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## Efficacy of theory-based interventions to promote physical activity. A meta-analysis of randomised controlled trials

M. Gourlan<sup>a,b,c,\*</sup>, P. Bernard<sup>a,b</sup>, C. Bortolon<sup>a,b</sup>, A. J. Romain<sup>a,b,d</sup>, O. Lareyre<sup>a,b,c</sup>,  
M. Carayol<sup>a,b,e</sup>, G. Ninot<sup>a,b</sup> and J. Boiché<sup>a,b</sup>

<sup>a</sup>Laboratory Epsilon EA 4556, Dynamics of Human Abilities and Health behaviours, University of Montpellier 1 and 3, rue du Pr Henri Serre, Montpellier, F-34000, France; <sup>b</sup>Challenge for the Change of Behaviour (CCB) Group, Montpellier, France; <sup>c</sup>Epidaure, Prevention Department of Institut Regional du Cancer de Montpellier, Montpellier, F-34298, France; <sup>d</sup>Unit of Nutrition and Diabetes, University Hospital of Lapeyronie, Montpellier, F-34000, France; <sup>e</sup>INSERM UMR 1027, Paul Sabatier University, F-31073, Toulouse, France

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Implementing theory-based interventions is an effective way to influence physical activity (PA) behaviour in the population. This meta-analysis aimed to (1) determine the global effect of theory-based randomised controlled trials dedicated to the promotion of PA among adults, (2) measure the actual efficacy of interventions against their theoretical objectives and (3) compare the efficacy of single- versus combined-theory interventions. A systematic search through databases and review articles was carried out. Our results show that theory-based interventions ( $k = 82$ ) significantly impact the PA behaviour of participants ( $d = 0.31$ , 95% CI [0.24, 0.37]). While moderation analyses revealed no efficacy difference between theories, interventions based on a single theory ( $d = 0.35$ ; 95% CI [0.26, 0.43]) reported a higher impact on PA behaviour than those based on a combination of theories ( $d = 0.21$ ; 95% CI [0.11, 0.32]). In spite of the global positive effect of theory-based interventions on PA behaviour, further research is required to better identify the specificities, overlaps or complementarities of the components of interventions based on relevant theories.

**Keywords:** exercise; interventions; behaviour change; randomised controlled trials; meta-analysis

The benefits of regular physical activity (PA) for health promotion and rehabilitation are well documented. Levels of sufficient PA are associated with longer life expectancy (e.g., Lee et al., 2012) and higher well-being (e.g., Netz, Wu, Becker, & Tenenbaum, 2005). They are also a protection factor against certain chronic conditions, such as cancer (e.g., Wu, Zhang, & Kang, 2013). Based on scientific evidence, current recommendations specify that adults should perform at least 150 minutes of moderate-intensity aerobic PA per week to enjoy the above positive effects (WHO, 2010). However, several reports indicate that a large proportion of the worldwide adult population fails to adopt this PA behaviour on a regular basis (e.g., Kohl et al., 2012). Thus, identifying the characteristics of effective PA-promotion programmes has become a major concern for public health

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\*Corresponding author. Email: [mathieugourlan@yahoo.fr](mailto:mathieugourlan@yahoo.fr)

authorities. Available programmes may or may not be designed on a theoretical basis. Programmes which do not rely on a theoretical framework have mainly focused on identifying the most effective intervention techniques for specific behaviours or populations whereas theory-based programmes, instead, are based on recognised theories of behaviour specifying the presumed influences on mediators of behaviour that need to be changed in interventions to achieve behaviour change. Their models range from broad, ecological models encompassing all levels of factors to more specific ones focusing on a relatively small set of psychosocial processes (Glanz & Bishop, 2010).

We performed a meta-analysis of randomised controlled trials (RCTs) aiming (1) to investigate the efficacy of theory-based PA-promotion interventions in adult individuals; (2) to examine and compare the efficacy of PA-promotion interventions according to the theory they were based on; and (3) to assess and compare the efficacy of PA-promotion interventions based on a single theory with that of interventions based on combined theories.

### ***Health behaviour theories and PA***

Several health, social or educational psychology theories have been proposed to understand health behaviour change on the basis of psychosocial processes. Specifically, the Health Belief Model (HBM, Rosenstock, 1974), the Social Cognitive Theory (SCT, Bandura, 1997), the Transtheoretical Model (TTM, Prochaska, Johnson, & Lee, 2009), the Theory of Planned Behaviour (TPB, Ajzen, 1991), the Self-Determination Theory (SDT; Deci & Ryan, 2000), the Protection Motivation Theory (PMT; Rogers, 1983) and the Health Action Process Approach (HAPA; Schwarzer, 1992) have garnered the attention of health behaviour change researchers (Glanz & Bishop, 2010; Nigg & Paxton, 2008). These theories have been applied to the PA domain in order to identify the main constructs which are significantly associated with levels of PA in either healthy or unhealthy populations.

