attitudes and physical activity should be more tested further in future studies (see Blanton, Burrows, & Jaccard, 2016). Furthermore, it could be interesting in future meta-analyses to consider the measurement error (i.e., internal consistency) of implicit measures in the estimation of the mean effect size (Kurdi et al., *submitted*).

Conclusion

In conclusion, this meta-analysis provides evidence that implicit attitudes toward physical activity are positively associated with physical activity behavior in adults to a small degree. The field of implicit processes is still in its infancy in the physical activity context and many other studies are needed to better understand how, for whom and in which situations, implicit attitudes are associated with physical activity behavior. Following the evolution of these process questions, it is essential to investigate behavior change theory insights such as where implicit attitudes toward physical activity come from, how implicit attitudes could be modified, and whether such modification could lead to lasting physical activity behavior change.

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Footnote

[1]We used the term implicit here knowingly that there is no consensus yet in the literature regarding terminology. The term “implicit” can also refer to other terms like: type- 1 processes, associative, automatic, impulsive; while the term “explicit” refers to: type-2 processes, propositional, controlled, reflective. Although we acknowledge the controversy, this debate of terminology is not within the scope of this review and will not be further discussed.

Table 1. Studies identified in the systematic review

	Study	Participants	Design⁺	Implicit attitudes	Physical activity	Direct correlation	Additive correlational pattern°
1	Antoniewicz & Brand 2014*	*N* = 72 graduate sport and exercise students M_{age} = 26 ± 9 years 43% female M_{PA} = 305 ± 190 min of weekly exercise	Cross-sectional	*Task*: Affective Misatribution Procedure (AMP, Payne et al., 2005) *Stimuli*: photographs, grey rectangles (controls); *Primes*: fitness center scenarios *Scoring procedure*: difference between the proportion of ideographs evaluated positively after each type of prime (Payne et al., 2005) *Reliability*: Internal consistency not reported	*Measure:* Self-report questionnaire (constructed for the study) *Score:* Total time (min) of exercise per week *Type:* MVPA	*r* = .01 (*N* = 72)	Not examined, not a study objective
2	Antoniewicz & Brand, 2016*	*N* = 88 exercise program attendants M_{age} = 25 ± 7 years 51% female	*Association 1*: Cross-sectional *Association 2*: Prospective (14 weeks)	*Task*: Pictorial Brief Implicit Association Test (BIAT, Sriram and Greenwald, 2009) *Stimuli*: pictures and emoticons *Categories*: “exercise” and “non-sports” activities (pictures); “good” and “bad”	*Measure (association 1)*: self-report questionnaire (constructed for the study) *Score:* Total time (min) of exercise per week *Measure (association 2):* instructor-recorded	*Association 1* (cross-sectional): *r* = .03 (*N* = 86) *Association 2* (prospective):	Not examined, not a study objective

				(emoticons) *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: Internal consistency not reported	session attendance for exercise program *Score:* exercise adherence to a 14-week exercise program *Type:* MVPA (association 1 and 2)	*r* = .16 (*N* = 88)	
3	Berry et al., 2011*	*N* = 53 undergraduate university students M_{age} = 22 ± 5 years 74% female	Cross-sectional	*Task*: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli*: words *Categories*: “exerciser”, “couch potato”, “good”, and “bad” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: Internal consistency not reported	*Measure:* self-report questionnaire (The Godin Leisure Time Exercise Questionnaire, GLTEQ; Godin & Shephard, 1985) *Score:* frequency and intensity of MVPA bouts 15 min or longer expressed in METs of a typical week *Type:* MVPA	*r* = .38 (*N* = 53)	Not examined, not a study objective
4	Berry, 2016*	*N* = 155 university students (enrolled in first year psychology class) M_{age} = 19 ± 2	Cross-sectional	*Task*: Two Go/NoGo Association Task (GNAT; Nosek & Banaji, 2001) *Stimuli*: words *Categories*: “exercise”; generic, “good” (affective [fun]	*Measure:* self-report questionnaire (GLTEQ; Godin & Shepard, 1985) *Score:* frequency and intensity of MVPA bouts 15 min or longer expressed in METs of a	GNAT affective valence: *r* = .05 GNAT instrumental valence: *r*	Not examined, not a study objective

