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How can interventions increase motivation for physical activity? A systematic review and meta-analysis

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Abstract

Motivation is a proximal determinant of behavior in many psychological theories, and increasing motivation is central to most behavior change interventions. This systematic review and meta-analysis sought to fill a gap in the literature by identifying features of behavior change interventions associated with favorable changes in three prominent motivational constructs: intention, stage of change and autonomous motivation. A systematic literature search identified 88 intervention studies (N = 18,804) which assessed changes in at least one of these motivational constructs for physical activity (PA). Intervention descriptions were coded for potential moderators, including behavior change techniques (BCTs), modes of delivery and theory use. Random effects comparative subgroup analyses identified 19 BCTs and 12 modes of delivery associated with changes in at least one motivational outcome. Interventions which were delivered face-to-face or in gym settings, or which included the BCTs problem solving, self-monitoring of behavior or behavioral practice/rehearsal, or which included the combination of self-monitoring of behavior with any other BCTs derived from control theory, were all associated with beneficial changes in multiple motivational constructs. Meta-regression analyses indicated that increases in intention and stage of change, but not autonomous motivation, were related to increases in PA. The intervention characteristics identified here as effective in changing motivation seemed to form clusters related to behavioral experience and self-regulation, which have previously been linked to changes in behavior as well. These BCTs and modes of delivery merit further systematic study, and could be used as a foundation for improving interventions targeting increases in motivation for PA.

Keywords: Meta-analysis; motivation; intention; stage of change; behavior change techniques

Review Registration: This study was pre-registered in PROSPERO, the international prospective register of systematic reviews (ID#: CRD42015014922)

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Motivation drives and directs human behavior, and shaping motivation is therefore a central ambition of programs designed to change behavior (Schwarzer, Lippke & Lusczynska, 2011), including health behaviors such as physical activity (PA), dietary intake, smoking, alcohol consumption, condom use and disease self-management behaviors. Within research on health behavior change interventions, behavioral outcomes are often primary measures of effectiveness, and have therefore received most attention in the experimental and meta-analytical research. While this behavioral focus has led to important insights about which intervention components and behavior change techniques (BCTs) are associated with changes in health behaviors, it has also somewhat limited the extent to which the motivational processes that precede and underlie behavior change have been investigated. As motivation determines whether individuals will make efforts to change their behavior, whether they will take up action-focused components of behavior change interventions (McMurran & Ward, 2010), and whether newly-enacted behavioral changes are likely to be maintained (Kwasnicka, Dombrowski, White & Sniehotta, 2016), an incomplete understanding of how to increase motivation results in an incomplete understanding of how to change behavior itself. Research into how interventions can increase motivation for behavior change is therefore key to fully understanding the psychological process of behavior change and to developing effective behavior change interventions.

How is Motivation Conceptualized within Behavioral Theories?

Nearly all social-cognitive theories propose a hierarchy in which social-cognitive and environmental factors predict some seminal motivational construct, which triggers (or is closely aligned with) a shift from motivation to behavioral enactment. Crossing this 'decisional Rubicon' (Gollwitzer, 1990) from the motivational or pre-intentional phase into the post-intentional, volitional, or action phase rarely occurs spontaneously, and motivational constructs and their corresponding theoretical determinants have been conceptualized differently across theories. Three prominent theoretical conceptualizations of motivation are intention, stage of change, and autonomous motivation.

Behavioral intention. Numerous theories, such as the theory of planned behavior (TPB; Ajzen, 1991), reasoned action approach (RAA; Fishbein & Ajzen, 2011) and health action process approach (HAPA; Schwarzer, 2008), place intention, which indicates an individual's desire to perform a given behavior (Ajzen, 2002), as the proximal determinant of behavior which separates motivation and action. Within the RAA, intention is predicted by individuals' attitudes, subjective norms and perceived behavioral control (i.e. self-efficacy)

toward the behavior (Ajzen, 1991; Fishbein & Ajzen, 2011), which are in turn predicted by past behavior and various background variables (e.g. personality).

Despite extensive empirical research on motivational theories such as the TPB, RAA and HAPA, there is no clear consensus on the ideal methods to *change* the theoretical constructs that predict intention and behavior. Of these theoretical constructs, self-efficacy (i.e. one's belief in his or her abilities to undertake a behavior) (Bandura, 1977) is perhaps the most studied and experimentally-manipulated. A series of reviews and meta-analyses has examined BCTs and modes of delivery associated with changes in self-efficacy for physical activity and dietary behaviors (French, Olander, Chisholm & McSharry, 2014; Olander et al., 2013; Prestwich et al., 2014; Williams & French, 2011), but has not provided any clear consensus, with some meta-analytical findings contradicting theoretical assumptions.

Despite the predominance of intention in social cognitive theories such as RAA, TPB and HAPA, there is a limited understanding of the optimal methods or BCTs for directly influencing it. Identifying methods to strengthen intentions may therefore improve the efficacy of interventions and contribute to renewal or further development of these theories.

Stage of change and the transtheoretical model. While many social-cognitive theories are regarded as continuum models of behavior, the transtheoretical model (TTM; Prochaska & DiClemente, 1986) is a stage theory, which assumes that individuals move through multiple distinct "stages of change" on their journey to adopting and maintaining a behavior. The stages of change (usually five, but sometimes extended to six or more) range from precontemplation, wherein a person has not considered changing their behavior, through to maintenance, where a person has successfully adopted a new behavior for at least six months and works to prevent relapsing into old patterns of behavior.

Within each TTM stage, a specific set of cognitive, affective and behavioral "processes of change" are hypothesized to facilitate stage transitions (Prochaska & Velicer, 1997). For example, consciousness raising (i.e. gathering information about the behavior in question) and dramatic relief (i.e. introspection about feelings related to the behavior) should facilitate the transition from precontemplation to contemplation, but would not be expected to foster transitions from preparation to action or from action to maintenance (Prochaska & Velicer, 1997).

Only one process of change, self-liberation, is hypothesized to help individuals transition from the preparation stage, in which intentions are formed and strengthened, into the action stage, in which individuals have taken considerable steps toward full adoption of the new behavior. Self-liberation includes individuals' examining their beliefs that change is

possible and making commitments to act on those beliefs, and as such, parallels have been drawn between self-liberation and elements of both self-efficacy and intention from the TPB (Armitage, 2009). While intention formation is hypothesized to occur in the preparation stage, the TTM does not clearly propose methods for assessing variance in intention strength. Studies using the TTM have instead relied on examining transitions between stages or perceived pros and cons of changing (i.e. decisional balance) to assess motivation. Although a vast body of empirical research based on the TTM exists, these findings have not yet been compiled meta-analytically to identify the BCTs most influential in preparation phase transition.