Prochaska, Wright, and Velicer (2008) devised 12 criteria to evaluate the quality of health behaviour change theories: (1) clarity, (2) consistency, (3) parsimony, (4) testability, (5) predictive power, (6) explanatory power, (7) productivity, (8) generalisability, (9) integration, (10) utility, (11) efficacy and (12) impact. Many researchers have attempted to evaluate the predictive and explanatory power of those theories (i.e., 'why a behaviour change occurred and why it did not, [and predicts] when a behaviour change will and will not occur', p. 565) in order to better understand and predict health behaviours such as PA (Prochaska et al., 2008). Indeed, several meta-analyses or literature reviews have investigated the association of specific theoretical constructs with PA behaviour. A meta-analysis including 103 TPB-based studies reported a large effect size in the relationship between intention and PA (McEachan, Conner, Taylor, & Lawton, 2011). Moreover, a moderate association between self-efficacy and PA behaviour was identified in a meta-analysis focusing on SCT (Spence, Burgess, & Cutumisu, 2006). In yet another meta-analysis including 71 TTM-based studies, important differences in PA levels were found to depend upon participants' change status: acute differences were noted between those in the preparation stages and those in the action stages (Marshall & Biddle, 2001). Literature reviews examined other models and their specific application in the PA domain. First, Teixeira, Carraça, Markland, Silva, and Ryan (2012) reviewed a set of 66 studies grounded in SDT and concluded that there is a positive relationship between autonomous forms of motivation and PA. Second, Bui, Mullan, and McCaffery (2013)

examined 20 PMT-based studies and concluded to a significant association between coping-appraisal and PA level.

Altogether, these reviews and meta-analyses confirm the predictive power of the aforementioned theories on PA behaviour. However, they mainly – if not exclusively – rely on observational (i.e., cross sectional, prospective or longitudinal) studies and therefore fail to meet the efficacy criterion raised by Prochaska et al. (2008), which states that a ‘theory-based intervention is demonstrated to have significant efficacy, producing greater behaviour change than a placebo or control’ (p. 565).

### ***Theory-based RCTs to promote PA***

At the instigation of several scholars (e.g., Rothman, 2004), numerous theory-based interventions (i.e., whose content is based on the constructs of a single theory or of several ones; Eccles, Grimshaw, Walker, Johnston, & Pitts, 2005) have been implemented in recent years (Noar & Mehrotra, 2011). For instance, a recent meta-analysis explored the effectiveness of theory-based PA interventions conducted specifically on worksites (Taylor, Conner, & Lawton, 2012) and reported a significant increase in PA with a moderate effect size. Additionally, interventional research in health psychology is gradually integrating the specific methodological requirements of evidence-based medicine, which rely on RCTs meeting CONSORT criteria (Keefe & Blumenthal, 2004). In fact, the RCT design is now recognised as the highest level of evidence methodology available to establish the efficacy or effectiveness of health behaviour change interventions (Davidson et al., 2003). As such, it has been retained by numerous researchers to identify those interventions which are the most effective for the promotion of PA (Orrow, Kinmonth, Sanderson, & Sutton, 2012).

In the literature, a growing number of PA-promotion RCTs are theory-based (Michie & Johnston, 2012; Michie, Johnston, Francis, Hardeman, & Eccles, 2008). Some of these interventions are based on all the constructs of a particular theory. For instance, an RCT recently assessed the effectiveness of an SDT-based intervention to increase PA in sedentary overweight women (Hsu, Buchworth, Focht, & O’Connell, 2013). More specifically, the contents of group meetings, individualised exercise training sessions and of the counsellor’s manual were entirely based on the underpinning principles and theoretical constructs of SDT (for details, see Edmunds, Ntoumanis, & Duda, 2009). This kind of intervention can also be designed around one construct only, or part of the guiding theory. Sørensen, Kragstrup, Skovgaard, and Puggaard (2008) thusly explored the efficacy of counselling, coupled or not with supervised exercise, in improving PA practice among primary health care centre patients. The counselling sessions were based exclusively on TTM stages of change, with no consideration for other constructs, such as processes of change. Concept selection is made under the assumption that all constructs do not have comparable weight in the process of behaviour change (Rhodes & Pfaeffli, 2010). Similar considerations have led researchers to include concepts from several different theories to build their PA intervention (Pinto et al., 2011).