		years 70% female		and instrumental [fit]), and “bad” (affective [boring], and instrumental [unfit]) *Scoring procedure*: difference between M_{RT} of trials with “exercise” + “good” as a category and M_{RT} of trials with “exercise” + “bad” as a category *Reliability*: ICCs ranged from .72 to .85	typical week *Type:* MVPA	= .25 (all *N’s* = 131)	
5	Bluemke et al., 2010 *	*N* = 94 university students M_{age} = 23 ± 3 years 50% female	Cross-sectional	*Task*: Evaluative priming procedure (Eves, Scott, Hoppe, & French, 2007) *Stimuli*: words *Primes*: exercise-specific or generic verbs and adjectives *Scoring procedure*: M_{RT} to categorize positive and negative words before exercise prime, standardized (divided) by pooled SD_{RT} *Reliability*: not reported	*Measure:* self-report questionnaire (constructed for the study) *Score:* Total time (min) of weekly exercise for a typical week *Type:* MVPA	*Spearman rho* = .33 (*N* = 85)	Not examined, not a study objective
6	Brand & Schweizer, 2015 *	*N* = 74 persons recruited at a university campus	Cross-sectional	*Task*: Evaluative priming procedure (Bluemke et al., 2010)	*Measure:* self-report questionnaire (constructed for the study)	*r* = .21 (*N* = 74)	Not examined, not a study objective

		Men: M_{age} = 23 ± 4 years Women: 26 ± 4 years 41% female M_{PA} = 101 ± 118 min of weekly exercise		*Stimuli*: words *Primes*: exercise-specific or generic verbs and adjectives *Scoring procedure*: M_{RT} to categorize positive and negative words before exercise prime *Reliability*: not reported	*Score:* Total time (min) of exercise only (i.e., sportive activities) for a typical week *Type:* MVPA		
7	Brand & Antoniewicz, 2016	*N* = 44 fitness club exercisers M_{age} = 41 ± 14 years 41% female M_{PA} = 1.7 visits to a fitness club per week over 14 weeks	Retrospective (14 weeks)	*Task*: Single Target Implicit Association Test (ST-IAT; Bluemke & Friese, 2008) *Stimuli*: photographs and emoticons *Categories*: "exercise" (photographs); "good" and "bad" (emoticons) *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: not reported	*Measure:* recording of club's check-in database *Score:* number of visits in a fitness club over a 14-week period *Type:* MVPA	*r* = .23 (*N* = 44)	Not examined, not a study objective
8	Calitri et al., 2009	*N* = 125 British university students M_{age} = 23 ± 6	Retrospective (1 week)	*Task*: Extrinsic Affective Simon Task (EAST, De Houwer, 2003) *Stimuli*: words	*Measure:* interview (7-day PAR interview; Sallis et al., 1985) *Score:* type, frequency,	*r* = .22 (*N* = 98)	Additive pattern examined *Result:* Implicit attitudes were

		years 72% female		*Primes*: “exercise”, control, “positive”, and “negative” *Scoring procedure*: Difference of M_{RT} of trials with “exercise” + “negative” as a category and M_{RT} of trials with “exercise” + “positive” as a category *Reliability*: Split-half *adjusted r* = .40	intensity and duration of 7 days for PA bouts longer than 10 min, expressed in METs per week *Type:* MVPA		significantly associated with physical activity (β = .19) after controlling for attentional bias (β = .25), explicit instrumental (β = -.13) and affective (β = .25) attitudes and intentions (β = .10) toward physical activity
9	Chevance Caudroit et al., 2018	*N* = 76 persons with obesity M_{age} = 56 ± 12 years 65% female M_{BMI} = 39 ± 7 kg/m^2 M_{PA} = 17 ± 16 min of weekly MVPA	Prospective (4 months)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: “physical activity”, “positive”, and “negative” *Scoring procedure*: *DW-Score* (Chevance et al., 2017; Richetin et al., 2015) *Reliability*: not reported	*Measure:* Tri-axial accelerometer (van Hees et al., 2013) *Score:* Time (min) of MVPA over 7 days *Type:* MVPA	*r* = .15 (*N* = 76)	Additive pattern examined *Result:* Implicit attitudes were significantly associated with physical activity (β = .21) after controlling for age (β = -.45), BMI (β = -.33), past physical activity (β = .25), intentions toward physical activity (β = -.09), intentions to limit sedentary behavior (β = .14), and implicit

attitudes toward
sedentary behavior
(β = -.18)

10	Chevance et al., 2019	*N* = 79 person with respiratory diseases M_{age} = 62 ± 6 years 47% female M_{BMI} = 31 ± 7 kg/ m^2	Cross-sectional	*Task*: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli*: words *Categories*: “physical activity”, “sedentary behavior”, “positive”, and “negative” *Scoring procedure*: *DW-Score* (Chevance et al., 2017; Richetin et al., 2015) *Reliability*: Split-half *r* = .82	*Measure:* self-report questionnaire (GLTEQ; Godin & Shepard, 1985) *Score:* frequency and intensity of MVPA bouts 15 min or longer over the previous week-end (compilation score) *Type:* total PA	*r* = .02 (*N* = 78)	Not examined, not a study objective

