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A meta-analysis of techniques to promote motivation for health behaviour change from a self-determination theory perspective

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Abstract

A systematic review and meta-analysis was conducted of the techniques used to promote psychological need satisfaction and motivation within health interventions based on self-determination theory (SDT; Ryan & Deci, 2017). Eight databases were searched from 1970-2017. Studies including a control group and reporting pre- and post-intervention ratings of SDT-related psychosocial mediators (namely perceived autonomy support, need satisfaction and motivation) with children or adults were included. Risk of bias was assessed using items from the Cochrane risk of bias tool. 2496 articles were identified of which 74 met inclusion criteria; 80% were RCTs or cluster RCTs. Techniques to promote need supportive environments were coded according to two established taxonomies (BCTv1 and MIT), and 21 SDT-specific techniques, and grouped into 18 SDT based strategies. Weighted mean effect sizes were computed using a random effects model; perceived autonomy support $g=0.84$, autonomy $g=0.81$, competence $g=0.63$, relatedness $g=0.28$, and motivation $g=0.41$. One-to-one interventions resulted in greater competence satisfaction than group-based ($g=0.96$ vs. 0.28), and competence satisfaction was greater for adults ($g=0.95$) than children ($g=0.11$). Meta-regression analysis showed that individual strategies had limited independent impact on outcomes, endorsing the suggestion that a need supportive environment requires the combination of multiple co-acting techniques.

Keywords: Motivation, behaviour-change, health behaviour

Introduction

Much of the potential for reducing the world's disease burden in developed countries lies in changing people's health behaviours. Lifestyle behaviours such as diet and physical activity are implicated in the development of disease states such as obesity, Type 2 diabetes, and metabolic syndrome, and changing these health behaviours can have as powerful an effect on health and wellbeing outcomes as the best available medical interventions (Djoussé, Driver, & Gaziano, 2009; Irwin et al., 2008).

However, behavioural interventions have largely not lived up to this promising potential in the longer term as they have struggled to bring about the maintenance of behaviour change (Avenell et al., 2004; Dombrowski, Knittle, Avenell, Araujo-Soares, & Sniehotta, 2014). Evidence suggests that interventions that are grounded in behaviour change theory are more effective than those that are not (Prestwich et al., 2014), and thus research that helps us to enhance the effective application of theory to practice are warranted. Theory also helps to ensure that a systematic and comprehensive set of determinants are addressed linking to evidence (Michie et al., 2016), and is thus endorsed as part of best practice in intervention design (Craig et al., 2008; Moore et al., 2015).

Self-determination theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2017) has been highlighted as relevant to understanding the maintenance of health behaviour change (Kwasnicka, Dombrowski, White, & Sniehotta, 2016). SDT provides a framework for intervention development by setting out the necessary mechanisms of change that underpin changes in long term health behaviour (e.g., autonomy support, basic psychological needs and motivational regulations), and proposes techniques through which to influence these malleable constructs (Fortier, Duda, Guerin, & Teixeira, 2012). There is strong evidence for the efficacy of interventions based on SDT across a wide range of health domains including environmental behaviours (Pelletier & Sharp, 2008), tobacco dependence (Williams, Niemiec, Patrick, Ryan, & Deci, 2009), healthcare treatment adherence (Williams, McGregor, Zeldman, Freedman, & Deci, 2004), and physical activity (Edmunds, Ntoumanis, & Duda, 2008; Wilson et al., 2006). However, insight into how such effects are brought about is limited by poor specification of the intervention techniques employed (i.e., investigators may state that they provided an autonomy supportive environment without stating how they did so), and by a lack of information about the impact of specific techniques on the mediators of change proposed within SDT

(e.g., need support and motivation); that is, it is often assumed techniques will have the hypothesised impact on mediators without this being explicitly tested. As such, the aim of this paper is to synthesize findings across approximately five decades of empirical work to review the techniques used in SDT interventions and systematically identify their effect on specified mediators of change.

Self-determination theory

According to SDT, health behaviours are driven by a variety of motivations that vary along a continuum of autonomy (Deci & Ryan, 1985; Ryan & Deci, 2017). *Intrinsic motivation*, (acting for the inherent enjoyment of the activity involved) is the most autonomous form of motivation.