### ***Combination and comparison of theories to change PA behaviour***

Over the last decade, health researchers have highlighted the need for a more rigorous evaluation of the respective efficacy of single- versus combined-theory interventions (Glanz & Bishop, 2010; Noar, Chabot, & Zimmerman, 2008). Combining theories has helped researchers develop more parsimonious explanations and better understand the

predictive power of health behaviours (Hagger, 2009; Lippke & Ziegelmann, 2008). For example, Buman et al. (2011) implemented an intervention based on both SCT and SDT constructs to increase PA among older adults, and compared it to a standard community intervention. Similarly, interventions combining SDT and TPB (e.g., Hagger & Chatzisarantis, 2007) or TTM and SCT (e.g., Pinto et al., 2011) were implemented to promote PA. Prestwich et al. (2014) recently conducted a meta-analysis including 107 studies to investigate the effectiveness of theory-based interventions for promoting PA and eating behaviour changes. Interventions based on a single theory generated a larger effect than those based on a combination of theories.

Several authors (e.g., Montanaro & Bryan, 2014) have noted that theoretical comparisons may be a key step in the development of more efficacious interventions, allowing researchers to determine which components of which theories are the driving factors of behaviour change. As suggested by Gardner and colleagues (2014), it is equally important that researchers indicate the extent to which behavioural interventions work, and that they provide assumptions about why these interventions should work. In the available literature, the direct comparison of interventions based on different theories in empirical studies remains sparse (Lippke & Ziegelmann, 2008). In their meta-analysis, Prestwich et al. (2014) were able to compare the effectiveness of SCT- and TTM-based interventions. The authors reported no significant differences in the mean effect sizes of these two models.

### ***Limits of previous meta-analyses***

Recently, numerous meta-analyses have attempted to determine the efficacy of PA-promotion interventions (Avery, Flynn, Wersch, Sniehotta, & Trenell, 2012; Ng, Mackney, Jenkins, & Hill, 2012; Orrow et al., 2012). However, these studies mainly focused on (1) specific types of PA, (2) sub-populations or (3) means of message delivery. For instance, Kassavou, Turner, and French (2013) only included interventions which promoting walking. Another meta-analysis examined the effectiveness of PA interventions strictly among socio-economically disadvantaged women (Cleland, Granados, Crawford, Winzenberg, & Ball, 2013). Finally, several meta-analyses focused on the efficacy of mobile devices or web interventions to promote PA (Davies, Spence, Vandelanotte, Caperchione, & Mummery, 2012; Fanning, Mullen, & McAuley, 2012).

Thus far, the only meta-analyses including theory-based interventions are those of Prestwich et al. (2014) and Taylor et al. (2012); though quite valuable, these pioneering studies suffered from several limitations. First, they included interventional studies with mixed designs (i.e., RCTs, controlled trials and quasi-experimental studies). Second, they included studies designed to increase PA or to improve other health behaviours (i.e., eating behaviours). Last, Prestwich's investigation included studies published until 2008 only. Therefore, an updated systematic approach with a strict selection of studies had become necessary to overcome the weaknesses of previous meta-analyses.

### ***Summary***

In summary, this meta-analysis explored the efficacy of theory-based interventions to promote PA behaviour among adults in studies using an RCT design. We also examined a number of specific effects in the subgroups of the included studies. For theories associated with a set of RCTs meeting our inclusion criteria, the respective efficacy of each theory-based intervention was assessed; we evaluated whether any particular theory

had proven significantly more effective for PA-promotion interventions than others. Furthermore, we examined whether interventions based on a single theory versus a combination of theories resulted in significantly different efficacy in PA behaviour.

## **Method**

This systematic review is reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (Liberati et al., 2009).

### ***Inclusion criteria***

Studies were included in the systematic review if they met the PICOS criteria (Liberati et al., 2009):

- (1) Participants. Participants were adults ( $\geq 18$  years). Trials involving both adults and children/adolescents were not included.
- (2) Interventions. To be included, studies had to mention that their intervention was based on at least one theory (i.e., the theoretical framework had to be explicitly named in the text). Interventions could only target PA, or PA and other outcomes. No restriction was placed upon the mode of delivery of the intervention.
- (3) Controls. Included trials compared a group participating in a theory-based intervention (i.e., intervention group) with a group which either did not participate in an intervention, or took part in an intervention that was not theory-based (i.e., control group). No restriction was placed upon the nature of the comparison with the intervention group (i.e., no intervention, minimal intervention, attention placebo or active comparison control condition).
- (4) Outcomes. The included trials measured PA as primary or secondary end points at both pre- and post-intervention times. The PA indicator used had to be a direct measurement of the behaviour (e.g., PA duration, energy expenditure, number of steps). Trials based on physical fitness data (e.g., cardiovascular fitness) or intentions (e.g., stages of change) were not included. Measurement methods of PA could be self-reported (i.e., use of a questionnaire) and/or objective (e.g., pedometer).
- (5) Studies. Only RCTs were included.

