American Psychological Association
Journal of Consulting and Clinical Psychology

ISSN: 0022-006X
2020, Vol. 88, No. 8, 726–737
http://dx.doi.org/10.1037/ccp0000501

Self-Determination Theory Interventions for Health Behavior Change: Meta-Analysis and Meta-Analytic Structural Equation Modeling of Randomized Controlled Trials

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Objective: We conducted a meta-analysis of randomized controlled trials (RCTs) to promote health behavior change based on self-determination theory (SDT). The review aimed to (a) quantify the impact of SDT interventions on health behaviors, (b) test mediation by theoretically specified variables (autonomous motivation and perceived competence), and (c) identify moderators of intervention effectiveness. ***Method:*** Computerized searches and additional strategies identified 56 articles that yielded 65 independent tests of SDT interventions. Random effects meta-analysis and metaregressions were conducted via STATA; meta-analytic structural equation modeling (MASEM) was used to test mediation. ***Results:*** The sample-weighted average effect size for SDT interventions was $d_+ = .23$, and there were significant effects for physical activity, sedentary behavior, diet, alcohol consumption, and smoking cessation ($.16 \geq d_+ \geq .29$). Effect sizes exhibited both publication bias and small sample bias but remained significantly different from zero, albeit of smaller magnitude, after correction for bias ($d_+ \geq .15$). MASEM indicated that autonomous motivation and perceived competence mediated intervention effects on behavior. Metaregression analyses indicated that features of the sample, intervention, or methodology generally did not moderate effect sizes. ***Conclusion:*** The present review indicates that SDT interventions have a significant but small effect on health behavior change and suggests several directions for future research.

What is the public health significance of this article?
This review examines the efficacy of health behavior interventions based on self-determination theory. Findings indicate that interventions have a significant but small effect on behavior change.

Keywords: health behavior, meta-analysis, physical activity, randomized trial, self-determination theory

Supplemental materials: http://dx.doi.org/10.1037/ccp0000501.supp

This article was published Online First May 21, 2020.

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The data reported in this article have not been previously published. A copy of the data file used in this meta-analysis has been deposited at the Open Science Framework (https://osf.io/k8maf/?view_only=4e5e7ff1f078426cbb94892f76d8190a).

We thank Jennifer Walker and Rachael Posey (Medical Librarians) for invaluable assistance with the computerized literature searches. This research was partly supported by Zilveren Kruis and the Joep Lange Institute.

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Noncommunicable diseases accounted for 73% of all global deaths in 2017, and more than 50% of all deaths were attributable to just four risk factors related to lifestyle choices: high blood pressure, smoking, high blood glucose, and high body mass index (The Lancet, 2018). The implication is that behavioral interventions that effectively target diet, physical activity, alcohol consumption, and smoking have the potential to reduce rates of mortality and morbidity considerably (Kaplan, 2019). Health behavior theories specify a range of constructs that (a) predict health behaviors and (b) can be modified by interventions (Sheeran, Klein, & Rothman, 2017). One prominent theory that has been used extensively to promote health behavior change is self-determination theory (SDT; Ryan & Deci, 2017; Ryan, Patrick, Deci, & Williams, 2008). However, a quantitative synthesis of the efficacy of SDT interventions in changing health behaviors remains to be undertaken. We undertook a meta-analysis of randomized controlled trials (RCTs) to (a) determine the efficacy of SDT interventions in promoting health behavior change, (b) test mediators of SDT intervention effects, and (c) identify factors that moderate intervention effectiveness.

According to SDT, the "psychological states most essential for making meaningful change in terms of health behavior are: (1) being autonomously motivated for the change, and (2) perceiving oneself to be competent to make the change" (Ryan & Deci, 2017, p. 455). *Autonomous motivation* is an overarching term for regulatory styles that reflect self-endorsed reasons for behavioral engagement, such as enjoyment (intrinsic motivation), alignment with one's core values (integrated regulation), and personal utility (identified regulation). Autonomous motivation is often contrasted in the SDT literature with *controlled motivation*, the overarching term that refers to non–self-determined regulatory styles. These styles of behavioral regulation reflect internal pressure or the need to prove something to others (introjected regulation), or external pressure and contingent rewards (external regulation). Perceived competence is the second antecedent of health behavior change (Ryan & Deci, 2017). According to Williams et al. (2006), perceived competence refers to feeling able to attain health outcomes or perform health behaviors and is similar to the construct of self-efficacy (Bandura, 1997).

Ng et al. (2012) distinguished two variants of SDT as applied to health. The first, proposed by Ryan et al. (2008), traces the impact of interventions promoting autonomy support through basic psychological needs for autonomy, competence, and relatedness to styles of behavioral regulation (autonomous vs. controlled motivation), and ultimately to health behaviors and health outcomes. Health care systems support autonomy by encouraging individuals to engage in health behaviors for their own reasons, fostering effective management of barriers to change, and conveying feelings of acceptance and respect. Autonomy support, in turn, leads to the satisfaction of three basic psychological needs—for autonomy (the need to feel in control of one's behavior), competence (the need to feel effective in producing desired outcomes), and relatedness (the need to feel accepted by, and meaningfully related to, others)—which serve to enhance autonomous motivation and perceived competence, and so engender behavior change.