Autonomous motivation and self-determination theory. Self-determination theory (SDT; Deci & Ryan, 2000) proposes several sub-categories of motivation, which can be situated on a spectrum ranging from autonomous motives to controlled motives. On one side of this SDT spectrum is intrinsic motivation, which is fully autonomous, and is characterized by the inherent satisfaction and pleasure gained from engaging in a behavior (Ryan & Deci, 2000). Beyond intrinsic motivation lie extrinsic motivations, which are further classified by the degree to which they are internalized (Ryan & Connell, 1989): from integrated (most autonomous) on the one hand, to external (most controlling) on the other.

Autonomous motivation is characterized by a sense of choice, volition, and freedom from external pressure to engage in the behavior, and consists of intrinsic motivation and two types of external motivation: integrated and identified. In other words, motivation for a behavior is autonomous when it is engaged in for pleasure or fun (intrinsic motivation), when it is congruent with an individual's sense of self (integrated regulation), or when it is personally important to the individual (identified regulation).

Autonomous motivation is associated with positive changes in health behaviors (Hagger & Chatzisarantis, 2009; Teixeira et al., 2012), as well as long-term maintenance of various health behaviors and health outcomes (Ng et al., 2012). Controlled motivations, on the contrary, include external regulation (in which behavior is enacted to obtain a reward or avoid punishment) and introjected regulation (in which behavior is enacted to avoid guilt) (Deci & Ryan, 2000), and are associated with less behavioral maintenance and poorer psychological well-being (Ng et al., 2012).

SDT suggests that the internalization of behavioral regulation may be achieved by supporting individuals' needs for autonomy, competence, and relatedness (Ryan, 1995). This could include offering meaningful rationales for behavior or choices for behavioral enactment, using autonomy-supportive language, recognizing individuals' efforts, and

fostering positive interactions with others - techniques which are closely aligned with principles of motivational interviewing (MI; Markland, Ryan, Tobin & Rollnick, 2005) and have been theorized to increase autonomous motivation (Markland & Vansteenkiste, 2007). No previous meta-analyses have brought together empirical findings to identify the optimal methods to improve autonomous motivation for health behaviors, which could contribute to better initiation and maintenance within interventions.

Aims of the Present Review

Behavior change interventions frequently target improvements in motivational variables en route to changing behavior, and many such individual-level interventions have drawn from the theories presented above. Understanding how to optimally foster changes in motivation will help to improve psychological theories of motivation and behavior change, and improve the capabilities of future interventions to motivate individuals toward action. This systematic review and meta-analysis primarily aims to identify BCTs, which, when included in behavior change interventions, are associated with changes in prominent measures of motivation: intention, stage of change and autonomous motivation. In addition, as additional study- and intervention-related factors can moderate intervention effects on motivation, this study will examine the extents to which modes of delivery, theory use, and participant characteristics are associated with changes in motivational outcomes. Finally, this meta-analysis will examine the extents to which changes in intention, stage of change and autonomous motivation predict changes in behavior following interventions.

To accomplish these aims, this review will focus solely on interventions in one behavioral domain: physical activity (PA). This approach offers several benefits. First, interventions which increase motivation for one behavior may not necessarily increase motivation for another (Rutten et al., 2014). Therefore, combining interventions targeting differing behavioral outcomes meta-analytically could result in a clouded view of how well specific BCTs and other study characteristics contribute to outcomes in any specific behavioral domain. Second, the nature of health behaviors may also influence effectiveness of various BCTs. Different BCTs may be more effective in altering motivation for 'start behaviors' vs. 'stop behaviors' (approach/avoidance behaviors), and regular or lasting behaviors (e.g. exercise) vs. those that only need to be undertaken once or infrequently (e.g. cancer screening). Third, physical inactivity is strongly associated with premature mortality and the development of cardiovascular and metabolic diseases (Matthews et al, 2012), and presents considerable financial costs to society (Ding et al, 2016). There is a strong need for effective interventions targeting increases in PA. Finally, when compared to research on other

health behaviors, evidence for PA is more regularly based on objective measurements besides self-reported behavior, which adds additional validity and reliability to the results of intervention studies targeting this important outcome.

Methods

This systematic review and meta-analysis was prospectively registered in the PROSPERO international prospective register of systematic reviews (ID#:CRD42015014922).

Study Identification

Literature searches were conducted in PsycInfo, Web of Science, PubMed and Google Scholar using the comprehensive search strategy available in the appendix. A request for data from unpublished intervention studies was sent to members of the European Health Psychology Society. The final searches were conducted in February 2016.

To be eligible for inclusion, a study must have described an intervention delivered to adults and reported data on a measure of intention to be physically active, stage of change for PA or autonomous motivation for PA for at least two time points (i.e. just before the start of the intervention plus one other), so that pre-treatment to post-treatment changes in that variable could be assessed. Furthermore, study data needed to allow for the calculation of effect sizes, either from the article itself, supplementary material or after requests to the corresponding author(s). No further restrictions were placed on the types of interventions, study designs or participants. Studies were excluded if they did not meet the inclusion criteria, or if the first measurement point after baseline took place more than 26 weeks after the intervention started, as we were interested in examining changes in motivation in the early phases of PA behavior change. We also excluded studies which reported on changes in intention to increase PA, as changes in this measure would be confounded by any contemporaneous changes in PA behavior.

After conducting database searches, one researcher [Redacted for peer review] screened the titles and abstracts of retrieved records and eliminated duplicates and articles that certainly did not meet the inclusion criteria (e.g. animal studies, studies in children, studies in research domains not related to health or behavior change). At this stage, exclusions were only made in cases where it was certain that the record did not meet the inclusion criteria (e.g. not an intervention study, no mention of any outcome related motivation, physical activity, or energy balance-related outcomes like weight loss). For all

articles not excluded after title and abstract screening, we sought full-text reports to determine eligibility for inclusion.

After obtaining the full texts of articles, we established the reliability of identifying eligible studies within our research group in a two-step process. First a random selection of 10 full text articles was screened by all researchers, and decisions on inclusion/exclusion were discussed within the group. Second, after jointly screening a second round of 10 full text articles, we reached full consensus on inclusion/exclusion, and subsequently proceeded with single-author screening.