### ***Search strategies***

Studies were identified by searching through the MEDLINE, PsycINFO and PSYarticles databases through 15 May 2013, with no language restriction. Mesh and text-words were used in MEDLINE with limits (i.e., age > 18 years, RCT design). The following theories and their constructs (e.g., processes of change) were included successively in the search equation: Theory of Reasoned Action, TPB, TTM, SCT, HBM, PMT, SDT, HAPA, Precaution Adoption Process Model (PAPM), Rubicon Model (RM) and Model of Action Phases (MAP). Additionally, relevant reviews were scanned (see details in Appendix 1 in supplemental material).

The titles and abstracts found in the electronic databases were initially and independently screened by three trained reviewers (MC, Ph.D.; CB, PhDc; JB, Ph.D.) to determine their adequacy with this systematic review. The final selection was based on full-text reading and performed by four trained reviewers (OL, PhDc; PB, Ph.D.; AJR, Ph.D., GN, Ph.D.). Any disagreements were resolved by discussion with MG (Ph.D.).

### ***Coding procedures***

A standardised data extraction was performed by three pairs of independent reviewers (PB–CB, MC–AJR, JB–OL), who systematically recorded the data. Any disagreements were resolved by discussion with MG. Descriptive data were extracted by (1) study population and design: year, number of participants randomly assigned, mean age, gender, sample characteristics (e.g., sedentary adults, workers); (2) theory-based intervention: theory, mode of delivery of the intervention, supervised PA, frequency of sessions, intervention length, control condition; (3) outcome: primary, number of times PA was measured, number of subjects assessed in each randomisation group, measures of PA (pre-/post-intervention and follow-up times). For studies with multiple PA indicators (e.g., both PA duration and energy expenditure) and/or multiple methods of PA measurement (e.g., use of both self-report and pedometer), the data were averaged in order to generate a single summary effect size (Rosenthal & Rubin, 1986). For articles which reported insufficient information on programme outcomes, repeated attempts to contact corresponding authors were made to request more information.

Additionally, the methodological quality of each trial was examined using an 11-item scale derived from Cochrane collaboration's tools for assessing risk of bias in RCTs (Higgins et al., 2011). Specifically, the scale assessed whether studies provided information regarding (1) the eligibility criteria for participants; (2) the details of the intervention; (3) the standardisation of the intervention; (4) the specific objective(s) of the study; (5) the calculation technique used to determine the sample size; (6) the method used to randomise participants; (7) the blinding to group assignment of participants and of those conducting interventions; (8) the participants flow; (9) the characteristics of the care providers performing the intervention; (10) the baseline data of participants; and (11) the number of participants included in each analysis. A detailed description of each item is presented in Appendix 2 in supplemental material. All items were coded as 'yes', 'no' or 'not applicable'.

Finally, the extent to which the development and the evaluation of the interventions were explicitly based on a theory or several theories was coded using 10 items from the Theory Coding Scheme (TCS; Michie & Prestwich, 2010). Specifically, the coding scheme assessed whether (1) the targeted construct(s) was/were mentioned as predictor(s) of behaviour; (2) the theory was used to select intervention recipients; (3) the theory was used to select/develop intervention techniques; (4) the theory was used to tailor intervention techniques to recipients; (5) all intervention techniques were explicitly linked to at least one theory-relevant construct; (6) at least one, but not all, of the intervention techniques was explicitly linked to at least one theory-relevant construct; (7) groups of techniques were linked to groups of constructs; (8) all theory-relevant constructs were explicitly linked to at least one intervention technique; (9) at least one, but not all, of the theory-relevant constructs was explicitly linked to at least one intervention technique; and (10) theory-relevant constructs were measured. All items were coded as 'yes' or 'no'. Details and coding procedures of the TCS are presented in Appendix 3 in supplemental material. A theoretical implementation score was generated by summing the 10 items.

### ***Statistical analyses***

Effect sizes were calculated using Cohen's *d* (Cohen, 1988) with Comprehensive Meta-Analysis software, version 2.2.064 (Borenstein, Hedges, Higgins, & Rothsein, 2005).

Positive effect sizes indicated favourable changes in the theory-based intervention groups, compared to changes or lack thereof, in the control groups. Effect sizes of 0.2, 0.5 and 0.8 represent small, medium and large effects, respectively (Cohen, 1988). Effect sizes were calculated using average difference data between pre- and post-intervention measures, the number of participants and the pooled standard deviations of each group (i.e., intervention and control group) for each trial. When summary statistics were not reported, statistical test data (e.g.,  $t$ - or  $F$ -values) were used to make an estimation of Cohen's  $d$  (Lipsey & Wilson, 2001). As a complement to Cohen's  $d$ , 95% CIs were also reported.