11	Chevance, Caudroit et al., 2017	*Sample I*: *N* = 94 adults from the general population M_{age} = 35 ± 9 years 65% female M_{PA} = 317 min of weekly total PA *Sample II*: *N* = 59 obese adults M_{age} = 51 ± 12 years M_{BMI} = 37 ± 4 kg/ $m^{2;}$ 74% female M_{PA} = 195 min of weekly total PA	Cross-sectional	Task: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli*: pictures and words *Categories*: "physical activity" and "physical inactivity" (pictures); words: "positive" and "negative" *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: not reported	*Measure:* self-report questionnaire (Global Physical Activity Questionnaire; Bull, Maslin, & Armstrong, 2009) *Score:* Time (min) per week of total PA (planned exercise, commuting, activities at work, household and leisure time activities) across a typical week *Type:* total PA	*Sample I* (adults from the general population): r = .14 (*N* = 94) *Sample II* (obese adults): r = .24 (*N* = 59)	Additive pattern examined *Result:* (*sample I*) Implicit attitudes were not significantly associated with physical activity (β not reported) after controlling for explicit attitudes (β = .25), perceived behavioral control (β = .46), social norms and intentions (β not reported) (*sample II*) Implicit attitudes were significantly associated with physical activity (β = .25) after controlling for explicit attitudes (β = .38), perceived behavioral control, social norms and intentions (β not reported)

12	Chevance, Héraud et al., 2017a *	*N* = 119 person with respiratory diseases M_{age} = 62 ± 9 years 62% female M_{BMI} = 29 ± 7 kg/m^2	Prospective (6 months)	*Task*: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli*: words *Categories*: “physical activity”, “sedentary behavior”, “positive”, and “negative” *Scoring procedure*: *DW-Score* (Chevance et al., 2017b; Richetin et al., 2015) *Reliability*: Split-half *r* = .97	*Measure:* self-report questionnaire (Phone-Fitt Questionnaire; Gill, Jones, Zou, & Speechley, 2008) *Score:* type, frequency and duration for recreational activities over a for a typical week (compilation score) *Type:* MVPA	*r* = .32 (*N* = 54)	Additive pattern examined *Result:* Implicit attitudes were significantly associated with physical activity (β = .29) after controlling for exercise tolerance (β = .43) and intentions toward physical activity (β = .10)
13	Conroy et al., 2010	*N* = 201 university students M_{age} = 19 years 72% female M_{PA} = 9406 ± 3757 average daily steps across 7 days	Prospective (1 week)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: “physical activity”, “good”, and “bad” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003)	*Measure:* pedometer *Score:* average daily step count of 7 days *Type:* total PA	*r* = .14 (*N* = 201)	Additive pattern examined *Result:* Implicit attitudes were significantly associated with physical activity (β = .15) after controlling for sex (β = -.10), exercise self-efficacy (β = -.20), barriers efficacy (β = .37), outcome expectancies (β = -.08), intentions (β

							= .24) and perceived behavioral control (β = -.10) toward physical activity
14	Denman & Baldwin, 2015	*N* = 84 participants from the general population M_{age} = 34 ± 11 years 68% female M_{BMI} = 30 ± 9 kg/ m^2	Cross-sectional	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: “physical activity”, “bad”, and “good” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: not reported	*Measure:* self-report questionnaire (7-day, physical activity recall interview; Blair et al., 1985) *Score:* Total time (min) of exercise per week *Type:* MVPA	*r* = -.03 (*N* = 84)	Additive pattern examined *Result:* neither implicit (β = 2.56) nor explicit attitudes (β = -.93) were significantly associated with exercise minutes
15	Endrighi et al., 2016 *	*N* = 100 endometrial cancer survivors M_{age} = 57 ± 11 years 100% female M_{BMI} = 34 ± 9 kg/ m^2	Cross-sectional	*Task*: Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli*: words *Categories*: “exercise” and “physical inactivity”, “good”, and “bad” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003)	*Measure:* accelerometer, self-report time spent exercising per session and per day *Score:* composite of time (minutes) spent exercising *Type:* MVPA	Not reported and not provided	Additive pattern examined *Result*: Implicit attitudes were not significantly associated with physical activity after controlling for exercise self-efficacy (β not reported)