For the remaining full text articles, one researcher [Redacted for peer review] independently reviewed each against the inclusion criteria. In situations when it was not clear whether a study fulfilled the inclusion criteria and contained appropriate outcome data, the full-text was also reviewed by a second randomly-assigned researcher, and discussions took place within the study team until a consensus decision was reached. Where a study fulfilled all inclusion criteria but presented data in a way that was unsuitable for meta-analysis, the corresponding authors were contacted by phone, email or through scientific social networks (e.g. ResearchGate, LinkedIn) to obtain additional data.

Coding and Data Extraction

After identifying the final set of included studies, we coded all study arms for the following moderator variables: BCT use (using the v1 taxonomy of BCTs [Michie et al., 2013]); sample characteristics (age, gender, healthy/risk/disease group, BMI/overweight status, recruitment method, setting, existing level of PA, socioeconomic status, education, income level); intervention characteristics (intervention label, group/individual, whether it included components delivered through digital, mobile, face-to-face, paper-based, SMS, phone or email channels, the total contact time, number of contacts, interventionist, theoretical basis (using item five from the theory coding scheme of Michie & Prestwich, [2010]); and study characteristics (country, year, total length of follow-up, timing of measurements and the measurement instruments used for assessing outcomes). In accordance with the Iterative Protocol for Evidence Base Accumulation (Peters, De Bruin & Crutzen, 2015), control group BCT content was coded independently from intervention group BCT content to isolate the 'active ingredients' being tested within each arm. Coding all study arms, as opposed to only active treatment arms, allows for more insights into how intervention content relates to outcomes (Peters et al., 2015)

To ensure consistency in applying the coding scheme, a random selection of 5% of the included studies was pilot-coded by all researchers independently [Redacted for peer

review], and inter-rater reliability was calculated and checked against existing standards (Landis & Koch, 1977). All discrepancies in this pilot-coding were then discussed within the study team to reach consensus, and where applicable, decision rules were created to inform coding and discussions of subsequent studies. Potential BCTs identified in treatment descriptions of the included studies that did not match with any of the BCTs listed in the v1 taxonomy were discussed within the study group and added as supplements to the taxonomy following the procedures reported elsewhere (Henrich et al., 2015). Pilot-coding continued in this way (5% of included studies coded by all coders) for two rounds, until inter-rater reliability reached an acceptable level of k=0.70 (Landis & Koch, 1977). The remaining studies were independently coded by one researcher and checked by a second researcher selected at random using a computer program. Any disagreements were first discussed between the coder and checker, and when needed, within the entire study team until consensus was reached.

After coding, outcome data were extracted and input to Comprehensive Meta-Analysis software v3 (CMA; Borenstein, Hedges, Higgins & Rothstein, 2014) by one researcher [Redacted for peer review] and verified by another [Redacted for peer review]. Outcome data included all measures of intention, stage of change, autonomous motivation and PA for each study group at baseline and first post-treatment measurement point. Corresponding authors were contacted via phone or email to try to obtain any missing data or additional information needed to calculate effect sizes.

Statistical Procedures

Meta-analyses were conducted within CMA, and effect sizes were computed by entering means and standard deviations at baseline and post-treatment, standardized by the pooled standard deviation and corrected for pre-post correlations within groups (Morris & De Shon, 2002). For studies where this information was not available, alternative comparable methods were used (e.g. F-ratio and p-value, mean change scores, previously computed effect sizes such as Cohen's d), or the pre-post correlation was imputed using the mean of all other pre-post correlations available from interventions reporting on that outcome (Morris & De Shon, 2002). To calculate the effect sizes for stage of change outcomes, the action and maintenance stages were collapsed into one post-intentional stage, and the distributions of individuals in each stage were compared at baseline and post-treatment to calculate a within-group effect size (Lipsey & Wilson, 2001).

Cumulative effect size data were combined using random effects meta-analyses in CMA. Cohen's *d* values with corresponding 95% confidence intervals and two-sided p-values

were used as the primary measure of cumulative effect size, and indications of heterogeneity were examined with I-squared statistics. Outlying data points (studies with effect sizes further than three standard deviations from the mean cumulative effect size) were Winsorized and replaced with the next most extreme allowable value (Harkin et al, 2016).

Comparative subgroup analyses were used to identify BCTs and other moderators associated with changes in motivational outcomes. For each moderator which was both present and absent in at least three arms reporting on a specific outcome, a subgroup analysis within CMA compared the cumulative effect size of interventions which included the moderator to the cumulative effect size of interventions which did not include it. Effect sizes for these comparisons were computed using the methods of Borenstein, Hedges, Higgins & Rothstein (2009). Additional subgroup analyses and meta-regressions within CMA were used to examine the associations between effect sizes and factors related to study design and population including age, disease status, overweight status, baseline sedentary behavior status, recruitment methods, intervention setting, mode of delivery (digital vs other; group vs individual; mobile vs other; face-to-face vs self-guided), total number of BCTs used, contact time, contact sessions, and stated theoretical basis.

Finally, meta-regression analyses examined the extent to which changes in intention, stage of change and autonomous motivation predicted changes in objectively- and subjectively-assessed PA. All analyses were prespecified in the registration of this review.

Results

Identification of Studies

The PRISMA flow diagram in Figure 1 provides details on the search and study selection procedures, which identified 88 studies that reported baseline to post-treatment changes in either intention to be physically active, autonomous motivation or stage of change.

Descriptive Study Characteristics

Of the 88 included studies, 77 reported data from multiple groups and 11 reported data from single study arms only. These 88 studies included 198 study arms overall, comprising 18,804 participants. Outcome data on intention, stage of change and autonomous motivation were reported in 75, 96 and 34 study arms respectively. Supplementary File 1 provides details of all included study arms, including settings, treatment descriptions, and demographic information of the study samples. All supplementary files can be viewed on at the URL: https://osf.io/2fqr3/?view_only=a99735adb1a64f1c973e064a8aa309b1

Behavior Change Techniques

In coding the included studies for their use of BCTs, three additional BCTs were identified that were not sufficiently covered by the v1 taxonomy (Michie et al., 2013). Definitions for each of these were discussed and standardized within the research team and added to the taxonomy to inform subsequent coding. The newly identified BCTs were: 17.1) "provision of pedometer or other wearable device," which was defined to include measurement devices that could act as a cue to behavior, such as pedometers, heart rate monitors and accelerometers, but which were not formally part of an intervention strategy; 17.2) "motivational interviewing," for which the definition provided in a previous BCT taxonomy was used (Michie et al., 2011); and 17.3) "instructing individuals on aspects of the behavior to be carried out," which was coded in instances where the interventionist specified the modality, intensity, time or location of the behavior to be performed (as opposed to specifying the quantity or frequency of the behavior, which would have then been coded as behavioral goal setting). These newly identified BCTs were identified in 28, 17 and 65 study arms, respectively.