The second variant of SDT identified by Ng et al. (2012) is the more parsimonious model developed by Williams, Gagné, Ryan, and Deci (2002, 2006) specifically for health care settings. Williams et al.'s model focuses on the impact of autonomy supportive interventions on both autonomous motivation and perceived competence, and how changes in these proximal determinants influence health. This model forms the focus of the present review.[1]

Although reviews are largely supportive of SDT predictions, there are notable gaps in the evidence base. First, it is not yet clear how effective are SDT interventions in promoting health behavior change. Multiple SDT interventions proved effective in changing behavior (e.g., Chatzisarantis & Hagger, 2009; Fortier, Sweet, O'Sullivan, & Williams, 2007; Gourlan, Sarrazin, & Trouilloud, 2013; Ha, Lonsdale, Ng, & Lubans, 2017), but there are also multiple reports of ineffective interventions (Duda et al., 2014; Gillison, Standage, & Skevington, 2013; Mayer et al., 2018; Mendoza et al., 2017). This offers a clear rationale for a quantitative synthesis that estimates the magnitude of SDT intervention effects, and for moderator analyses to identify factors that determine effectiveness. Second, previous reviews of SDT interventions did not address all relevant outcomes. Gillison, Rouse, Standage, Sebire, and Ryan (2019) meta-analyzed 84 experimental and quasi-experimental studies of SDT interventions to promote health behaviors. The review observed significant changes in perceived autonomy support ($g = .84$) and autonomous motivation ($g = .41$) but did not report intervention effects on perceived competence and did not test SDT effects on health behaviors.

Third, evidence that autonomous motivation and perceived competence predict health behaviors relies on correlational data (Ng et al., 2012; Teixeira, Carraça, Markland, Silva, & Ryan, 2012). However, the fact that a particular variable predicts behavior in correlational tests does not indicate whether interventions that increase scores on that variable will change behavior (Sheeran, Harris, & Epton, 2014). This is because (a) correlational designs cannot rule out the influence of third variables (i.e., variables such as health literacy, conscientiousness, or optimism that could engender spurious links between the predictors and behavior) and (b) evidence indicates that findings from correlational tests generally overestimate the behavioral impact of intervention studies that change the relevant predictor (Sheeran et al., 2017). A synthesis of experimental or intervention studies is needed to determine whether SDT interventions change health behaviors and to formally assess whether autonomous motivation and perceived competence mediate the impact of SDT interventions on behavior change.

The foregoing discussion indicates that a new, comprehensive review of SDT interventions, focused on high-quality evidence from RCTs, is needed. Accordingly, the present review aimed to: (a) quantify the impact of SDT interventions on health behavior change via meta-analysis; (b) determine whether SDT interventions promote health behavior change by increasing autonomous

[1] Although it would have been desirable to test Ryan et al.'s (2008) model wherein (a) interventions determine levels of perceived autonomy support, (b) perceptions of autonomy support, in turn, predict satisfaction of needs for autonomy, competence, and relatedness, (c) needs satisfaction predicts autonomous motivation and perceived competence, and (d) autonomous motivation and perceived competence predict health behavior change, too few data were available to do so in the present review. There were 17, 12, 12, and 11 tests of intervention effects on perceptions of autonomy support and satisfaction of needs for autonomy, competence, and relatedness, respectively. However, few studies reported relevant intercorrelations among these variables, which meant that the relationships specified by Ryan et al. (2008) could not be modeled.

motivation and perceived competence using meta-analytic structural equation modeling (MASEM); and (c) identify sample, intervention, or methodological features that moderate intervention effectiveness using metaregression analyses.

Method

The meta-analysis was registered at Prospero (CRD42018097040) and followed PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009). The PRISMA Checklist is presented in Table S1 in the online supplemental materials. Study data have been deposited on the Open Science Framework (https://osf.io/k8maf/?view_only=4e5e7ff1f078426cbb94892f76d8190a).

Search Strategy

Studies were obtained via (a) a computerized search of relevant databases (PubMed, PsycINFO, Web of Science) initiated on February 19, 2018, (b) a manual search of the reference lists of previous reviews and articles that met the inclusion criteria for the review, and (c) requests for unpublished studies via e-mails to key researchers and the listservs of professional societies (Society for Personality and Social Psychology, Society of Behavioral Medicine, European Health Psychology Society, selfdeterminationtheory.org). The computerized search strategy included terms for (a) self-determination theory, (b) RCT (e.g., trial, intervention), and (c) various health behaviors. Search terms were optimized for each database by a medical librarian (see Table S2 in the online supplemental materials for the precise search terms).

There were four inclusion criteria for the review. First, the study used a randomized controlled or cluster randomized design; quasi-experimental and observational/correlational studies were excluded. Second, the study included an intervention based on self-determination theory (i.e., the authors stated that the intervention was based on SDT and/or constructs specified by SDT were targeted by the intervention). Third, a measure of health behavior was taken in the wake of the intervention. Health behaviors were defined as "overt behavioral patterns, actions, or habits that relate to health maintenance, to health restoration and to health improvement" (Gochman, 1997, p. 3). Fourth, the report was written in English.

Figure 1 shows the flow of information through phases of the present review. The computerized database search identified 640 articles and theses, of which 46 were duplicates. Screening of titles and abstracts resulted in the exclusion of a further 440 records because they did not concern health behaviors or did not report findings from a RCT. Assessment of the eligibility of 154 full-text records led to the exclusion of 98 articles. Reasons for exclusion were (a) duplicate study information was reported (protocol paper, baseline findings, etc.; $n = 28$), (b) study did not involve self-determination theory ($n = 27$), (c) study did not report a measure of behavior ($n = 21$), (d) study was not a RCT ($n = 19$), (e) publication was a conference abstract ($n = 2$), or (f) compared two different SDT interventions ($n = 1$). Fifty-six papers met our inclusion criteria. Because some papers reported multiple studies or trials had multiple intervention groups, a total of 65 effect sizes could be computed from these reports. The online supplemental materials present the characteristics of each study included in the review (Table S3 and S4), and the references for the 56 papers.