				Reliability: Split-half *adjusted r* = .81			
16	Escriva-Boulley & Boiché (unpublished)*	*N* = 107 adults M_{age} = 42.9 years 75% females M_{PA} = 1*49 min*	Cross-sectional	*Task:* Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) *Stimuli:* words *Categories:* "physical activity", "sedentary behavior", "positive", and "negative" *Scoring procedure*: *DW-Score* (Chevance et al., 2017b; Richetin et al., 2015)	*Measure:* self-report questionnaire (Bélanger-Gravel & Godin, 2010) *Score:* frequency and duration of all PA sessions reported in minutes per week *Type :* MVPA	*r = .12* (N = 107)	Not examined, not a study objective
17	Eves et al., 2007 *	*N* = 188 Royal Air Force trainees M_{age} = 20 ± 4 years 22% female	*Association 1*: Retrospective (1 week) *Association 2*: Cross-sectional	*Task*: Evaluative priming task (Fazio, 2001) *Stimuli*: words *Primes*: exercise (moderate [walking] and vigorous [running] intensity), control, "good", "bad", "happy", and "sad" *Scoring procedure*: unclear *Reliability*: not reported	*Measure (association 1)*: self-report questionnaire (7-day, physical activity recall interview; Blair et al., 1985). *Score:* frequency of physical activity of 7 days *Type:* MVPA Measure *(association 2)*: pedometer *Score:* average daily step count of 7 days *Type:* total PA	Not reported and not provided	Not examined, not a study objective

18	Gerber et al., 2018	*N* = 101 patients showing a psychiatric disorder directly recruited from psychiatric clinics M_{age} = 40 ± 12 years 49% female M_{PA} = 226 min of weekly MVPA	Prospective (1 week)	*Task*: Single Target Implicit Association Test (ST-IAT; Bluemke & Fries, 2008) *Stimuli*: photographs and emoticons *Categories*: “exercise” (photographs); “good” and “bad” (photographs) *Scoring procedure*: D-Score (Greenwald, Nosek, & Banaji, 2003) *Reliability*: not reported	*Measure* (*associations 1-3)*: interview using the SIMPAQ (Rosenbaum & Ward, 2016) *Score:* Time (min) per week of “walking”, “exercise activities”, and “other physical activities” *Measure (associations 4 & 5):* accelerometer *Score:* Time (min) of 7 days of light physical activity and moderate- to-vigorous physical activity. *Type:* MVPA (associations 2 and 5); LTPA (association 4); “other” (associations 1 and 3)	*Association 1* (interview, walking): *r* = -.10 *Association 2* (interview, exercise activities): *r* = .14 *Association 3* (interview, other PA): *r* = .03 *Association 4* (accelerometer, LTPA): *r* = -.07 *Association 5* (accelerometer, MVPA): *r* = .09 (all *N’s* =	Not examined, not a study objective

						101)	
19	Hyde et al., 2012	*N* = 164 university students (enrolled in undergraduate kinesiology course) 46% female M_{PA} = 7763 average daily steps across 7 days	*Associations 1 & 2*: Retrospective (1 week) *Associations 3 & 4*: Cross-sectional *Associations 5 & 6*: Prospective (1 week)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: “physical activity”, “good”, and “bad” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: Split-half r = .73	*Measure (associations 2 & 6):* pedometer *Score:* average daily step count of 7 days *Type:* total PA *Measure (associations 1, 3, 4 & 5):* self-report questionnaire (International Physical Activity Questionnaire - Short Form; Booth, 2000) *Score:* frequency, intensity and duration of 7 days expressed in METs *Type:* MVPA	*Association 1* (self-reported): r = .01 *Association 2* (pedometer): r = -.08 *Association 3* (self-reported): r = -.12 *Association 4* (self-reported): r = .05 *Association 5* (self-reported): r = -.13 *Association 6* (pedometer): r = -.07	Not examined, not a study objective

						(all *N's* = 164)	
20	Muschalik et al., 2018 *	*N* = 340 university students M_{age} = 20 years 61% female	*Associations 1-3*: Retrospective (1 & 2 months) *Associations 4-6*: Cross-sectional *Associations 7-9*: Prospective (1, 2 and 3 months)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: "physical activity", "positive", and "negative" *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: Split-half *r* = .83	*Measure*: self-report questionnaire (Short Questionnaire to Assess Health-enhancing physical activity, Wendel-Vos et al., 2003) *Score*: frequency, intensity and duration of 7 days expressed in METs for total PA (commuting, activities at work, household, planned exercise and leisure time activities) *Type*: total PA	*Association 1*: *r* = .07 (*N* = 240) *Association 2*: *r* = -.06 (*N* = 120) *Association 3*: *r* = .05 (*N* = 128) *Association 4*: *r* = .07 (*N* = 340) *Association 5*: *r* = .00 (*N* = 240) *Association 6*: *r* = .01 (*N* = 128) *Association 7*: *r* = .00 (*N* = 240)	Additive pattern examined *Result:* Implicit attitudes non-significantly associated with physical activity (β = .11) after controlling for gender (β = .14), age (β = .11), perceived pros (β = .07) and cons (β = -.06), social norms (β = -.07), social modeling (β = -.08), self-efficacy (β = .22), and intentions (β = .17) toward physical activity (β are reported here for PA measure at 3-month only)