Across the 198 coded arms of the included studies, 69 of the 96 possible BCTs were identified as present in at least one study arm, and the most commonly occurring BCTs were behavioral goal setting (k = 107), providing information on health consequences (k = 87), problem solving (k = 70), action planning (k = 67), instructing on aspects of the behavior to be carried out (k = 65), and behavioral self-monitoring (k = 62). The most intensive study arm included 23 BCTs delivered across a 12-week exercise counselling program (Kim et al, 2004), and 42 arms (mainly no treatment or waiting list control arms) did not include any codable BCT content. Full information on the BCTs included in each intervention arm is available in Supplementary File 2, and additional intervention-level moderators are included in Supplementary File 1.

Cumulative Effect Sizes

To examine the effects of interventions upon motivational constructs when compared to control groups, cumulative effect sizes were calculated across RCT studies. The largest effects of interventions were found in studies which reported on autonomous motivation (d = 0.32; 95% CI [0.13, 0.50]; p = .001; k = 20; I^2 = 77.62), with smaller cumulative effect sizes evident for intention (d = 0.16; 95% CI [0.05, 0.26]; p = .003; k = 40; I^2 = 62.55) and stage of change (d = 0.19; 95% CI [0.10, 0.27]; p < .001; k = 48; I^2 = 60.37). Cumulative effects were also calculated for individual study arms, when not compared to control groups. Forest plots displaying cumulative effect sizes from randomized controlled trials and individual study

arms are presented in Supplementary File 3. These cumulative effects indicated considerable heterogeneity, which we subsequently sought to examine with moderator analyses.

Moderator Analyses

Behavior change techniques. Moderator analyses revealed several BCTs univariately associated with changes in motivational constructs. Six BCTs were associated with beneficial changes in intention and 14 BCTs with beneficial changes in stage of change, while one BCT (demonstration of behavior) was associated with beneficial changes in autonomous motivation. The presence of problem solving, self-monitoring of behavior, and behavioral practice or rehearsal were each independently associated with beneficial changes in two motivational outcomes. Furthermore, four BCTs were found to be independently associated with adverse changes in stage of change. Table 1 provides effect sizes and confidence intervals for comparative subgroup analyses of BCTs for which at least one significant moderation effect occurred. Full data from all conducted comparative subgroup analyses are available in Supplementary File 4.

Modes of delivery. In examining modes of delivery as potential moderators of effect sizes, interventions which included face-to-face delivered components produced significantly larger effect sizes ($p < .05$) than interventions which did not include face-to-face delivered components on all three motivational constructs under study. Interventions which included group-delivered components produced significantly larger effects on intention and stage of change than interventions without any group-delivered components. Furthermore, interventions which included telephone follow-ups, took place in gyms or fitness centers or were delivered by gym workers had larger effects on stage of change and autonomous motivation than interventions delivered in other settings. Interventions which included contacts via postal mail were significantly associated with unfavorable changes in intention and autonomous motivation. Several other mode of delivery aspects were significantly associated with one single outcome under study. See Table 2.

Participant characteristics. Characteristics of the study samples (including whether the sample presented with a chronic illness, included only sedentary individuals at baseline or included only overweight individuals) were also examined as moderators of effect size. Interventions delivered exclusively to sedentary individuals produced greater effects on stage of change than interventions which did not exclude active individuals. Interventions delivered exclusively to overweight individuals produced greater effects on stage of change and autonomous motivation than interventions which did not exclude individuals of normal

weight. No other participant characteristics moderated effect size for any other outcomes (Table 2).

Meta-Regression Analyses

Relationships between continuous moderators and changes in motivational variables. A greater number of included BCTs was associated with greater intervention effects on intention (b = 0.02, k = 75, p = .014, R^2 = 0.02) and stage of change (b = 0.03, k = 96, p < .001, R^2 = 0.06), but not on autonomous motivation. Effect sizes for changes in intention to be physically active were not significantly associated with any other continuous moderators under study (sample gender, BMI, number of treatment contacts, contact hours). Effect sizes for stage of change and autonomous motivation were however both significantly associated with an increased BMI in the sample (for SoC: b = 0.06, k = 48, p < .001, R^2 = 0.34; for autonomous motivation: b = 0.04, k = 26, p = .002, R^2 = 0.36). Effect sizes for stage of change were furthermore significantly associated with a higher percentage of female participants (b = .01, k = 95, p < .001, R^2 = 0.00), a greater number of treatment contacts (b = 0.01, k = 67, p < .001, R^2 = 0.03), and a greater number of intervention contact hours (b = 0.01, k = 50, p = .012, R^2 = 0.00).

Relationships between changes in motivation variables and changes in PA. Effect sizes for changes in PA (both objective and subjective measures; see tab 5 of Supplementary File 2) were significantly associated with effect sizes for changes in intention (b = .55, k = 53, p < .001, R^2 = 0.06) and stage of change (b = 0.27, k = 57, p = .007, R^2 = 0.07), but not with effect sizes for changes in autonomous motivation (b = -0.09, k = 22, p = .729, R^2 = 0.00).

Discussion

The present study sought to identify characteristics of behavior change interventions associated with changes in intention, stage of change and autonomous motivation - the seminal motivational constructs proposed by several prominent behavioral theories. Of all potential moderators examined, only face-to-face intervention delivery was associated with beneficial changes in all three motivational outcomes under study. In total, 19 BCTs, ten modes of delivery and four other study characteristics moderated the effects of interventions on at least one of the motivational outcomes under study, and these significant moderators seemed to cluster in several ways.