Analysis Strategy

We used Cohen's d as the effect size metric. Effect sizes represent the difference in the behavior of interest at follow-up for the treatment compared with the control condition; larger positive values indicate more effective interventions (i.e., higher rates of healthy behaviors and lower rates of unhealthy behaviors). When multiple indicators of behavior were reported in a single study, we used each individual effect size to assess the impact of interventions on these different outcomes and also computed the weighted average effect size within the study to represent the overall study effect. When studies included more than one treatment condition, we divided the sample size for the control group by the number of intervention groups, so as not to "double count" participants (Higgins & Green, 2011). To offer a strong test of the effectiveness of SDT interventions on health behaviors, effect sizes were computed using (a) data from the longest follow-up after the intervention and (b) intention-to-treat analyses if both intention-to-treat and per protocol analyses were reported (Sheeran et al., 2014).

We used STATA Version 14.0 (StataCorp, 2015) to conduct random effects meta-analyses and metaregressions. After correcting sample sizes for clustering, we computed the sample-weighted average effect size and computed heterogeneity statistics (Q, I^2). Next, we checked for publication bias using the funnel plot and Egger's regression. Duval and Tweedie's (2000) trim and fill procedure was used to correct for publication bias. Small sample bias was assessed using the procedure recommended by Coyne, Thombs, and Hagedoorn (2010); we coded whether or not studies had adequate power (i.e., 55% power to detect a medium-sized effect even when it is present) and regressed effect sizes on this predictor. We also used random effects metaregressions to test associations between effect sizes and (a) sample characteristics, (b) features of the intervention, and (c) methodological features, including study quality (risk of bias).

Coded Variables

Sample, intervention, and methodological characteristics. Sample, intervention, and methodological characteristics that could potentially moderate effect sizes were coded from each study (see Table S3 in the online supplemental materials). Sample characteristics included designations such as clinical (i.e., participants diagnosed with physical ailments), sedentary/inactive, overweight, adolescents, and older adults as well as mean age, gender composition of sample, and mean body mass index (BMI); intervention characteristics included the source and setting of the intervention, total contact time, as well as modes of delivery; methodological features included whether the control condition was active and aspects of study quality, assessed using the Cochrane Collaboration's Tool for Assessing Risk of Bias (Higgins & Green, 2011).

Reliability of coding. Charles Wright and Megan Villegas independently coded effect sizes ($k = 38$, 34% of tests) along with sample, intervention, and methodological characteristics ($k = 20$, 36% of tests). Coding proved reliable ($M_{ICC} = .98$, $M_{KAPPA} = 0.94$; all ICC and Kappa values were greater than 0.70). Discrepancies were resolved through discussion.

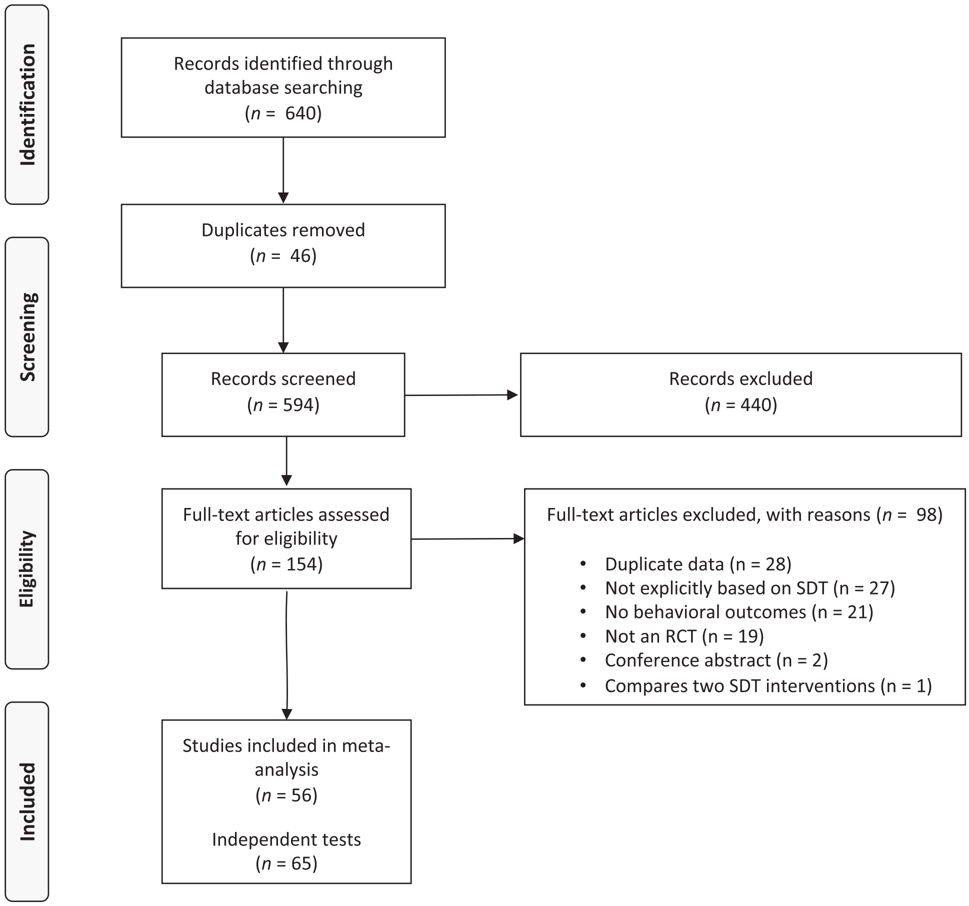

Figure 1. Flow of information through the phases of the review. RCT = randomized controlled trial; SDT = self-determination theory.