However, when the health behaviour is not inherently enjoyable, one may still be autonomously motivated acting through integrated regulation (e.g., acting in line with one's own goals and values) and identified regulation (e.g., acting to obtain personally valued outcomes). When behaviour is not autonomous but driven by external forces (e.g., to avoid guilt or shame through *introjected motivation*, or in response to reward and punishment through *external regulation*) long-term health behaviour change is unlikely (e.g., see Ng et al., 2012).

Engaging in behaviours for more autonomous reasons results in more adaptive health outcomes, including more positive well-being, and better behavioural adoption and maintenance (Deci & Ryan, 2008). More autonomous motivation is facilitated through the satisfaction of three basic psychological needs; autonomy (feeling that one is empowered and has choice), competence (feeling that one can be effective and capable), and relatedness (feeling close to, and valued by others) (Ryan & Deci, 2000b). However, as with the application of all theories into practice, the challenge for practitioners is knowing how to facilitate need satisfaction most effectively in terms of the specific techniques and strategies. A step change in facilitating this process has been brought about over the past decade through the development of taxonomies of behaviour change techniques.

Taxonomies of behaviour change techniques

Taxonomies of behaviour change techniques for different health behaviours have been developed to more systematically describe, develop and test the active elements of behaviour change interventions (Abraham & Michie, 2008; Michie et al., 2016) and to describe the content and relational-based techniques of inter-personal counselling styles (e.g., Hagger & Hardcastle, 2014; Hardcastle et al.,

2017; Lane, Huws_Thomas et al., 2005). Within this approach, a behaviour change technique can be defined as “*an observable, replicable and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an “active ingredient” (e.g., feedback, self-monitoring and reinforcement)*” (Michie et al., 2013, pp82). By using a standardised description of techniques, researchers are able to conduct more meaningful comparisons of interventions according to the components they include, and thereby identify which techniques, or clusters of techniques, show the most promise in bringing about behaviour change in and across different health settings (Dombrowski et al., 2012; Gagnon, Forter, McFadden & Plante, 2018; Michie, Abraham, Whittington, McAteer, & Gupta, 2009; Williams & French, 2011). The systematic specification of SDT-based interventions, specifically in relation to how practitioners can create a need supportive environment, has not been a core part of this process. While some of the techniques specified within other taxonomies do describe what SDT-based researchers are doing (given that there is often overlap between theories), there is not currently a systematic and consistent way of describing and analysing the content of SDT-based interventions. This paper sets out to clarify the techniques that can be used to translate SDT-based interventions into practice exploring whether these can be captured using existing taxonomies, and whether there are techniques that are unique to this theoretical approach.

To develop the most effective health interventions, researchers and health practitioners not only need a clear taxonomy of the SDT-based strategies that can be employed, but also need to know the efficacy of these strategies. Knowledge of the impact that strategies have on the mediating constructs (i.e., need satisfaction and motivation) is also important for theory expansion. To date there has been no investigation of the efficacy of SDT-based intervention strategies across studies and contexts on the proposed psychosocial mediators of behaviour change. Systematic and meta-analytic reviews that have been published provide support for the efficacy of autonomy (and/or other needs) support in promoting positive outcomes (e.g., Ng et al., 2012; Teixeira, Carraça, Markland, Silva, & Ryan, 2012; Webb, Joseph, Yardley, & Michie, 2010), but there are none to date that address the efficacy of the strategies that can be used to create such autonomy- (or need-) supportive environments. The purpose of this systematic and meta-analytic review is to provide researchers and

applied practitioners with the knowledge of how to operationalise SDT in an applied health setting. Specifically, we sought to (i) identify, synthesise and document the range of techniques that have been used to promote autonomous functioning, as defined within SDT, and (ii) meta-analyse the efficacy of SDT-based techniques in bringing about change in need satisfaction and motivation within health interventions.