Moderators of Changes on Motivational Outcomes

Behavior change techniques and modes of delivery. Interventions including BCTs derived from control theory (i.e. behavioral goal setting, action planning, self-monitoring of

behavior, feedback on behavior, and problem solving) (Carver & Scheier, 1982; Michie et al., 2009) were associated with greater changes in intention and stage of change than other interventions. Inclusion of any control theory BCT was associated with progression in stage of change, and inclusion of either 'problem solving' or 'self-monitoring of behavior' was associated with favorable changes in intention. Within previous meta-analyses of health behavior change interventions, interventions including control theory BCTs have led to greater changes in behavior than those which did not (Avery et al., 2012; Dombrowski et al., 2012; Knittle, Maes & De Gucht, 2010; Michie et al., 2009). Applying the same method as a previous meta-analysis on PA and healthy eating interventions (Michie et al., 2009), our analyses showed that interventions including self-monitoring of behavior plus any other control theory BCT produced greater changes in intention and stage of change than interventions which did not include this set of BCTs. Control theory BCTs were also among those most commonly identified as present in the included interventions, and seem integral to changing motivation, in addition to their previously-identified effects on behavior.

Interventions including exercise classes typically included the following BCTs: instruction on how to perform the behavior, behavioral practice or rehearsal, and demonstration of behavior (Michie et al., 2013). These three BCTs were all associated with changes in stage of change; behavioral practice or rehearsal was associated with changes in intention; and demonstration of behavior was the lone BCT significantly associated with increases in autonomous motivation. In addition, delivery in gym settings, group settings, and via face-to-face interactions were each associated with changes in motivational outcomes. These BCTs and modes of delivery seem to form a cluster related to exercise class attendance, and may alter motivational outcomes via the hands-on experiences that help to make a new behavior achievable, familiar, and (ideally) enjoyable, as well as connecting the individual to other people socially. Offering individuals opportunities to try the target behavior (e.g. behavioral practice) and prompting preparations for behavior during the intervention, regardless of an individual's motivational status (Sutton, 2008), may be a good means for increasing motivation. Consistent with theories, practicing skills and receiving meaningful first-hand feedback in a social setting may furthermore influence individuals' perceptions of personal capacities and perceived constraints regarding the target behavior, increasing perceived behavioral control and normative beliefs from the TPB (Hagger & Chatzisarantis, 2009) and fulfilling needs for competence and relatedness from the SDT (Ryan & Patrick, 2009).

Although face-to-face and group-delivered interventions had significant effects on motivational outcomes, BCTs related to social support and social influences were not significantly associated with any motivational outcomes. Furthermore, the BCTs practical social support (e.g., prompting an individual to find an exercise buddy or source of social support) and restructuring the social environment (e.g., workplace weight loss or PA competitions) were associated with negative changes in stage of change, as was intervention delivery by a peer facilitator or a physiotherapist. These seemingly conflicting findings hint at the possibility that a mix of opportunities for both upward and downward comparisons may be ideal for increasing motivation (Collins, 1996), and indicate the need for closer examinations of how the quality and content of social support and social interactions impact on intervention effectiveness. As an example, experiencing coercion or external pressure from others is likely to lead to negative changes in motivation and behavior (Deci & Ryan, 2000), but being surrounded by others who face similar challenges is likely to have a positive impact. To shed light on the impact of social interactions, studies should make efforts to thoroughly describe delivered interventions and make use of new taxonomies which can capture qualitative differences in social interactions (Hardcastle, Fortier, Blake & Hagger, 2017).

Within this systematic review, few intervention components or modes of delivery were associated with changes in autonomous motivation. This lack of effects could potentially be attributable to limited statistical power, but may also indicate that the mechanisms of change for autonomous motivation operate through channels other than the BCTs present in the v1 taxonomy (Michie et al., 2013). While still limited by incomplete intervention descriptions, the use of newly-developed taxonomies which list techniques derived from motivational interviewing (Hardcastle et al., 2017) and techniques specifically identified to change SDT regulatory styles (Teixeira & Hagger, 2016) could potentially identify additional intervention factors which moderate effects on autonomous motivation. It should also be noted that the construct autonomous motivation includes factors related to enjoyment (i.e. intrinsic motives), as well as habits and congruence with personal values (i.e. integrated and identified regulations, respectively). As such, the BCTs examined here may have altered one form of autonomous motivation but not the entire autonomous motivation construct. It was not possible to examine this however, as many studies utilized autonomous motivation measures which made no distinctions between intrinsic, integrated and identified regulatory styles. Future intervention studies should utilize SDT measures which distinguish between them.

Meta-regression analyses revealed a positive association between the number of BCTs an intervention included and the magnitude of its effects on intention and stage of change. This relationship did not hold however for changes in autonomous motivation. In line with previous meta-analyses demonstrating a link between a greater number of included BCTs and larger effect sizes on behavioral and weight-related outcomes (Hynynen et al., 2016; McLean, Griffin, Toney & Hardeman, 2003), our analyses suggest that interventions which involve more BCTs lead to greater changes in motivational outcomes as well. However, more is not necessarily better, and choices of which BCTs to include within an intervention should be guided by theory-driven mechanisms of action (Michie et al, 2016), as well as the time and resources available for intervention delivery.

Theory-based interventions. Interventions explicitly targeting behavioral determinants from the TPB (including RAA and HAPA models) or social cognitive theory (SCT) produced greater effect sizes on intention and stage of change than studies which did not explicitly target TPB or SCT constructs. This finding extends those of previous meta-analyses, which had found that internet-based health behavior change interventions based on the TPB had greater effects on health behaviors than other interventions (Webb, Joseph, Yardley & Michie, 2010), and that interventions explicitly based on SCT significantly increase PA among cancer survivors (Stacey, James, Chapman, Courneya & Lubans, 2015). Given the important theoretical position of self-efficacy cognitions within both the SCT and TPB, and the well-defined direct links between self-efficacy and behavior in multiple domains, our results confirm the importance of fostering cognitions related to personal control over behavior in influencing both motivation and behavior.

Sample characteristics. Studies which included only overweight or obese individuals yielded larger effect sizes on stage of change and autonomous motivation than studies which did not have weight as an inclusion criterion. Higher BMI was also associated with greater changes in stage of change and autonomous motivation. These findings could be explained by the inverse relationships between BMI and autonomous motivation and stage of change reported previously (Markland & Ingledew, 2007; Wee, Davis & Phillips, 2005), which could have resulted in floor effects (i.e., more scope for improving). Our finding that studies which only included sedentary individuals had larger effects on stage of change than studies which made no such restrictions could potentially be explained by floor effects as well. To identify which intervention methods work best for whom, future studies should examine interactions between characteristics of individuals and BCT content, ideally on a per-participant level instead of trial-level.