Results

Trial Characteristics

On average, tests of interventions involved 115 participants in the treatment condition and 91 participants in the control condition (*SD* = 159 and 144, respectively). Interventions primarily targeted adults ages 24–49 years ($k = 39$), adolescents aged 12–18 years ($k = 15$), and university students ($k = 8$), but there were 13 studies of sedentary/inactive participants and 12 studies with clinical samples. Participants were predominantly white ($M = 58.1\%$) and female ($M = 62.1\%$) and had a mean age of 35.7 years ($SD = 17.0$). Participants had an average BMI of 26.45 ($SD = 3.10$) in the 22 studies that reported BMI.

Almost one half of articles included in the review came from the United States (27 of 56). Interventions were conducted at schools or universities ($k = 14$), in hospital/clinic settings ($k = 13$), community centers ($k = 11$), and/or at home ($k = 7$), and predominantly involved group counseling sessions ($k = 21$), one-to-one, in-person counseling sessions ($k = 21$), or counseling via telephone ($k = 15$) or online ($k = 11$). Interventions were mainly delivered by a researcher ($k = 25$) or a counselor ($k = 12$). Most interventions lasted at least one month and up to six months. The mean number of intervention sessions was 8.25 ($SD = 15.94$), and the average contact time was 9.52 hr ($SD = 18.73$). Follow-up periods for interventions ranged from immediate to 2 years ($M = 12.60$ weeks, $SD = 25.05$). The mean attrition rate was 19.14%. Most studies were adequately powered according to Coyne et al.'s (2010) criterion ($k = 41$). Study quality assessed via the Cochrane tool generated mixed results (see Table S5 in the online supplemental materials). Selective reporting ($k = 5$) and failure to blind outcome assessors ($k = 14$) were infrequent; however, incomplete outcome data ($k = 26$), lack of random sequence generation ($k = 33$), and lack of allocation concealment ($k = 36$) were relatively common.

Impact of SDT Interventions on Health Behaviors

The sample-weighted average effect size for 65 trials was of small magnitude ($d_+ = .23$, 95% CI [.16, .29]). Table 1 presents effect sizes by type of behavior. Most interventions targeted physical activity ($k = 50$), sedentary behavior ($k = 10$), diet-related behaviors ($k = 8$), and smoking cessation ($k = 6$), and were similarly effective in promoting these behaviors ($.16 \le d_+ \le .25$), $Q = 3.97$, $p = .27$. SDT Interventions led to significant reductions in alcohol consumption and significant improvements in dental

Table 1
Sample-Weighted Average Effect Sizes for Self-Determination Theory Interventions to Promote Health Behaviors

Outcome	*N*	*k*	*d*	95% CI	*Q*	I^2
All studies	13,383	65	.23	[.17, .29]	145.27***	56.6
Physical activity	8,772	50	.25	[.16, .33]	147.16***	66.7
Self-report	6,896	34	.23	[.13, .33]	101.96***	67.6
Objective assessment	1,580	16	.29	[.12, .46]	44.28***	66.1
Sedentary behavior	886	10	.22	[.09, .36]	6.29	0.0
Diet	1,534	8	.20	[.04, .36]	9.61	48.0
Smoking cessation	2,263	6	.16	[.05, .27]	6.29	20.5
Screen time	932	3	.17	[−.02, .35]	4.27	53.2
Dental care	278	3	.35	[.11, .59]	0.70	0.0
Alcohol consumption	337	2	.27	[.06, .49]	0.00	0.0
Blood glucose monitoring	237	2	.26	[−.01, .54]	1.10	8.8
Cancer screening	881	1	.01	[−.12, .14]	—	—
Asthma management	301	1	.34	[.11, .57]	—	—

Note. *N* = number of participants; *k* = number of independent tests; *d* = sample-weighted average effect size; 95% CI = 95% confidence interval; *Q* and I^2 = homogeneity statistics.
*** $p < .001$.

care and asthma management but had no effect on blood glucose monitoring, screen time, or cancer screening. It made no difference to effect sizes whether physical activity was measured objectively via accelerometer/pedometer data ($d_+ = .29$) or by self-reports ($d_+ = .23$), $Q = 5.86$, $p = .12$. There was no difference in the effect size observed for the 26 studies that used an immediate follow-up in the wake of the intervention compared to the 30 studies that used a longer-term follow-up ($d_+ = .24$ and .22, respectively), $Q = 0.12$, $p = .734$. It also made little difference to the sample-weighted average d_+ if a single effect size was computed for studies that had multiple treatment arms ($d_+ = .25$, 95% CI [.18, .32], $k = 56$, $Q = 161.72$, $p < .001$, $I^2 = 66.0\%$).

Figure S1 in the online supplemental materials presents the forest plot of effect sizes. Effects were heterogeneous ($Q = 148.58$, $p < .001$), and heterogeneity was of moderate magnitude ($I^2 = 56.9$). Inspection of the funnel plot (see Figure 2) suggested that the observed effects were characterized by publication bias and Egger's regression proved significant ($B = 1.17$, $SE = 0.36$,

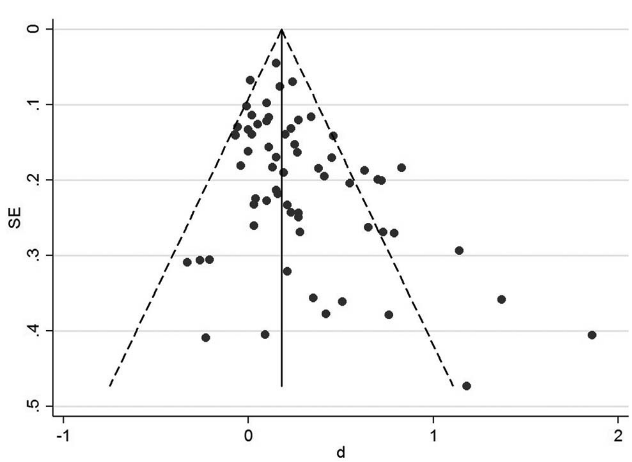

Figure 2. Funnel plot of effect sizes. Effect sizes (*d*) for behavior are plotted against the standard errors (*SE*) of the effect sizes.