There is no one-size-fits all solution to health interventions, and intervention fidelity, design and how an intervention is delivered can vary widely and be important in predicting outcomes (Hoffmann et al., 2014). Therefore a third aim is to explore the factors that facilitate or moderate the effects of the identified techniques on the psychosocial mediators. To this end, characteristics of intervention design that have previously been shown to moderate the effectiveness of health interventions will be investigated. We will test two hypotheses: First, that in line with work in other domains the inclusion of multiple techniques will enhance the impact of an intervention (Webb et al., 2010). Second, that perceptions of autonomy support and need satisfaction will be stronger in group-based interventions that harness support from both a facilitator and other group members than in one-to-one delivery of interventions (Jordan, Holden, Mason, & Foster, 2010). Two exploratory analyses were also conducted: Past work with children and adolescents has demonstrated that they may have greater demand for structure (i.e., clear communication of rules and guidelines, opportunities to meet or exceed expectations, informational competence-based feedback and predictability) in order to perceive a genuine sense of autonomy than adults (Jang, Reeve, & Deci, 2010). Such elements of structure may be perceived as controlling by adults. Therefore, to examine this possibility and other potential differences in how social environments are experienced across different developmental periods (Ryan & Deci, 2002) we compared the effects of SDT-based intervention techniques when conducted with children (age ≤ 17 years) and adults (age ≥ 18 years). Finally, given discussion regarding the impact on outcomes due to choice of control group (Williams, 2010), we also planned to test whether type of control group also moderated outcomes.

Methods

The systematic review was conducted in line with PRISMA guidelines (see Supplementary checklist). No external funding was provided for this research.

Search Strategy

Three complimentary strategies were employed to locate published and unpublished manuscripts for inclusion in the study. First, a search of eight electronic databases (Web of Science, PsychInfo, Pubmed/Medline, Cochrane database, DARE, Biomed Central, Sociological abstracts, ProQuest) was performed using the keywords “Self-Determination Theory” combined with “intervention/ psychological need satisfaction/ internaliz(s)ation intervention/ internaliz(s)ation facilitat* / lab study/ experimental/ autonomy support/ competence support/ relatedness support” for studies published between 1970 and December 2017 2016. Following the deletion of duplicates, an initial pool of 2453 articles was generated, which were individually screened for eligibility from the title and abstract. Clearly ineligible studies were removed (i.e., those that were not original research, or intervention studies) (Figure 1).

<Figure 1>

Second, the SDT website was searched (<http://www.psych.rochester.edu/SDT>). All listed publications were scrutinized against the inclusion criteria, and further database searches were conducted for all listed SDT faculty members by name. This process resulted in the identification of further articles ($k=43$). Third, a request for unpublished work was circulated on the SDT listserve, and researchers active in SDT-related intervention research were emailed individually to seek unpublished data. This approach identified a further 6 articles. Reference lists from all included papers were examined for further pertinent articles (PR). A total of 339 studies were found screened, of which 70 provided insufficient data for extraction. All authors were contacted via email to request additional information, of which 19 replies had been received after 3 weeks. Of these 19, five studies were included. Exclusion reasons for the remainder were; intervention not grounded in SDT ($k= 7$), no access to data ($n= 3$), no pre-post assessments made ($n=2$), not an intervention ($n=2$) and repeat data from studies already included ($n=1$).

Inclusion and exclusion criteria

As the present review represents an initial stage in identifying the range of strategies used, we chose not to restrict our review to particular health domains or populations. Therefore, we included studies conducted with both children and adults relating to interventions to bring about change in any health behavioural domain. Studies were assessed according to the following inclusion criteria;

1. Interventions conducted with adults and children without a mental disability.
2. A comparison of effects between an intervention and control group in a health-related setting. Acceptable control groups included no intervention, standard care (e.g., a usual school lesson, standard healthcare provision etc), an alternative intervention that was not related to enhancing autonomous motivation (e.g., provision of information/advice, but not specifically autonomy supportive), or comparison groups that invoke controlling motivational regulations (e.g., experiencing controlling conditions, rather than purely a lack of autonomy support).
3. Provision of pre- and post-intervention ratings of SDT-related psychosocial mediators of behaviour change (as described in the subsequent Dependent variables section of this paper) for both intervention and control groups *or* sufficient statistics from which to calculate between group effect size (e.g., *F* statistic, mean change score).
4. Available in the English language.

Dependent variables

The following dependent variables (which are all proposed mediators within SDT) were specified; autonomy support, need satisfaction (namely autonomy, competence and relatedness), or motivation (including composite indices of controlled or autonomous motivation, a relative autonomy index, or motivational regulations; external regulation, introjected regulation, identified regulation, integrated regulation and intrinsic motivation).