Cumulative Effect Sizes

While not the primary aim of this meta-analysis, this study investigated the cumulative effects of physical activity behavior change interventions on intention, stage of change and autonomous motivation. Relative to control groups, active intervention arms produced small and significant cumulative effects on these motivational constructs, which is consistent with findings from a meta-analysis which investigated the effects of interventions on self-efficacy (French et al., 2014). The small effect sizes found here differ considerably however from a previous meta-analysis which found a large cumulative effect size of d = 0.66 for changes in intention (Webb & Sheeran, 2006). While this difference is substantial, it is expected, as the Webb & Sheeran (2006) meta-analysis only included studies which had significantly increased behavioral intentions, whereas the current study also included studies which failed to change intention.

Associations between Changes in Motivation Outcomes and Behavior

Of the three motivational constructs under study here, changes in intention demonstrated the strongest relationship with contemporaneous changes in PA (b = 0.55), and at a level comparable to the correlation of r = 0.57 found in a previous meta-analysis (Webb & Sheeran, 2006). As interventions delivered in real world settings do not always lead to increases in intention, the present study provides a realistic estimate of the relationship between changes in intention and changes in behavior in real-world PA interventions. Despite the strength of this relationship, considerable evidence for the intention-behavior gap remains (Sheeran & Webb, 2016), and automatic, non-intentional routes to behavior and behavior change merit considerable attention in predicting behavior and developing future interventions and theories.

Changes in stage of change were also associated with changes in PA. This is consistent with the findings of Armitage and Arden (2002), who examined the ability of TPB variables to predict stage transitions within the TTM, and could be explained by their conclusion that stage of change may function as a proxy measure of behavior, as opposed to capturing distinct social cognitions. In calculating effect sizes for stage of change outcomes in this study, we attempted to mitigate the effects of the entanglement of behavioral, intentional and cognitive factors in stage of change assessment items by collapsing the action and maintenance stages. However, it is not fully possible to disentangle these variables, and a chance remains that the strength of relationship found is due to this measurement non-specificity.

Despite the interventions included here producing larger cumulative effect sizes on autonomous motivation than on either intention or stage of change, no significant relationship existed between changes in autonomous motivation and changes in PA behavior. This is in line with previous research indicating that SDT constructs better explain behavioral maintenance than they do behavioral initiation (Wasserkampf et al., 2014), but somewhat conflicts with previous meta-analyses that had demonstrated links between SDT motivation, intention and behavior (Hagger & Chatzisarantis, 2009; Ng et al., 2012). These previous meta-analyses did not however investigate relationships between *changes* in these variables, and the lack of a relationship between changes in autonomous motivation and behavior could indicate that interventions failed to assist individuals in transferring new behavioral routines from intervention contexts into daily life. For example, interventions which included consistent attendance to exercise classes or coaching may have resulted in changes in autonomous motivation (i.e. more enjoyment of behavior), but not necessarily in behavioral enactment after the conclusion of the exercise classes or coaching. Interventions which include significant amounts of behavioral practice should be combined with self-regulatory strategies to keep activities going in the absence of formal instruction and to help translate autonomous motivation into sustained action (Nurmi et al., 2016).

Motivation and the First Steps toward Behavior Change

While the current study examined how intervention components relate to increases in motivation once an individual has taken part in an intervention, it does not shed light on the best methods for getting people interested in participating in interventions in the first place. One might be *interested* in an intervention aimed at weight reduction, for example, but not *motivated* to exercise daily. Or conversely: One might be *motivated* to quit smoking, but still not be *interested* in using an Internet-delivered intervention to guide him or her through the smoking cessation process (Crutzen & Ruiter, 2015). In other words, intervention uptake is itself a behavior which is influenced by specific determinants, but this has received limited attention in the currently-dominant efficacy-based paradigm (Kohl, Crutzen, & De Vries, 2013). As intervention uptake is not necessarily dependent on the content of an intervention itself, meta-interventions may help to stimulate interest in intervention participation (Albarracín, Durantini, Earl, Gunnoe, & Leeper, 2008). Previous experimental studies on meta-interventions have focused on using various Google AdWords (Crutzen, Ruiter, & De Vries, 2014), different methods of introducing a counseling program (Albarracín et al., 2008), as well as gender-tailored brochures (McCulloch, Albarracín, & Durantini, 2008). To optimize such meta-interventions, however, it is crucial to gain more insight into

determinants of intervention uptake (Noguchi, Albarracín, Durantini, & Glasman, 2007) and to link the content of these meta-interventions to these determinants. The BCTs identified here as associated with changes in motivational constructs could potentially be used as an initial set of testable intervention components to affect both intervention uptake and deliberative motivational constructs toward a target health behavior.

Study Strengths and Limitations

The current study involved robust and replicable search, screening and coding procedures, and followed recommendations put forth in the Iterative Protocol for Evidence Base Accumulation (Peters et al., 2015) and PRISMA (Moher, Liberati, Tetzlaff & Altmann, 2009) statements. BCT content and modes of delivery were coded separately for intervention and control groups, as the BCTs and modes of delivery offered by active and control interventions can overlap considerably (De Bruin et al., 2010). Without knowing whether a BCT was being tested in the first place (i.e., delivered exclusively in the intervention group), it impossible to draw conclusions about which BCTs work and which do not (Peters et al., 2015). The coding method employed here, coupled with moderator analyses based on within-group (as opposed to between-groups) effect sizes (Morris & De Shon, 2002), allows for a more straightforward examination of how active intervention content affects outcomes. As this study investigated moderators of intervention effectiveness for multiple theoretical conceptualizations of motivation (i.e., intention, stage of change, and autonomous motivation), construct validity is high, and the results will be of interest to behavioral scientists and intervention developers from varying theoretical backgrounds.

While the large sample sizes in this study offered considerable power in detecting effects, causal inferences should not be drawn based on the identified significant associations. Additionally, the results should be treated with further caution as we excluded 96 studies for which appropriate or additional data could not be obtained from study authors. These findings should instead serve as a tool from which hypotheses for experimental studies can be generated and new evidence-based interventions can be developed (Peters et al., 2015). Furthermore, this study assessed the effects of moderators univariately, so we cannot yet speculate on how patterns of co-occurrence in BCTs and modes of delivery might have influenced the results. Further analyses involving classification and regression trees (Dusseldorp, Van Genugten, Van Buuren, Verheijden, & Van Empelen, 2004) could potentially be used to model how organic patterns of co-occurrence impact upon motivational outcomes in future studies.