						Association 8: r = .10 (N = 128) *Association 9*: r = .05 (N = 120)	
21	Oliver & Kemps, 2018	N = 103 university students M_{age} = 27 ± 11 years 69% female M_{BMI} = 34 ± 9 kg/ m^2 M_{PA} = 6073 ± 2730 average daily steps across 7 days	Retrospective (1 week)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: “activity”, “I like”, and “I dislike” *Scoring procedure*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) *Reliability*: not reported	*Measure*: pedometer which participants were to remove when exercising (i.e., working out at the gym, participating in a team sport or going for a run, as well as walking for the purpose of exercising) *Score*: daily step count average of 7 days for incidental PA only *Type*: incidental PA	r = -.28 (N = 103)	Additive pattern examined *Result:* Implicit attitudes were significantly associated with physical activity (β = -.27) after controlling for autonomous (β = .23) and controlled motivation (β = .31) toward physical activity
22	Padin et al., 2017	N = 150 university students M_{age} = 19 ± 2 years 60% female	Cross-sectional	*Task*: Personalized Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006; Olson & Fazio, 2004) *Stimuli*: words	*Measure*: Self-report questionnaire (International Physical Activity Questionnaire, IPAQ; long form; Booth, 2000) *Score (association1):*	*Association 1*: r = .12 *Association 2*: r = .17	Additive pattern examined *Result: (association 1)* Implicit attitudes were not significantly associated with

		M_{BMI} = 24 ± 4 kg/ m^2 M_{PA} = 2100 METs min per week		*Categories*: "physical activity", "I like", and "I don't like" *Scoring procedure*: *D-Score* without error penalty (Greenwald, Nosek, & Banaji, 2003; Richetin et al., 2015) *Reliability*: not reported	leisure time physical activity of the past 7 days transformed to METs/minutes per week (Ainsworth et al., 1993) *Score (association 2):* average number of minutes spent engaging in a single bout of walking or moderate-to-vigorous PA during their leisure time *Type*: MVPA	(all *N's* = 148)	physical activity (*b* = 677) after controlling for explicit instrumental (*b* = -128) and affective attitudes (*b* = 27) toward physical activity; *(association 2)* Implicit attitudes were significantly associated with physical activity (*b* = 12.45) after controlling for explicit instrumental (*b* = -.70) and affective attitudes (*b* = .09) toward physical activity
23	Rebar et al., 2015	*N* = 91 university students M_{age} = 20 years 42% female	Prospective (2 weeks)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: "physical activity", "good", and "bad" *Scoring procedures*: *D-Score* (Greenwald, Nosek, & Banaji, 2003) and *IPE-Score* (Rebar	*Measure*: Tri-axial accelerometer over 13 days *Score*: average activity counts *Type*: total PA	*D-Score: r* = .12 *IPE-Score*: *r* = .25 (all *N's* = 91)	Not examined, not a study objective

			et al., 2015). *Reliability* (D-Score): split-half *r* = .73			
24 Rebar & Conroy, 2013a (unpublished)*	*N* = 128 university students M_{age} = 20 years 59% female	Prospective (13 days)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: "physical activity", "good", and "bad" *Scoring procedures*: *IPE-Score* (Rebar et al., 2015) *Reliability*: not reported, not applicable with this scoring procedure	*Measure*: Tri-axial accelerometer over 13 days *Score*: average activity counts *Type*: total PA	*r* = .13 (*N* = 128)	Not examined, not a study objective
25 Rebar & Conroy, 2013b (unpublished)*	*N* = 195 university students M_{age} = 20 years 51% female	Prospective (7 days)	*Task*: Single Category Implicit Association Test (SC-IAT; Karpinski & Steinman, 2006) *Stimuli*: words *Categories*: "physical activity", "good", and "bad" *Scoring procedures*: *IPE-Score* (Rebar et al., 2015) *Reliability*: not reported, not applicable with this scoring procedure	*Measure:* pedometer over 7 days *Score:* Average daily step count *Type :* total PA	*r* = .03 (*N* = 195)	Not examined, not a study objective