Identification of Behaviour Change Techniques

All studies meeting the inclusion criteria were reviewed independently by two researchers (FG and PR) to identify and code the specific behaviour change techniques listed. Where available,

we referred to protocol papers and supplementary data files for additional information, and where information was not clear the authors were contacted to provide a more detailed breakdown of intervention content. The descriptions provided were matched against the v1 93-technique behaviour change taxonomy (Michie et al., 2013) and the Motivational Interviewing Taxonomy (MIT) (Hardcastle, Fortier, Blake & Hagger, 2017), referring to the detailed descriptions published in relation to each taxonomy. Where there is overlap between taxonomies (e.g., BCT v1 1.7 Review Outcome Goal and MIT 37 Review Outcome Goal) both codes were allocated. Techniques not captured by either taxonomy were attributed a new descriptor as an SDT specific technique. Interventions described by the authors as '*motivational interviewing*' were coded as this alone; no attempt was made to then apply Hardcastle et al. (2017) taxonomy as our aim was not to judge the quality of MI delivery but investigate its impact on SDT-related outcomes.

The coders met to identify differences in coding and resolve differences in interpretation after coding of the first five studies; we found the process of fitting author descriptions according to SDT conventions to taxonomies not devised with this in mind to be challenging. For example, a frequently used technique to promote an autonomy supportive climate within the SDT literature is the provision of structure, but this can be facilitated in ways described by many existing techniques (e.g., goal setting, graded tasks, demonstration etc) as well as more relational activities (e.g., providing parameters within which choice can be made, so that choice is not overwhelming). Similarly, some SDT descriptors may overlap with other techniques but not match descriptions completely, for example 'listening' to participants is implicit within the MIT (e.g., technique 1, Open-ended questions), but not explicit (i.e., only if the practitioner demonstrates they are listening to the response). Thus, we engaged in an iterative process of comparing and discussing independently coded studies to arrive at the agreed set of codes for each. Reviewer agreement was calculated from the final 24 independently coded studies ($K = .68$) accepting any alternative from the agreed similar codes (e.g., BCT 1.7 Review Outcome Goals or MIT 37 Review Outcome Goal).

As our intent was to highlight how need support is being operationalised within practical settings, to render the presentation of this data meaningful we clustered the techniques identified using other taxonomies around the descriptions commonly given by study authors to broader SDT

‘strategies’, relating to original theoretical SDT texts (e.g., Deci & Ryan, 1985; Deci et al., 1994; Deci & Ryan, 2008). While we acknowledge that a technique that supports one basic need may also impact others, we considered it useful to map techniques to specific needs. This method aims to support researchers and practitioners looking for ways to bolster particular needs and ensure they have designed a comprehensive intervention. The allocation of particular strategies to needs was determined through expert consultation, initial theoretical publications (Deci et al., 1994; Deci & Ryan, 1985), and author intent in the studies downloaded.

Analysis

All analyses were computed on SPSS version 22 using Macros for computing weighted mean effect sizes published by Lipsey & Wilson (2001). Mean change scores for each study were obtained by subtracting pre- from post-intervention scores, and calculating the pooled standard deviation of change. Where full information was not available, the corresponding author was contacted with a request to supply the remaining data. The effect size for each study was calculated as the standardized mean difference between the change in the experimental and control groups using Hedges bias correction for small or uneven sample sizes (i.e. pooled standard deviation; Hedges & Olkin, 1985). For studies with multiple time points, the time point closest to 3 months (the most common time-frame for intervention) was used as the primary outcome. A composite score for autonomous regulation was computed for studies reporting individual regulations only where this was not provided (i.e., mean of intrinsic and identified regulations). Effect size statistics were further weighted by the inverse of the sampling error variance to account for more accurate estimates stemming from larger studies (Hedges & Olkin, 1985). A final estimate of effect for the entire sample of studies was then estimated through calculating a mean of the weighted effect sizes using a random effects model (Lipsey & Wilson, 2001). In line with recommended approaches (Osbourne, 2013) extreme outliers were identified when the Z-score exceeded 3.29 (indicating that the probability of obtaining this through random sampling is less than one time in a thousand; Tabachnick & Fidell, 2007) and removed from the analysis ($k=4$ of 330 data points). Effect sizes were interpreted through applying Cohen’s criteria of small (0.2) medium (0.5) and large (0.8).