Study heterogeneity was assessed using the omnibus homogeneity test ( $Q$ ) and the  $I^2$  as indicators (Borenstein, Hedges, Higgins, & Rothstein, 2009). Anticipating heterogeneity for this data-set ( $Q < 0.05$ ;  $I^2 \geq 75\%$ ; e.g., Prestwich et al., 2014), we performed the calculation of pooled effect sizes using a random effects model. The publication bias was assessed using multiple methods, including funnel plot identification, Begg and Mazumdar (1994) adjusted rank correlation and Egger's regression intercept (Egger, Smith, Schneider, & Minder, 1997).

### ***Moderator analysis***

In accordance with the second and third objectives of this work, moderator analyses were conducted to test whether the effect size depended on (1) the theory the intervention was based on, and (2) the fact that the intervention was based on a single theory or a combination of theories. The effect of those categorical moderators was analysed using a meta-analytic analogue to the analysis of variance test. As described by Lipsey and Wilson (2001), this analysis allows the regrouping of effect sizes into mutually exclusive groups on the basis of an independent variable (i.e., the moderator), and tests the level of heterogeneity among the effect sizes at both between-group and within-group positions. If the between-group heterogeneity statistic ( $Q_b$ ) is significant, it indicates that the mean effect sizes across groups differ by more than the sampling error. In addition, a significant within-group heterogeneity statistic ( $Q_w$ ) indicates that heterogeneity still exists within the group, beyond that caused by the moderator (Lipsey & Wilson, 2001). A moderator was tested only if there were at least three interventions at each moderator level (e.g., at least three interventions based on a given theory; Higgins, Thompson, Deeks, & Altman, 2003).

## **Results**

### ***Search results***

The literature search initially returned 1531 articles; 1454 articles were excluded using the following criteria: (1) observational study, (2) absence of theory-based intervention, (3) absence of RCT design, (4) absence of PA measure, (5) lack of statistical information for PA and inability to obtain it from the study's authors and (6) protocol article. Seventy-seven RCTs were included, involving a total of 82 intervention groups meeting all inclusion criteria (see the flow diagram in Appendix 4 in supplemental material).

### ***Overall characteristics of the database***

The total number of participants across the interventions was 19,357 (experimental = 10,574 and control = 8783) with a mean age of 48.4 years (SD = 13.93). The

characteristics of the 82 interventions are presented in Appendix 5 in supplemental material. The samples were mixed-sex in a majority of interventions ( $k = 62$ , 75%) and included women exclusively in 20 interventions. Sedentary adults were sampled in 18 (23%) studies. Among clinical populations, adults with diabetes or cancer were represented in respectively 10 (13%) and 5 (6%) interventions.

Of the 82 theory-based interventions, 61 (74%) were reported to be explicitly based on a single theory. Of these interventions, 31, 16, 8, 5 and 1 were based respectively on TTM, SCT, TPB, SDT and PMT. No study was found to be based on the following theories: HBM, PAPM, MAP, RM and HAPA. Among the interventions explicitly based on a combination of theories ( $k = 21$ , 26%), 14 interventions reported combining 2 theories, while the remaining 7 were based on combinations of 3–5 theories.

Regarding the characteristics and the outcomes of the 82 theory-based interventions, the following was noted: 44 (52%) used a single mode of delivery (e.g., Internet) and 28 combined at least two modes of delivery (e.g., telephone and face-to-face sessions); supervised sessions of PA were reported in 14 (16%) interventions; PA was explicitly reported as the primary outcome in 74 (89%) interventions; PA was assessed with self-reported, objective or both measures in 70 (83%), 3 (4%) and 11 (13%) interventions, respectively; the control conditions identified were: no intervention ( $k = 18$ , 22%), minimal intervention (e.g., booklet;  $k = 36$ , 44%), attention placebo (e.g., weight management;  $k = 13$ , 15%), active control intervention (e.g., website;  $k = 17$ , 19%).

### ***Methodological quality and theoretical implementation***

The assessment of the methodological quality for each trial is presented in Appendix 6 in supplemental material. The most frequently met criteria were the eligibility of participants (item 1, 95%), the specific objective(s) of the study (item 4, 88%) and the details of the intervention (item 2, 83%; see Appendix 7 in supplemental material). Conversely, the blinding to group assignment of the participants and of the individuals conducting the interventions (item 7, 27%), the number of participants included in each analysis (item 11, 35%) and the calculation technique used to determine the sample size (item 5, 46%) were the least met criteria.