26	Zenko & Ekkekakis, 2019	*N* = 95 (73% university students) M_{age} = 25 years 61% female M_{BMI} = 25 kg/m^2 M_{PA} = 236 min per week	Retrospective (1 week)	*Tasks*: Affective Misatribution Procedure (*association 1*); Evaluative Decision Task (*associations 2, 3*); Extrinsic Affective Simon Task (*associations 4, 5*); Go/NoGo Association Task (associations 6, 7); Personalized Single-Category Implicit Association Test (*association 8*); Single-Category Implicit Association Test (*associations 9, 10*) Please see the original article for a description of each stimuli, scoring procedures and reliability estimates.	*Measure*: International Physical Activity Questionnaire (IPAQ-SF; Craig et al., 2003) *Score*: average 10 minutes bouts engaged in MVPA and walking exercise behavior during a usual week reported in minutes per week *Type*: MVPA	*Association 1*: *r* = .16 (*N* = 82) *Association 2*: *r* = -.09 (*N* = 80) *Association 3*: *r* = -.14 (*N* = 80) *Association 4*: *r* = .03 (*N* = 81) *Association 5*: *r* = .05 (*N* = 81) *Association 6*: *r* = -.07 (*N* = 80) *Association 7*: *r* = .12 (*N* = 80) *Association 8*: *r* = -.08 (*N* = 92) *Association 9*:	Not examined, not a study objective

	r = -.005 (*N* = 92) *Association 10*: *r* = -.14 (*N* = 87)

Note. *Correlation(s) not mentioned in the manuscript and provided from the authors; +Designs are presented in accordance with the aim of this meta-analysis and in reference to the correlations reported between implicit attitudes and physical activity behavior (e.g., solely cross-sectional correlations were retrieved in experimental and interventional studies); °According to Perugini, Richetin & Zogmaister (2005) an additive pattern is observed when an implicit measure explains a unique portion of variance of the dependent variable in addition to what is explained by an explicit measure; IA = Implicit Attitudes; PA = physical activity; MVPA = Moderate to vigorous PA; total PA = all type of PA including exercise, commuting, activities at work, household and leisure time activities; Incidental PA = PA without planned PA or exercise; other = other type of PA; BMI = body mass index; RT = reaction time.

Table 2. Summary of the potential moderators of the implicit attitudes and physical activity association (none were statistically significant)

Moderator	***k* effect sizes**	***r* (95 % CI)**	***Z***	***p*-value**
Participants				
General population	4	.10 (-.03, .24)	.91	.13
Patients	9	.08 (-.01, .16)	.93	.09
Students	42	.05 (.09, .08)	.98	.01
Age *°				
Mean age > 30 years old	13	.08 (.00, .04)	.98	.02
Mean age < 30 years old	36	.07 (.00, .02)	.99	< .001
Study design				
Cross-sectional	19	.09 (.04, .15)	.99	< .001
Prospective	18	.06 (.01, .11)	.98	.02
Retrospective	18	-.00 (-.06, .05)	.16	.70
PA measure (1)				
Self-reported	43	.06 (.02, .09)	.99	< .001
Objective	12	.04 (-.03, .11)	.82	.25
PA measure (2)				
MVPA	32	.07 (.02, .11)	.99	< .001
Other	23	.04 (-.01, .08)	.90	.14
Implicit measure (1)				
Classification task	49	.05 (.02, .08)	.99	< .01
Priming task	6			
Implicit measure (2)				
IAT or relative	42	.04 (.01, .09)	.98	.02
Other	13	.09 (.01, .04)	.98	< .01
Study quality *				
High (score ≥ .08/1)	12	.05 (-.02, .11)	.89	.15
Medium (.02 < score < .08/1)	35	.04 (.00, .02)	.95	.06
Low (score ≤ .02/1)	8	.17 (.07, .26)	.99	< .01
Laboratory				
Berry	3	.20 (.07, .34)	.99	< .01
Boiché	6	.15 (.05, .27)	.99	< .01
Conroy	11	.09 (.01, .16)	.98	.02
Brand	11	.02 (.00, .03)	.57	.45
Other	24	.02 (.00, .02)	.72	.34
Study objective = testing correlation				
Yes	37	.05 (-.00, .11)	.94	.08
No	18	.06 (.01, .09)	.99	< .01

Note. * Age and study quality have been treated as continuous variables in the moderator analyses; they are reported here as categorical values to simplify the interpretation; ° There are missing values for the variable ‘age’.