$p = .002$). Trim and fill analysis to correct for publication bias led to the imputation of $k = 11$ additional effects and yielded an adjusted $d_+ = .15$ (95% CI [.08, .22]).

Metaregression indicated that the effects were characterized by small sample bias ($B = -.30$, $SE = 0.10$, $p = .004$). Studies that were adequately powered according to Coyne et al.'s (2010) criterion yielded a smaller average effect size ($d_+ = .18$, 95% CI [.12, .24]) compared with underpowered studies ($d_+ = .50$, 95% CI [.30, .70]). Seven studies included in the review were unpublished (13.0%). Metaregression of effect sizes on publication status (published = 1, unpublished = 0) indicated that the association was not significant ($B = -.11$, $SE = 0.14$, $p = .42$).

Meta-Analytic Structural Equation Model

Having demonstrated that SDT interventions are effective in promoting health behavior change, we next tested whether these changes were mediated by autonomous motivation and perceived competence. First, we meta-analyzed the impact of interventions on subsequent autonomous motivation and perceived competence. Second, we meta-analyzed the *z*-transformed correlations among autonomous motivation, perceived competence, and health behaviors reported in the primary studies. These correlations were then submitted to a meta-analytic structural equation model (Jak, 2015) to assess whether autonomous motivation and perceived competence mediated the effect of SDT interventions on health behaviors.

The impact of SDT interventions on autonomous motivation was tested in 45 trials; the sample-weighted average effect size was of small magnitude ($d_+ = .23$, 95% CI [.12, .34], $Q = 204.65$, $I^2 = 78.5\%$). The impact of SDT interventions on perceived competence was assessed in 26 trials and generated a small average effect size ($d_+ = .21$, 95% CI [.11, .30], $Q = 61.45$, $I^2 = 59.3\%$). We also tested whether SDT interventions influenced controlled motivation; however, the effect was negligible ($d_+ = -.01$, 95% CI [−.14, .13], $Q = 60.55$, $p < .001$, $I^2 = 65.3\%$). Because controlled motivation hardly qualifies as a mediator of intervention effects, this variable is not considered further. Forest plots and funnel plots are presented in the online supplemental materials.

Autonomous motivation had a medium-sized average correlation with behavior ($r_+ = .27$, 95% CI [.21, .32], $k = 17$). The average correlation between perceived competence and behavior was also medium-sized ($r_+ = .34$, 95% CI [.24, .44], $k = 12$); autonomous motivation and perceived competence were significantly associated ($r_+ = .38$, 95% CI [.26, .49], $k = 9$). All three average correlations were heterogenous ($Q = 55.16$, 103.80, and 59.46, respectively, $p < .001$) and heterogeneity was of substantial magnitude ($I^2 = 71.0$, 89.4, and 86.6, respectively).[2]

We undertook meta-analytic structural equation modeling of the correlation matrices using the *metaSEM* package Version 1.2.3 in R Version 3.6.1. Figure 3 presents the path model. The paths from SDT intervention to autonomous motivation and perceived competence were both significant, and the paths from autonomous motivation and perceived competence to health behaviors were significant. We tested the indirect paths from intervention to behavior via autonomous motivation ($B = .035$, 95% CI [.006, .082]) and via perceived competence ($B = .027$, 95% CI [.011, .051]); both indirect paths proved significant indicating that these constructs mediated the SDT intervention effects on behavior. The direct path from SDT intervention to health behaviors became nonsignificant (Estimate = .046, 95% CI [−.008, .101]); 57.4% of the total effect of SDT interventions on health behaviors was channeled through the mediators.

Moderator Analyses

Table 2 presents the results of the metaregression analyses used to test moderation by sample, intervention, and methodological features. Of the many moderators tested, only two factors predicted effect sizes. Overweight samples ($B = .508$, $SE = .160$, $p = .002$) and higher mean BMI of study participants ($B = .053$, $SE = .017$, $p = .010$) were associated with larger effects. It is notable that intervention setting, delivery, intensity, or source were not related to effectiveness, and interventions were effective irrespective of the time interval between the end of the intervention and obtaining behavioral data, the use of active control conditions, and whether the intervention targeted a single behavior or multiple behaviors. We also assessed whether risk of bias predicted effect sizes; no significant associations were observed (see Table S6 in the online supplemental materials).

Discussion

This is the first meta-analysis of the efficacy of SDT as a conceptual framework for designing and delivering interventions to promote health behavior change. Across 65 randomized tests, we found that the sample-weighted average effect size was $d_+ = .23$ (95% CI [.16, .29]). Interventions were similarly effective for physical activity, dietary change, and smoking cessation. Despite extensive efforts to include the gray literature, there was evidence of publication bias and small sample bias. After correcting for publication bias, the overall sample-weighted effect size reduced to $d_+ = .15$ (95% CI [.08, .22]). The implication is that interventions based on SDT lead to significant changes in health behaviors but the magnitude of behavioral change is small.[3]

Mediation and moderation analyses were also undertaken. We tested a process model of SDT intervention effects (Williams et al., 2002, 2006) using meta-analytic structural equation modeling. Findings indicated that autonomous motivation and perceived competence predicted health behavior, and these variables simultaneously mediated of the effects of SDT interventions on health behaviors. We assessed more than 30 potential moderators of SDT intervention effects that pertained to features of the sample, intervention, and methodology. A single feature, the mean BMI of the sample, was associated with health behavior change, and this finding must be viewed in the context of the large number of tests of moderation.