The assessment of the theoretical implementation for each intervention is presented in Appendix 8 in supplemental material. The mean theoretical implementation score was 6.35 (SD = 2.09, median = 6). The highest score was 8, but six studies received a score of 1. The criteria that interventions met the most frequently were the use of a theory to develop intervention techniques (item 3, 93%), the mention of theoretical constructs (item 1, 86%) and the measurement of theory-relevant constructs (item 10, 72%; see Appendix 9 in supplemental material). Conversely, the use of the theory to select recipients of the intervention (item 2, 19%), the explicit association of all theory-relevant constructs with at least one intervention technique (item 9, 23%), and the explicit association of all intervention techniques with at least one theory-relevant construct (item 5, 32%) were the least met criteria.

### ***Publication bias***

The funnel plot displaying the impact of theory-based interventions (relative to control) appeared to be asymmetrical (see Appendix 10 in supplemental material). In addition, both Begg and Mazumdar adjusted rank correlation ( $\tau = 0.30$ ,  $p < .001$ ) and Egger's

intercept [Intercept = 2.49,  $t(80) = 6.63$ ,  $p < .001$ ] appeared significant. These results therefore provide evidence of a publication bias for this data.

### Overall intervention effects

The raw data of the included interventions are available on the ‘open science framework’ website (see Gourlan et al., 2014). The overall average effect size of the 82 interventions was 0.31 (95% CI [0.24, 0.37]), indicating a significantly more positive impact of theory-based interventions on the PA practices of participants, compared to control groups. Significant heterogeneity ( $Q = 348.52$ ,  $p < .001$ ,  $I^2 = 76.85\%$ ) was noted. The effect sizes of each of the 82 interventions are presented in Appendix 11 in supplemental material.

### Moderating variables

Since significant study heterogeneity was found, we used a mixed model for the moderator analysis. We first tested the theory type as a categorical moderator (i.e., SDT, SCT, TTM, TPB). The only intervention based on PMT was excluded from this analysis. The results of the summary effect sizes of interventions according to theory are presented in Table 1. All theories had significant impact on PA behaviour, ranging from  $d = 0.26$  (95% CI [0.03, 0.48]) for TPB to  $d = 0.61$  (95% CI [0.32, 0.89]) for SDT. Nonetheless, moderation analyses revealed no significant differences between theories ( $Q_b = 5.26$ ,  $p > .05$ ). A categorical moderation analysis was also performed to compare the efficacy of interventions based on a single theory versus a combination of theories. The analysis revealed that the number of theories used to design an intervention was a significant moderator ( $Q_b = 4.03$ ,  $p < .05$ ). Specifically, interventions based on a single theory ( $d = 0.35$ ; 95% CI [0.26, 0.43]) reported a stronger impact than interventions based on multiple theories ( $d = 0.21$ ; 95% CI [0.11, 0.32]; see Table 1).

## Discussion

The aims of this meta-analysis were to assess the efficacy of theory-based interventions in increasing PA in adults, examine and compare the efficacy of PA interventions according

Table 1. Summary effect sizes and moderator analyses for single-theory and combined-theory interventions.

Moderator	No. of interventions	$d$ [95% CI]	$I^2$	Qw	Qb
Theory used (for single-theory interventions)					5.26
SDT	5	0.61 [0.32, 0.89]	51.28	8.21	
SCT	16	0.42 [0.28, 0.56]	42.89	26.26*	
TTM	31	0.31 [0.20, 0.42]	80.13	151.01**	
TPB	8	0.26 [0.03, 0.48]	83.22	41.72**	
Single- versus combined-theory interventions					4.03*
Single theory <sup>a</sup>	61	0.35 [0.26, 0.43]	77.85	270.99**	
Combined theories	21	0.21 [0.11, 0.32]	73.13	74.44**	

SDT, Self-Determination Theory; SCT, Social Cognitive Theory; TTM, Transtheoretical Model; TPB, Theory of Planned Behaviour; 95% CI, 95% confidence interval; Qb, between-groups heterogeneity statistic; Qw, within-groups heterogeneity statistic.

<sup>a</sup>Intervention based on PMT was included (Bassett & Prapavessis, 2011).

\* $p < .05$ ; \*\* $p < .001$ .

to the theory or theories they were based upon, and compare the efficacy of PA interventions based on a single theory with the efficacy of those based on a combination of theories.