Figure 1. Flow diagram of inclusion process

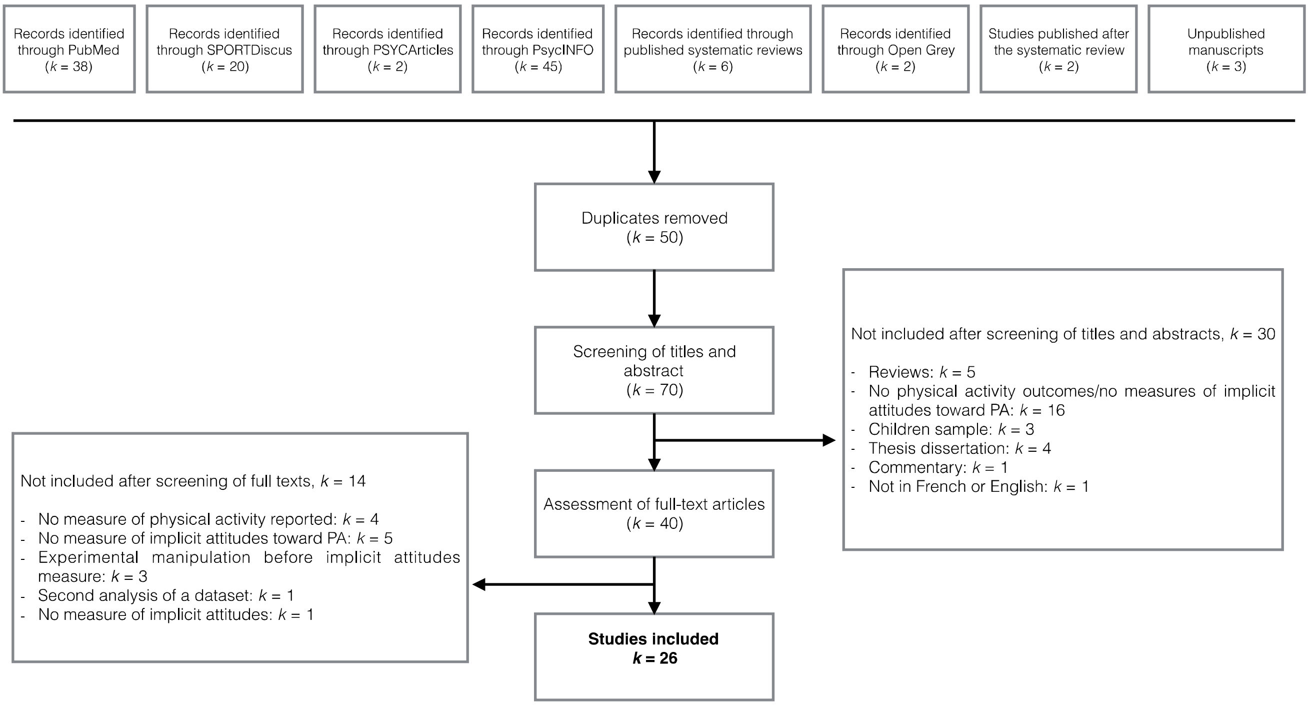
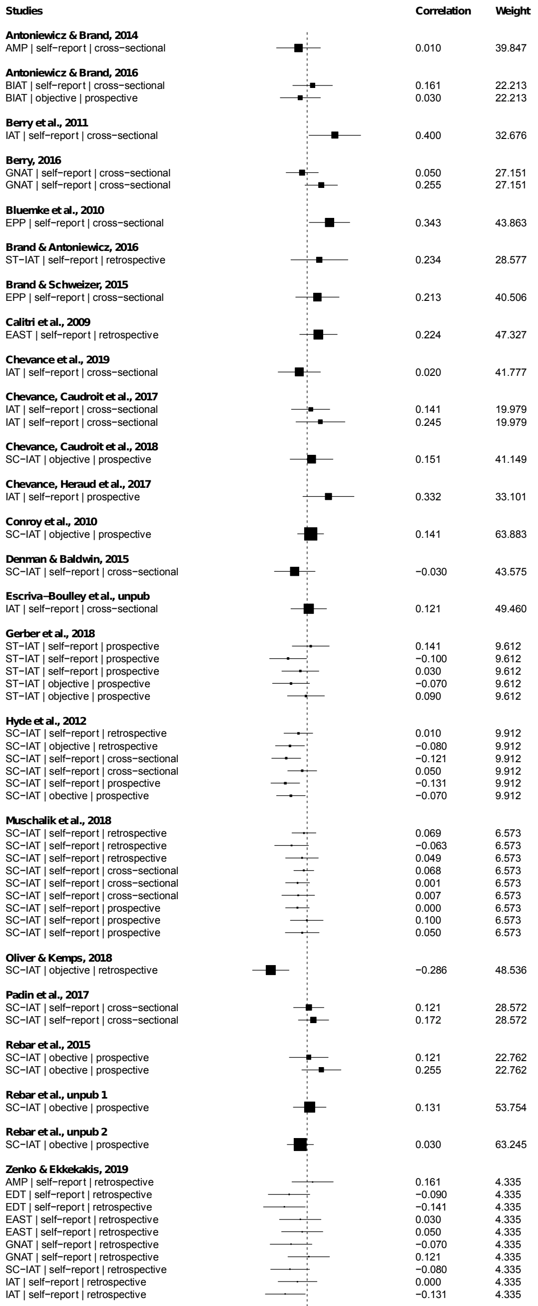
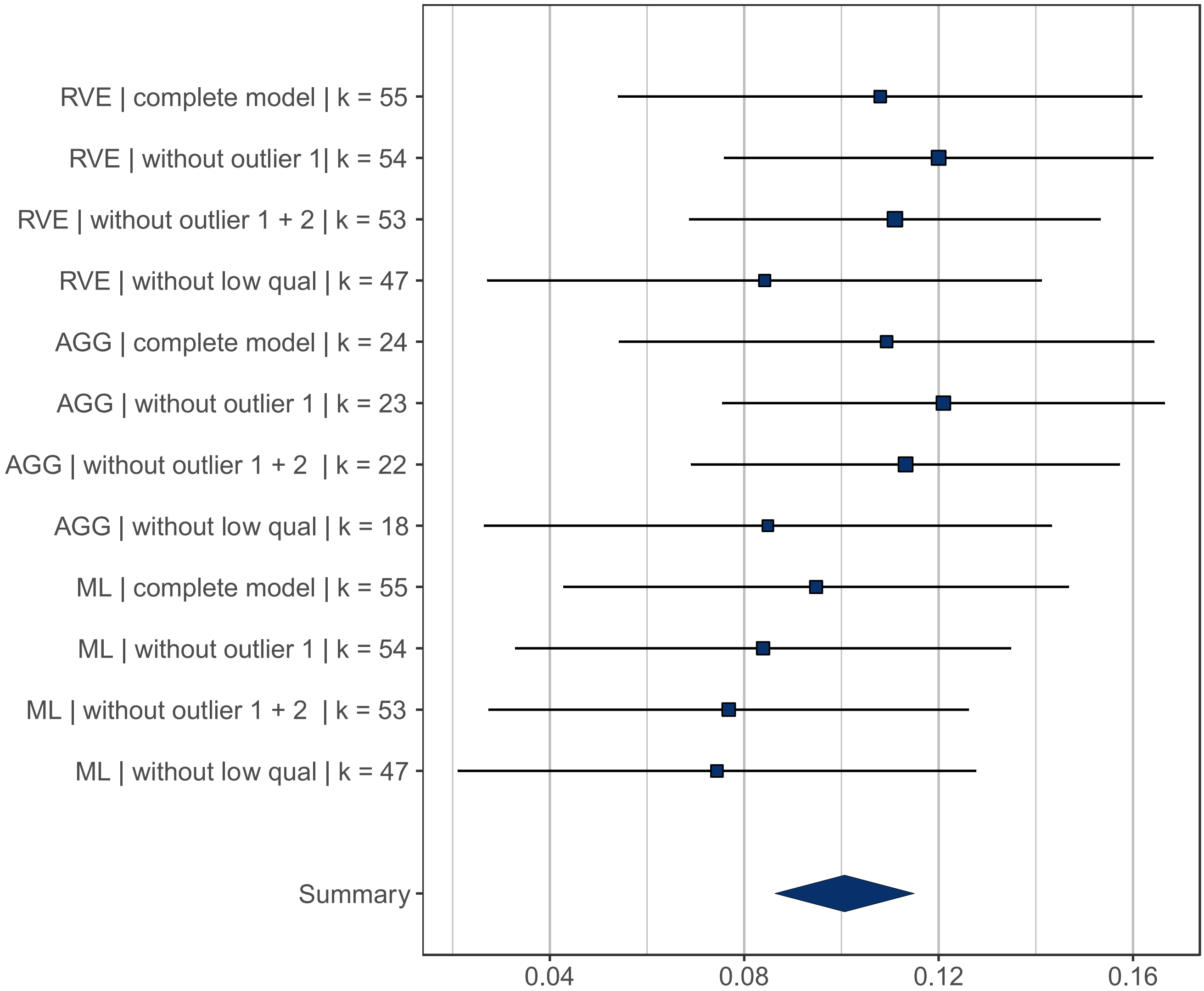


Figure 2. Forrest plot



Note. AMP = Affective Misattribution Procedure; IAT = Implicit Association Test; BIAT = Brief Implicit Association Test; SC-IAT = Single Category Implicit Association Test; ST-IAT = Single Target Implicit Association Test; GNAT = Go No Go Association Test; EPP = Evaluative Priming Procedure; EAST = Extrinsic Affective Simon Task; EDT = Evaluative Decision Task; unpub = unpublished manuscript

Figure 3. Forrest plot of the sensitivity analyses



Note. RVE = Robust Variance Estimation; AGG = aggregated meta-analysis; ML = multi-level meta-analysis; outlier 1 = Oliver & Kemps, 2018; outlier 2 = Berry et al., 2011; low qual = studies with a low quality score (≤ .02/1); k = effect sizes.