Finally, our BCT coding procedures relied on the text present in intervention descriptions from published articles, supplementary materials and any secondary references provided by the authors. While this method is often used in meta-analyses and captures intervention content reasonably well (Presseau et al., 2015), some BCT content may have been missed due to incomplete intervention descriptions. Other limitations of this method exist as well: First, it does not make it clear whether BCTs were applied correctly during an intervention. As the effectiveness of an intervention component depends on whether its parameters for use are satisfied (e.g., although modelling of behavior can be an effective BCT, a modelling case where a celebrity quits smoking instantly and effortlessly is unlikely to contribute to behavior change; [Peters, De Bruin, & Crutzen, 2015]). Second, this coding method does not provide any information on whether the coded BCTs were delivered as intended and uniformly to all intervention participants (i.e., intervention fidelity; [Knittle, 2015]). While information on fidelity is rarely reported (especially at the BCT level), it is a major issue affecting inferences that can be made (De Bruin, Crutzen, & Peters, 2015). Finally, even with high fidelity of delivery, the enactment of the prompted BCTs by the participants may be suboptimal (e.g., participants might not complete self-monitoring records or action plans), which can also affect outcomes (Hankonen et al., 2015; Knittle et al., 2016). Such aspects of *actual* intervention content could not be accounted for in the present study. Hence, we would like to echo previous calls to improve reporting quality of intervention development and evaluation research (Albrecht, Archibald, Arseneau, & Scott, 2013).

Conclusion

This is, to our knowledge, the first study to identify BCTs and intervention features associated with changes in motivation, as conceptualized in several influential behavioral theories. The results indicate that self-monitoring and other self-regulatory BCTs play a significant role in changing intention and stage of change. Additionally, interventions which contain content delivered face-to-face and components frequently delivered as part of exercise classes resulted in greater changes in intention, stage of change and autonomous motivation. These results are immediately applicable to PA promotion, and future research should investigate whether similar patterns hold when examining changes in motivation in relation to other behaviors. These results can be used in designing interventions and experimental studies to increase motivation and encourage uptake of self-regulatory interventions targeting health behavior change.

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References included in the meta-analyses are presented in the Appendix. [One reference redacted for peer review]

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Table 1 - Effect sizes obtained from comparative subgroups analyses of BCTs which revealed a significant association with at least one motivational construct.

Moderator – Interventions containing the following	Intention (k = 75)	Stage of Change (k = 96)	Autonomous Motivation (k = 34)
BCT 1.1 - Behavioral Goal Setting	0.12 (-0.01, 0.25)	**0.20 (0.04, 0.36)**	0.14 (-0.02, 0.29)
BCT 1.2 - Problem Solving	**0.17 (0.03, 0.31)**	**0.33 (0.16, 0.51)**	0.08 (-0.05, 0.22)[a]
BCT 1.4 - Action Planning	0.13 (-0.01, 0.27)	**0.27 (0.07, 0.46)**	0.08 (-0.05, 0.22)[a]
BCT 2.2 - Feedback on Behavior	0.04 (-0.22, 0.3)	**0.29 (0.05, 0.54)**	0.04 (-0.08, 0.17)
BCT 2.3 - Self-monitoring of behavior	**0.30 (0.13, 0.47)**	**0.28 (0.11, 0.46)**	0.06 (-0.09, 0.20)
BCT 3.2 - Practical social support	-0.16 (-0.38, 0.06)	**-0.27 (-0.46, -0.09)**	N/A
BCT 4.1 - Instruction on how to perform behavior	0.17 (-0.01, 0.34)	**0.43 (0.11, 0.75)**	0.19 (-0.02, 0.40)
BCT 5.3 - Info about social / environmental consequences	**0.33 (0.17, 0.49)**	-0.16 (-0.39, 0.08)	-0.13 (-0.32, 0.07)
BCT 6.1 - Demonstration of behavior	0.11 (-0.05, 0.28)	**0.39 (0.12, 0.66)**	**0.19 (0.03, 0.35)**
BCT 8.1 - Behavioral practice	**0.25 (0.03, 0.47)**	**0.46 (0.05, 0.86)**	0.21 (-0.02, 0.45)
BCT 8.7 - Graded tasks	N/A	**0.44 (0.20, 0.68)**	0.08 (-0.06, 0.21)
BCT 9.2 - Pros and cons	0.06 (-0.18, 0.29)	**0.22 (0.01, 0.44)**	0.02 (-0.12, 0.17)
BCT 10.7 - Self-incentive	N/A	**0.50 (0.07, 0.92)**	N/A
BCT 12.2 - Restructuring the social environment	N/A	**-0.23 (-0.42, -0.03)**	0.14 (-0.15, 0.42)
BCT 12.5 - Adding objects to the environment	N/A	**0.42 (0.2, 0.64)**	0.08 (-0.10, 0.25)
BCT 12.6 - Body changes	N/A	**-0.47 (-0.69, -0.24)**	0.05 (-0.22, 0.32)
BCT 15.1 - Verbal persuasion about capability	0.08 (-0.09, 0.26)	**-0.21 (-0.38, -0.04)**	N/A
BCT 15.2 - Mental rehearsal of successful performance	**0.48 (0.13, 0.84)**	N/A	N/A
BCT 17.1 - Offer pedometer or wearable	N/A	**0.45 (0.18, 0.71)**	0.04 (-0.13, 0.21)
Control theory techniques BCT 2.3 + BCT 1.1, 1.2, 1.4 or 2.2	**0.26 (0.07, 0.46)**	**0.28 (0.11 - 0.46)**	-0.02 (-0.18, 0.13)

Note. Data shown are Effect size (LL 95% CI, UL 95% CI). Effect sizes are the difference between effect sizes from interventions which included a BCT and those which did not. Results in bold indicate that the 95% CI for the difference does not include zero. Positive effect sizes represent beneficial effects on motivational outcomes. Comparisons with the same superscript letters compared

the same groups of interventions. N/A = No comparison possible because fewer than three interventions reporting on the outcome included the BCT in question.

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Table 2 - Effect sizes obtained from comparative subgroups analyses of moderator variables which revealed a significant association with at least one motivational construct.