### ***Efficacy of theory-based RCTs in promoting PA***

A large number of studies were identified and a total of 82 interventions met the inclusion criteria of the present meta-analysis. Only five of the theories identified in the literature were represented in our selection: the TTM, the SCT, the TPB, the SDT and the PMT. The results indicated that interventions based on those theories are effective, inducing a small to medium effect size on PA behaviour ( $d = 0.31$ ; Cohen, 1988). This meta-analysis is therefore the first to establish the efficacy of theory-based interventions in promoting PA with a robust method (i.e., the RCT design). This finding is consistent with that of Taylor et al. (2012), who reported a  $d$  of 0.34 for theory-based interventions implemented in a distinct set of workplace studies. Hence, theory-based interventions promoting PA appear to be equally effective for workers and various healthy or unhealthy adults. These effect sizes need to be interpreted in light of the potential health impact of PA behaviour change. Indeed, given the large and increasing prevalence of inactive people in Western countries, even a slight PA increase in the general population could have a major health impact (Khan et al., 2012).

Although this work clearly suggests that theory-based interventions are effective for promoting PA, our results should nonetheless be interpreted cautiously. Indeed, several potential methodological biases were identified: while more than 80% of the interventions reported their participant eligibility criteria, specific objectives and the details of their interventions, less than 50% of them reported the blinding to group assignment of participants and of individuals administering the interventions, the number of participants included in each analysis and the calculation technique used to determine the sample size. Yet, recent evidence shows that failing to report blinding, number of participants analysed or sample size calculations technique is associated with biased estimates of interventional efficacy (Chan, 2008; Gluud, 2006). Additionally, failing to report baseline data may threaten the external validity of the results (Boutron et al., 2008). Thus, in order to enhance the methodological quality of theory-based interventions promoting PA and to limit the biases currently found in some interventions, a systematic, closer alignment with a set of methodological quality criteria such as the CONSORT statement (Boutron et al., 2008) is recommended for future research.

### ***Efficacy of SDT, SCT, TTM and TPB in promoting PA***

This meta-analysis was also designed to examine and compare the efficacy of interventions according to the theory upon which they were based. Subgroup analyses indicated that interventions based on SDT, SCT, TTM and TPB reported, on average, a significant impact on PA. In addition, our comparative statistical analyses did not show the superiority of any theory over the others regarding its impact on PA practice. Our findings are consistent with those of Prestwich et al. (2014). These authors did not observe any significant efficacy difference between interventions based on TTM and SCT. To a certain extent, the relative redundancy of the theories may explain the absence of a differential effect. Indeed, some authors have posited certain theory constructs overlap (Glanz, Rimer, & Viswanath, 2008). For example, the self-efficacy construct at the core of SCT is also present in the TTM; the status of this construct is likely to account

for the trajectory of individuals at various progression stages (Marshall & Biddle, 2001). In the same vein, the TPB includes the construct of perceived behavioural control and SDT includes the need for competence; both are conceptually close to self-efficacy and tap the individual's mastery perceptions of a specified context such as PA (Noar & Zimmerman, 2005). This theoretical overlap is bound to generate similarities between the components of interventions based on different theories (Montanaro & Bryan, 2014), and the confusion is maintained by the fact that many theories do not specify methods and techniques to modify their core constructs (e.g., Hardeman et al., 2002).

The small/moderate effect sizes observed could be due, in part, to the fact that several interventions did not systematically use all the theory-specified constructs. Since all the constructs of a given theory do not have comparable weight on behaviour modification (Amireault, Godin, Vézina-Im, 2013; Rhodes & Pfaeffli, 2010), construct selection is relevant. Accordingly, several authors have advocated the implementation of 'theory-driven' (i.e., using all the constructs of a theory) *versus* 'theory-inspired' interventions (Michie & Johnston, 2012).

In conclusion, we offer two perspectives. First, we invite theoretical scholars to develop specific recommendations and manuals for interventions targeting PA (e.g., Marcus & Forsyth, 2009). Second, we recommend that research focus on identifying the behaviour change techniques (see Michie et al., 2013) likely to be the most effective for modifying the core constructs of each theory. This line of research could lead to a better understanding of the 'intervention overlap', in addition to the 'theoretical overlap' between theories.

### ***Efficacy of single-theory interventions versus combined-theory interventions***

The last aim of this meta-analysis was to compare the efficacy of interventions based on a single theory with that of interventions based on a combination of theories. Similarly to Prestwich et al. (2014), moderation analyses revealed that interventions based on single theory are more effective. Thus, our results do not support recommendations for the design of PA-promotion interventions on the basis of multiple theories (Glanz & Bishop, 2010). However, given the characteristic heterogeneity of the multiple-theory interventions surveyed, this finding must be interpreted with caution. Indeed, these interventions were based on a wide variety of theory combinations, in terms of both number and nature (e.g., TTM + SCT or SCT + SDT or TTM + SDT + PMT; see Appendix 5 in supplemental material). It is important to note that authors who have advocated the use of multiple theories have highlighted the necessity to develop a strong rationale for their integration into the intervention (Hagger, 2009). However, many combined-theory interventions included in this meta-analysis (e.g., Chasan-Taber et al., 2011) did not explain, or cite previous studies which explained, the premises of their theoretical integration. Thus, future interventions evaluating the efficacy of combined-theory interventions in increasing PA should attempt to apply theoretical integrations that have already garnered strong rational and empirical support for the explanation of PA behaviour adoption (e.g., Hagger & Chatzisarantis, 2007).