Findings from the present meta-analysis support the efficacy of SDT interventions in promoting health behavior change, but also help to specify strengths and weaknesses of this approach. Key strengths are that (a) SDT interventions engender significant change in health behaviors, (b) the structure of the SDT finds empirical support in randomized tests; in particular, intervention effects are mediated by the factors specified by the theory (autonomous motivation and perceived competence), and (c) SDT interventions are similarly effective irrespective of multiple features of the intervention (source, setting, mode of delivery, and intensity), sample, and methodology (e.g., use of active control conditions, long-term behavioral follow-ups, targeting multiple health behaviors).

The key weakness identified by the present review is that SDT interventions are not very powerful, especially given that the interventions involved an average of 8.25 sessions and 9.52 hr of contact time. The experimental medicine approach (Sheeran et al., 2017) indicates that interventions' power or behavioral impact depends upon two component processes: *Target engagement*—the extent to which the intervention engages relevant targets (here, autonomous motivation and perceived competence), and *target validity*—the extent to which these targets determine behavior change. We observed that the impact of interventions on autonomous motivation and perceived competence was small and these

[2] We also tested whether the measurement of autonomous motivation influenced effect sizes. Autonomous motivation can be measured in its own right or relative to controlled motivation (i.e., absolute vs. relative autonomy). Meta-regression analyses indicated that the use of absolute vs. relative measures did not influence either the magnitude of the impact of interventions on autonomous motivation ($B = .07$, $SE = .17$, $p = .67$) or the strength of the association between autonomous motivation and health behavior ($B = .05$, $SE = .08$, $p = .55$).

[3] It seems reasonable to characterize the magnitude of the impact of SDT interventions on health behavior change as small on several grounds. First, d values of .15 and .23 are conventionally considered small according to Cohen's (1992) characterization of effect sizes, and these values remain small using Funder and Ozer's (2019) recent and more lenient guidelines. Second, the impact of SDT interventions observed here is approximately one-half ($d_+ = .23$) or one-third ($d_+ = .15$) the median effect size, $d_+ = .44$, observed in Lipsey and Wilson's (1993) meta-analysis of the efficacy of psychological, educational, and behavioral programs. Third, when Rosenthal and Rubin's (1982) binomial effect size display (BESD) is applied to $d_+ = .15$, the rate of behavior change corresponds to an increase from 46% in the control condition to only 54% in the treatment condition. Finally, because most interventions targeted physical activity, we converted effect sizes into a relevant metric—the number of additional steps per day conferred by the intervention. For $d_+ = .15$, number of additional steps per day is only 814 (Wright, Rhodes, Ruggerio, & Sheeran, 2020). Thus, conventional characterizations of effect size, comparison with a benchmarking meta-analysis, and the use of the BESD and a meaningful metric of real-world impact each suggest that the interventions reviewed here have a small effect on behavior.

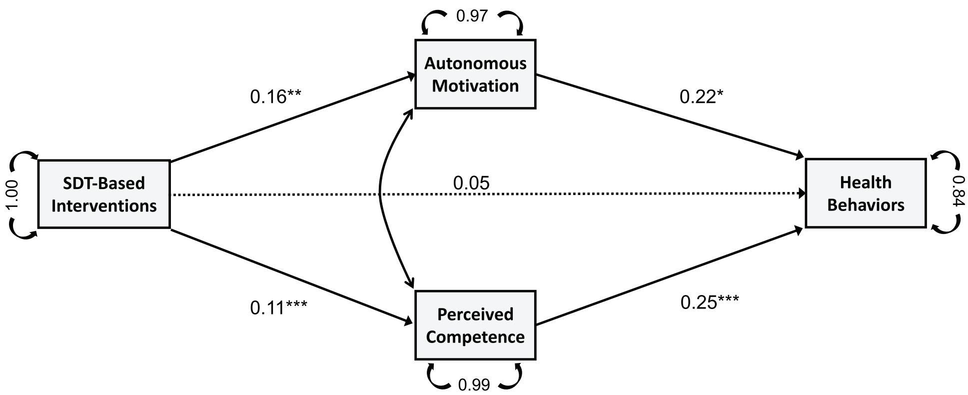

Figure 3. Meta-analytic structural equation model: Self-determination theory interventions promote health behavior change via increased autonomous motivation and perceived competence. Solid lines indicate significant paths; dashed line indicates nonsignificant path; curved line indicates that autonomous motivation and perceived competence were allowed to covary ($r_+ = .38$). $^{*} p < .05$, $^{**} p < .01$, $^{***} p < .001$.

targets had small associations with behavior in the MASEM. That is, effect sizes for target engagement and target validity both were small.

Why did SDT interventions not have a larger effect on the specified targets? In the present review, the impact of SDT interventions on autonomous motivation was smaller than that observed in Gillison et al.'s (2019) meta-analysis of the behavior change techniques used in SDT interventions ($d_+ = .23$ vs. .41), whereas the effect on perceived competence was similar to that observed in a meta-analysis of interventions to promote self-efficacy for physical activity ($d_+ = .21$ vs. .16; Ashford, Edmunds, & French, 2010). None of these reviews observed even medium-sized effects ($d_+ = .50$), however, which likely speaks to the difficulty of changing autonomous motivation and perceived competence for consequential health behaviors in field settings.