Moderator	Intention (k = 75)	Stage of Change (k = 96)	Autonomous Motivation (k = 34)
Components delivered face-to-face	**0.21 (0.07, 0.35)**	**0.33 (0.17, 0.49)**	**0.19 (0.04, 0.34)**
Components delivered in a group	**0.19 (0.03, 0.35)**	**0.22 (0.03, 0.42)**	-0.05 (-0.26, 0.17)
Components delivered via telephone	-0.15 (-0.38, 0.08)	**0.45 (0.14, 0.75)**	**0.14 (0.01, 0.27)**
Components delivered via postal mail	**-0.22 (-0.41, -0.02)**	-0.10 (-0.35, 0.14)	**-0.27 (-0.48, -0.06)**
Components delivered in gym	N/A	**0.74 (0.32, 1.17)**	**0.22 (0.05, 0.40)**
Components delivered in a university	**0.33 (0.10, 0.56)**	0.09 (-0.34, 0.51)	N/A
Components delivered by a gym worker or trainer	-0.06 (-0.21, 0.08)	**0.54 (0.34, 0.74)**	**0.25 (0.10, 0.41)**
Components delivered by a researcher	**0.28 (0.06, 0.49)**	-0.11 (-0.37, 0.15)	N/A
Components delivered by a physiotherapist	N/A	**-0.34 (-0.48, -0.19)**	N/A
Components delivered by a peer facilitator	N/A	**-0.18 (-0.36, -0.01)**	N/A
Some intervention component explicitly targeted SCT variables*	**0.19 (0.01, 0.36)**	**0.31 (0.04, 0.58)**	-0.01 (-0.12, 0.11)
Some intervention component explicitly targeted TPB/RAA/HAPA variables*	**0.32 (0.15, 0.48)**	**0.28 (0.12, 0.44)**	N/A
Delivered to sedentary individuals	0.10 (-0.05, 0.25)	**0.48 (0.33, 0.64)**	-0.12 (-0.28, 0.04)
Delivered to overweight individuals	-0.06 (-0.29, 0.18)	**0.67 (0.34 - 1.00)**	**0.25 (0.02, 0.49)**

Note. Data shown are Effect size (LL 95% CI, UL 95% CI). Effect sizes are the difference between interventions which included a component and those which did not. Positive effect sizes represent beneficial effects on motivational outcomes. Results in bold indicate that the 95% CI for the difference does not include zero. N/A = No comparison possible because fewer than three arms reporting on the outcome included the BCT/component in question. * = item five from Michie & Prestwich (2010), "Theory/predictors used to select/develop intervention techniques."

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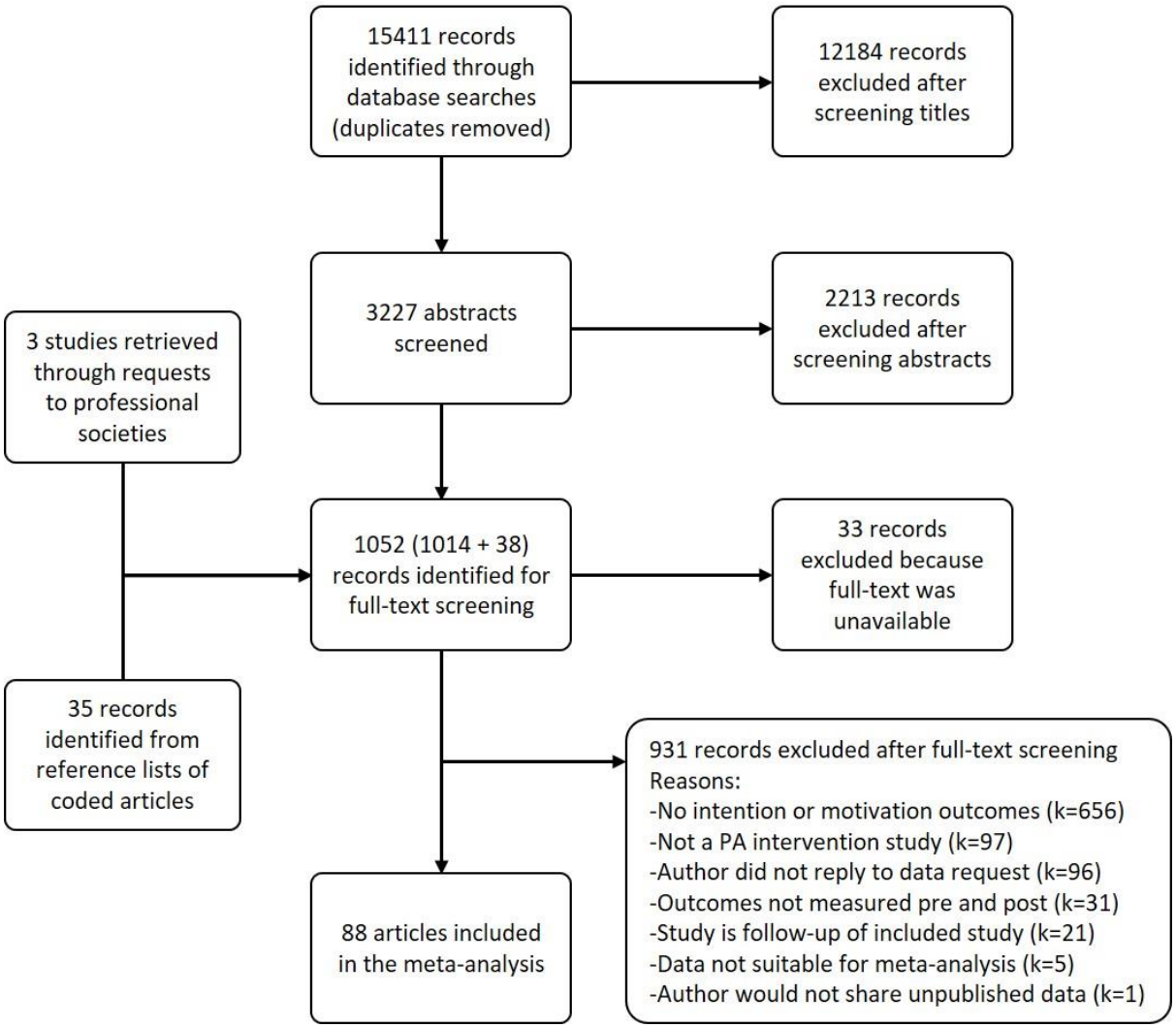
Figure 1. PRISMA Flow Diagram of Search Procedures



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