The homogeneity of estimates was assessed through a Q test (sum of weighted square differences from the group mean, distributed on a χ^2 distribution; Lipsey & Wilson, 2001), and the I² index was then calculated to quantify the degree of heterogeneity (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). An analogue to ANOVA was used to partition the variance between and within groups to establish whether homogeneity is improved (i.e. value of Q reduced) by accounting for *a priori* grouping characteristics, thus potentially reducing the degree of unexplained heterogeneity between studies.

Meta-regression analyses were conducted to explore the association between the presence/absence of specific techniques and study outcomes. To provide the broadest perspective of what facilitated need satisfaction, given that techniques may support multiple needs, where possible we regressed all identified SDT strategies against need satisfaction and motivation. This was not possible for relatedness given the smaller number of studies reporting this outcome, so in this case we restricted the analysis to just those techniques designated as primary contributors to this need (Table 1). All techniques were entered simultaneously. As most studies included a number of strategies, the odds ratios of success (i.e., a significant improvement relative to control group) were computed for when 2, 3 or 4 or more strategies were reported to be used.

Intervention Quality

Intervention quality was rated through five questions from the Cochrane risk of bias tool (coded yes/no); random group allocation, treatment allocation concealed, groups similar at baseline, outcome assessor blind, intention to treat analysis. A sensitivity analysis was conducted to compare weighted effect sizes computed using all studies, versus only those with random treatment allocation, and those reporting their findings using an intention-to-treat analysis or not.

Results

Of an initial pool of 4335 articles extracted from database searches ($k=4302$) and other sources ($k=43$), 339 full studies were reviewed, and 74 studies met the inclusion criteria (Figure 1). The majority were randomized controlled trials ($k=41$) or cluster RCTs ($k=18$). Quality scores range from

1 to 5 out of a possible score of 5; 59 (80%) of studies were randomised, 23 (31%) were reported on an intent-to-treat basis, and 84% of studies scored three or more (Supplementary Table 1).

Techniques used in intervention research

The techniques used to target specific mediators of behaviour change are summarised in Table 1. Seventy techniques from existing taxonomies were identified (42 BCTs and 28 techniques from the MI taxonomy), and 21 techniques that were not adequately describe and thus were allocated new ‘SDT’-specific labels. These together formed 18 SDT strategies, of which a mean of seven were used per study (range 1 to 15).

<Table 1>

Measures of mediators

The outcomes of interventions were grouped into five theoretically coherent clusters for analysis; perceived autonomy support ($k=20$), autonomy satisfaction ($k=26$), competence satisfaction ($k=34$), relatedness satisfaction ($k=18$), and autonomous motivation ($k=58$). Controlled motivation was not included as an outcome as this is not considered a positive target for intervention.

Studies were conducted in a variety of health related domains; physical activity ($k=50$), health education ($k=5$), diet ($k=3$), medical adherence ($k=5$), dental health behaviours ($k=2$), weight loss ($k=5$), smoking cessation ($k=1$), alcohol reduction ($k=2$) and carer behaviours ($k=1$). In terms of setting, trials were run in schools ($k=25$), health premises ($k=15$), community settings ($k=18$), universities or colleges ($k=7$), workplaces ($k=1$), in labs ($k=1$) and online ($k=7$). Most could be classed as health promotion activities as they focused on community living children or adults without established health conditions ($k=66$; 89%). The majority of studies included both male and female participants ($k=54$), but five studies worked with males only, and 15 with females only. There was considerable variation in the duration of interventions, with 19 studies reporting on short one-off interventions (e.g., instructions given at the start of class, or brief advice by a doctor), four delivered within one week, nine lasting between a week and a month, and 42 extending contact beyond one month. Finally, 42 studies reported on ‘usual care’ control groups, 28 tested an alternative non-autonomy supportive intervention and 4 compared against a negative (controlling) climate. Details of

the characteristics of the 74 studies included in the final analysis are provided in Supplementary File 2.

Main analysis

Weighted mean between-group effect sizes were all in the predicted directions; perceived autonomy support $g=0.84$, autonomy $g=0.81$, competence $g=0.63$, relatedness $g=0.28$, and motivation $g=0.41$. Forest plots displaying these results are set out in Figures 2 - 6. Sensitivity analyses indicated similar effects (i.e., same interpretation of small, moderate or large effects) were found for autonomy, motivation and autonomy support when the analysis was restricted to only studies using intention-to-treat analysis, with a larger effect reported for competence, but a lesser (no) effect for relatedness. Similar effects were estimated when restricting to studies with only randomized allocation (see Table 3). As the effects were thus largely similar for higher and lower quality studies, all were included in the moderator analysis.