### ***Towards the development of rigorous theory-based interventions***

This study also evaluated the theoretical fidelity of interventions. An in-depth analysis with TCS items (Michie & Prestwich, 2010) revealed several theoretical implementation weaknesses in most of the included interventions. Notably, the results showed that such

criteria as ‘all theory-relevant constructs were explicitly linked to at least one intervention technique’ and ‘all intervention techniques were explicitly linked to at least one theory-relevant construct’ were met by less than one-third of the interventions. In other words, in a vast majority of theory-based interventions promoting PA among adults, at least one intervention technique reported was not linked to any theoretical construct mentioned and/or at least one theoretical construct mentioned was not linked to any intervention technique reported. As highlighted by some authors, theory-based interventions may help us understand why interventions are effective or ineffective, mostly by informing on the key psychosocial variables that are hypothesised to be related to the behaviour, as well as on the intervention techniques that are related to those key psychosocial variables. However, in most of the interventions assessed, the specific links between the intervention techniques reported and the theoretical constructs mentioned were not established. This fact tends to limit the extent to which these interventions contributed evidence of the factors of health behaviour change (Lippke & Ziegelmann, 2008). In this context, future theory-based interventions should more closely align with, and mention their use of, the TCS (Michie & Prestwich, 2010). In turn, this approach would lead theory-based interventions to provide a more valid basis for refining and developing improved theories (Michie & Abraham, 2004).

#### ***Limitations and recommendations for future research***

In spite of its innovative character, this study suffers from several limitations. First, only theory-based interventions were considered. As a consequence, no evidence was provided of the relative superiority in efficacy of theory-based interventions over non-theory-based interventions. Following the pioneering work of Preswitch et al. (2014), who did not find that any design proved superior in efficacy, future meta-analysis should include both theory- and non-theory-based interventions. Additionally, it is plausible that relevant trials were not included in our meta-analysis because of our search strategy; for instance, search limits in Medline may have led to the elimination of some articles (Winchester & Bavry, 2010); also, poorly described theory-based interventions may have been overlooked.

Moreover, substantial heterogeneity was found. In addition to multiple theories, this heterogeneity may have been caused by the variety of message delivery modes (e.g., emails, booklets) or the volume of intervention identified in the included trials. Additionally, our analysis revealed that a publication bias may exist in the literature, whereby small-sample studies with small effects are systematically ignored (Sterne et al., 2011). This bias may have inflated the effects of theory-based interventions. Third, the nature of PA measures used in the included interventions could have affected the results. Indeed, self-report scales have been associated with an overestimation of PA levels (Lee, Macfarlane, Lam, & Stewart, 2011), leading some scholars to recommend using both self-report and objective tools simultaneously (Napolitano et al., 2010). In this set of RCTs, only 13% ( $k = 11$ ) followed this recommendation. Thusly, it is possible that more modest effect sizes could be obtained with a more prevalent use of objective PA assessments. Finally, no study matched our inclusion criteria for HAPA, RM, MAP and PAPM; only one study was available for PMT, and less than 10 interventions were included for SDT and TPB. As a consequence, our conclusions about the efficacy of RCTs promoting PA among adults cannot be considered definite, because of the current lack of robust interventions based on all relevant theories.

Several questions remain unanswered at present. Further research should investigate the potential moderators of interventional efficacy, such as participants' adherence, the nature of the control group and selected sample characteristics (Peters, de Bruin, & Crutzen, 2013). In another line of research, studies could purport to assess the behavioural change techniques used in each theory. Future investigations could help identify the differential effects of theories and the behavioural change techniques for specific subgroups (e.g., adults with chronic disease), contexts (e.g., rehabilitation centre, public health campaign) and/or aims (e.g., maintenance of PA, reduction of sedentary behaviour). Last, researchers should explore theoretical foundations for the aggregation of theories and build experimental studies before the development of trials (Peters et al., 2013).

### Conclusion

This meta-analysis suggests that theory-based interventions are significantly efficacious in promoting PA. Altogether, our results suggest that stakeholders and intervention developers can design effective interventions using one of the following theories: TTM, SCT, SDT or TPB. Moreover, an intervention to modify PA behaviour seems more effective when it is based on a single theory rather than on a combination of theories. Consequently, to promote PA, researchers and practitioners should opt to implement interventions based on one of the above theories and target both individual and interpersonal factors to promote PA based on one of the above theories.

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### Supplemental material

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