Two considerations may be important in this regard. First, it is challenging to train people in positions of authority to adopt a need-supportive communication style, based on SDT principles (Ntoumanis, Quested, Reeve, & Cheon, 2018). For instance, authority figures may hold personality dispositions (e.g., dominance orientation, authoritarianism), or beliefs about motivational style that do not align well with the principle of supporting others' needs for autonomy, competence, and relatedness. Need-supportive communication can be perceived as ineffective ("Sounds nice, but it won't work!"), idealistic, impractical, or too time consuming. In contrast, people in authority may believe that a controlling communication is both effective and easy to apply, especially under time pressure (e.g., when there are brief windows of opportunity for one-to-one consultation). Furthermore, prevailing cultural norms (within an organization or society at large) as to what the expected and common (i.e., normative) approaches should be for motivating and communicating with others, can influence the degree to which health care professionals, teachers, and others adopt need-supportive communication. For these reasons, it may be difficult to instantiate the need-supportive communicative styles that could effectively promote autonomous motivation and perceived competence.

The second consideration is that there may be a tension between public health goals and SDT's conceptual goal of enabling individuals to make authentic decisions about health behavior change (i.e., make choices based on reasons that are fully endorsed by the self). According to Ryan and Deci (2017), participants' autonomy should be considered an important outcome in its own right, and not merely serve as a means for attaining specific behavioral goals such as tobacco cessation or increased physical activity. A reflective and true choice could involve the decision *not* to engage in a particular health behavior (e.g., not to participate in an exercise program, or try to quit smoking or lose weight), and should, according to Ryan and Deci (2017), be supported by health practitioners. Although this stance is aligned with principles of modern biomedical ethics (e.g., Beauchamp & Childress, 2001), there are cultural, financial, and political constraints that must be navigated by policymakers, practitioners, and researchers as they endeavor to promote health behavior changes that participants may not fully endorse.

The effects of changing autonomous motivation and perceived competence on health behavior change were modest in the present review, and of equivalent magnitude to the effect sizes observed in Ng et al.'s (2012) meta-analysis of observational studies. How might the SDT framework be extended so as to generate larger changes in health behaviors? SDT focuses on individuals' conscious motivation, which suggests that developments might profitably address three issues. First, research on the *intention-behavior gap* (review by Sheeran & Webb, 2016) indicates that motivation often does not get translated into action, even when participants have high perceived competence or self-efficacy (Sheeran, 2002). This is because motivation is only the starting point for successful goal striving: People still have to manage self-regulatory problems such as forgetting to act, missing opportunities, or getting derailed by temptations, distractions, or unwanted internal states (e.g., mood, ego-depletion) to successfully achieve their goals (Gollwitzer & Sheeran, 2006). Koestner and colleagues have shown that supplementing autonomous motivation and perceived competence with if–then plans or *implementation intentions* (Gollwitzer, 1999) improves rates of behavioral performance and goal attainment (Koestner, Lekes, Powers, & Chicoine, 2002, 2006, 2008). Implementation intentions are plans that have the structure: *If [opportunity/obstacle] – then I will [response].*

Table 2
Meta-Regression of Effect Sizes on Sample, Intervention, and Methodological Features

Moderator variable	Used (%)	*B*	*SE*	*p*	R^2
Sample features					
Gender (% female)[a]	—	.002	.002	.385	8.06
Race/ethnicity (% non-white)[b]	—	.000	.002	.994	19.13
Age[c]	—	−.002	.002	.382	2.66
BMI[d]	—	.053	.017	.010	76.52
Sedentary/inactive participants	13 (23.2)	.083	.094	.382	0.12
Clinical patients	12 (21.4)	−.069	.093	.465	1.13
Overweight participants	4 (7.1)	.508	.160	.002	35.33
University students	6 (10.7)	.155	.128	.232	6.32
Adolescents	11 (19.6)	−.061	.093	.515	6.40
Older adults	3 (5.4)	−.092	.174	.599	2.60
Intervention features					
Setting of intervention					
Home	7 (12.5)	−.186	.099	.065	14.16
Clinic/Hospital	13 (23.2)	.109	.094	.254	3.61
Community center	11 (19.6)	−.039	.090	.663	6.17
School/University	14 (25.0)	.034	.089	.700	0.87
Mode of delivery					
One-to-one	21 (37.5)	.039	.080	.626	6.34
Group session	21 (37.5)	.050	.079	.530	1.36
Online	11 (19.6)	.002	.092	.982	5.63
Telephone advice/counseling	15 (26.8)	.021	.086	.810	5.91
Digital materials	6 (10.7)	−.086	.132	.515	5.46
Mail	7 (12.5)	−.173	.105	.106	11.64
Intensity					
Contact time of intervention[e]	—	.002	.003	.601	3.83
Number of sessions[f]	—	.002	.003	.386	3.32
Duration of intervention[g]	—	.027	.017	.117	2.22
Source of intervention					
Researcher	27 (48.2)	−.019	.077	.803	4.81
Nurse	5 (8.9)	.108	.136	.429	0.51
Doctor	5 (8.9)	.148	.121	.226	3.11
Counselor	14 (25.0)	.055	.089	.535	4.75
Educator	7 (12.5)	.033	.106	.759	3.42
Fitness Trainer	6 (10.7)	.033	.130	.800	5.44
Methodological features					
Time to follow-up[h]	—	−.001	.001	.338	0.93
Active control group	23 (42.6)	.029	.077	.710	8.63
Usual care	22 (40.7)	.003	.077	.969	5.13
Waitlist control	8 (14.8)	.024	.110	.830	5.65
Multi-behavior intervention	11 (20.4)	.002	.095	.981	5.50

Note. "Used" is the number (percentage) of studies that deployed the relevant feature.
[a] Fifty-five studies reported gender information. [b] Twenty-nine studies reported race/ethnicity information. [c] Fifty-two studies reported age information. [d] Twenty-two studies reported participants' body mass index (BMI). [e] Thirty-six studies reported total contact time of information. [f] Fifty-one studies reported the number of intervention sessions. [g] Fifty-three studies reported the duration of the intervention. [h] Fifty-six studies reported the time interval between the end of the intervention and the final behavioral follow-up.