<Figures 2 -6>

There was significant heterogeneity in outcomes between studies for all mediators. On this basis, tests were conducted in line with the *a priori* predictions relating to study characteristics to explore potential sources of variation.

<Table 2>

Number of techniques: We aimed to test the hypothesis that the number of SDT strategies used within a study predicts more positive study outcomes by computing odds ratios of the likelihood of achieving a meaningful effect on need satisfaction (i.e., an effect size ≥ 0.30) in the presence of two, three or four or more techniques. For all outcomes confidence intervals were very wide, spanning zero, so no robust conclusions as to the impact of the number of techniques used could be drawn (Supplementary Table 2). We also considered the odds of success for interventions implementing motivational interviewing as a means of promoting satisfaction for autonomy and autonomous motivation, given its increasing use within applied SDT research (Markland, Ryan, Tobin, & Rollnick, 2005; Patrick & Williams, 2012; Vansteenkiste & Sheldon, 2006). While the confidence

intervals were large and positive, they spanned zero (OR autonomy = 4.81, CI: -0.11, 3.25; OR autonomous motivation = 2.99, CI: -0.04, 1.23) so do not provide a robust indication of effect.

Group versus one-to-one interventions: One-to-one interventions resulted in greater increases in competence satisfaction than group-based interventions ($g=0.96$, CI: 0.57, 1.36 vs 0.28, CI: -0.11, 0.68). There was no evidence for differences for other outcome variables.

Child versus adult interventions: There was a large difference in the effect of interventions on competence satisfaction in children ($g = 0.11$, CI: -0.34, 0.56) compared with adults ($g = 0.95$, CI: 0.59, 1.31). Given that the majority of interventions with children took place in a group setting (8%, predominantly in schools, 74%), we considered conducting post-hoc analyses to explore whether the moderation effects of age and type of delivery were conflated. There were too few studies of the effect of one-to-one interventions with children for robust analysis. However, the effects of group vs one-to-one delivery persisted for studies involving adults only; one-to-one interventions resulted in a weighted mean effect size for competence satisfaction of 1.03 (CI: 0.57, 1.50; $k=15$) versus 0.74 (CI: -.01, 1.49; $k=6$) for group interventions.

Type of control group: Forty-two studies (57%) compared interventions against a standard care or wait list control (i.e., no additional input provided). Four (5%) compared against need thwarting or controlling control conditions, and the remainder (28, 38%) provided alternative motivationally neutral input (e.g., information or advice beyond usual practice provided, but not in an autonomy supportive fashion). As may be expected, larger effect sizes were found for autonomy support and satisfaction in studies comparing interventions against need thwarting control conditions (Table 3). Effect sizes were also stronger when outcomes were compared against a neutral alternative intervention than to standard care or no treatment, except for competence satisfaction where the difference neared significance in the opposite direction (i.e., comparisons against neutral conditions were weaker than standard care).

Duration of intervention: There were no significant differences detected according to the duration of the intervention.

Performance of individual strategies

The meta-regression analyses conducted to explore the strength of effect of different techniques used within SDT-based interventions indicated that the techniques together explained 82% of the variance in autonomy satisfaction, and 56% of the variance in competence satisfaction, 50% of the variance in relatedness satisfaction, and 32% variance in autonomous motivation (Table 4). Given the lower numbers for relatedness, it was not possible to run the full analysis with all 18 strategies (R^2 approached unity), so only those theoretically loading onto relatedness (as shown in Table 1) were entered into the equation. As expected, the direction and strength of associations between strategies and outcomes was similar across needs. Autonomy satisfaction was only significantly positively predicted by the use of non-controlling language ($\beta=1.86$, $p<0.05$), but negatively predicted by involvement ($\beta=-2.56$, $p<0.01$). The only significant strategy in predicting competence was facilitating group co-operative tasks, although this operated in a negative direction ($\beta=-1.52$, $p<0.01$). Conversely, relatedness satisfaction was positively predicted by facilitating group co-operative tasks ($\beta=0.58$, $p<0.05$) but negatively by involvement ($\beta=-0.69$, $p<0.01$). Autonomous motivation was positively predicted by the inclusion of a rationale for behaviour change ($\beta=1.07$, $p<0.01$), but negatively by structure ($\beta=-0.75$, $p<0.01$) and the provision of information ($\beta=-1.17$, $p<0.01$).