The if part of the plan specifies good opportunities to act (e.g., particular times and places) or obstacles to goal attainment (e.g., laziness, TV viewing habits), whereas the plans' then part specifies instrumental responses to those cues (e.g., "I will go to the gym on Monday after work!", "I will tell myself I'll be full of energy after going to the gym!"). Meta-analyses support the efficacy of implementation intentions in promoting behavior change (e.g., Adriaanse et al., 2011; Bélanger-Gravel, Godin, Bilodeau, & Poirier, 2013; Gollwitzer & Sheeran, 2006). Koestner et al. (2002, 2006, 2008) observed that autonomous motivation and perceived competence have synergistic relations with if-then planning, which suggests that implementation intentions could be deployed to complement future SDT interventions on health behaviors.

Second, SDT interventions do not explicitly target nonconscious or automatic processes such as antagonistic habits (e.g., cue-driven sedentary behaviors) and implicit associations (approach/avoidance biases, automatic affect) that can militate against health behavior performance (e.g., Brand & Ekkekakis, 2018; Rhodes, McEwan, & Rebar, 2019; reviews by Rothman et al., 2015; Sheeran, Gollwitzer, & Bargh, 2013). It is also the case that health behavior performance is not merely the product of individual-level processes but is also a function of contextual affordances (Person × Situation interactions). For example, changing physical activity often requires interventions at multiple levels in addition to the individual level, such as modifying built environments, social environments, policies, and practices (Sallis, 2018). Greater analysis of how SDT variables interact with, or could help to circumvent, unwanted implicit influences and structural barriers would be valuable.

The validity of the present meta-analysis depends upon the database upon which it rests. Despite extensive searches, including the gray literature, we could locate only 56 papers that yielded 65 tests of SDT interventions. It appears that SDT, like other health behavior theories (Sheeran et al., 2017), relies largely on observational evidence (e.g., Ng et al., 2012; Teixeira et al., 2012). Additional intervention studies are clearly needed. Whereas physical activity has been studied extensively, fewer RCTs targeted diet and smoking cessation, and there were very few tests of alcohol consumption and adherence behaviors. Research is needed on these understudied behaviors, and other consequential health actions (e.g., vaccination, sleep hygiene) that have not yet been addressed by SDT. Studies of patient (e.g., CVD, cancer) and low–socioeconomic status samples should be a priority. Longer-term follow-ups would also be desirable given that the mean follow-up period was only 3 months in the present review.

Additional RCTs based on SDT will be of little value, however, if findings are not published. The extent of publication bias was substantial in the present review, and though we attempted to adjust for bias via trim and fill analysis, behavior change by researchers (e.g., trial registration) and reviewers (e.g., checking RCT protocols) will be the best corrective. Primary studies were also characterized by small sample bias. Future tests will need to recruit much larger samples than the mean number of participants in the trials reviewed here ($N = 206$) to achieve satisfactory power (see Table S4). Finally, we could retrieve intervention effects on autonomous motivation and perceived competence in only 45 and 26 trials, respectively, and respective correlations with health behaviors were available for only 17 and 12 trials. Authors should routinely report these data in future, and editors and reviewers should request it.

The present review indicates opportunities for further conceptual and intervention development in SDT research. At the conceptual level, SDT theorists could begin to specify how structural barriers and antagonistic implicit processes may undermine self-determined performance of health behaviors, or how self-determination could overcome these influences. Additional tests of the efficacy of supplementing SDT interventions with implementation intentions also are warranted. We observed that SDT interventions had no significant effect on controlled motivation in the present review. Future studies might profitably test whether interventions that simultaneously increase autonomous motivation and reduce controlled motivation have greater behavioral impact compared to changes in either type of motivation on its own. It is intriguing to note that the intensity of SDT interventions (contact time, number of sessions, intervention duration) was not associated with effect sizes. This opens up the possibility that brief SDT interventions could be effective and could serve to increase the scalability and reach of this approach. Finally, the funnel plots (Figures S3 and S5 in the online supplemental materials) demonstrated a good deal of variability in the impact of interventions on autonomous motivation and perceived competence. Further research geared at specifying the most effective change techniques in SDT interventions (e.g., Gillison et al., 2019; Teixeira et al., 2019) should serve to increase the impact of future SDT trials to promote health behavior change.

The present meta-analysis shows that SDT interventions have a significant but small effect on health behaviors. The structure of the theory is supported by findings showing that autonomous motivation and perceived competence mediate intervention effects on health behaviors, and that effectiveness of SDT interventions was largely unaffected by features of the sample, intervention, and methodology. Trials of SDT interventions to date are characterized by publication bias and small sample bias, however, and more and better-powered RCTs are warranted to evaluate this framework. Our review offers several suggestions about how the effectiveness of future SDT interventions might be improved.

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Received July 10, 2019
Revision received March 9, 2020
Accepted March 13, 2020 ■