<Table 3>

Discussion

This meta-analysis is the first to undertake an evidence synthesis of the effect of practical techniques to operationalise SDT within interventions in health domains. It indicates that the techniques currently used in behaviour change interventions grounded within SDT have large, positive effects on perceptions of autonomy support and autonomy satisfaction, and moderate effects on competence satisfaction and motivation. While many approaches can be described using existing taxonomies of behaviour change or counselling style, 21 distinct techniques grounded in SDT theory were also identified. The findings for competence satisfaction in particular were moderated by whether interventions were delivered to children or adults (competence satisfaction was greater in interventions delivered to adults), and in groups versus one-to-one settings (in adults one-to-one

settings resulted in greater competence satisfaction). The type of control group used also influenced the size, but not direction, of effects.

A final aim of this meta-analysis was to explore the independent effect of individual techniques, to explore which may be *necessary* components for successful SDT-based interventions, as has usefully been conducted with taxonomies relating to other theoretical techniques (Michie et al., 2009; Michie, Hyder, Walia, & West, 2011; Michie et al., 2012). Based on the present set of studies, there was limited evidence for the importance of specific strategies, although the use of non-controlling language appeared to be important for promoting autonomy satisfaction and the provision of a rationale important for promoting autonomous motivation. However, contrary to theory, several strategies (encouraging group activities, demonstrating involvement with a client, providing information and structure) were significant negative predictors of at least one outcome as will be discussed later.

Moderation Effects

Based on existing data, adults and children perceived similar benefits from the SDT-based interventions in terms of autonomy and relatedness satisfaction, autonomous motivation and perceived autonomy support, although adults reported greater gains in competence satisfaction compared with no meaningful gain in children. No studies provided a direct comparison of effects using the same intervention in both age groups, so it is possible that this finding relates to inherent differences between interventions delivered to adults and children rather than between their responses to a similar intervention; most child interventions took place in school in a similar format to, or even within, a school physical or health education class. As such, children's feelings of competence may naturally draw on contextual levels of need satisfaction relevant to these commonly encountered settings (particularly if interventions are delivered by children's existing class teachers) rather than reflecting a response to a novel setting. Many adult interventions involved an attempt to adopt new or unfamiliar behaviours, for example becoming physically active after years of inactivity, cutting down on alcohol or learning to take medication for which participants may have much less previous or contextual information to draw on. This fits with a hierarchical model of motivation, suggesting that children's perceptions of social climates may be driven by stronger contextual-level factors as

opposed to situational-level factors (Vallerand, 2007), and thus their need satisfaction is more difficult to influence. In addition, as many interventions included in this review were delivered in a ‘one off’ format, children may also not have time to shift their contextual beliefs (Gillison, Standage, & Skevington, 2013). However, research is needed to test these suppositions, and explore whether the difference between adults’ and children’s competence satisfaction reflects differences beyond novelty of the task. Past work that has measured adult and child need satisfaction within the same study has reported children to have higher levels of need satisfaction than their mothers (child $M = 3.89$ $SD=0.45$ vs mother $M=2.36$ $SD=0.91$), but this relates to cross-sectional observations and not their propensity for change (van der Kaap-Deeder et al., 2015).

In relation to other moderated effects, we found that interventions delivered in one-to-one settings resulted in greater competence satisfaction for adults than those delivered within groups. Only three studies attempted one-to-one interventions with children, so there is insufficient data to test if this is also the case for children. It would be useful to test whether greater competence satisfaction in one-to-one settings stems from factors beyond the greater opportunity for tailoring and provision of personalised feedback. Further research may also be valuable in exploring how competence support could be strengthened in group settings, and whether the most effective techniques to achieve this differ between settings. Exploring the finding that the facilitation of co-operative group tasks had a negative effect on competence satisfaction in the final meta-analysis would be a good starting point.

The final moderation effect showed that the type of control group influenced the size of effects, suggesting that attention to the nature of control groups is needed when interpreting study outcomes. Larger effect sizes were seen when need thwarting environments were induced as a comparator, and providing an alternative ‘neutral’ condition (i.e., absence of need support) also had larger effects than no treatment (e.g., wait list) controls. This may be as the people delivering standard care (e.g., school teachers, fitness advisors or clinicians) may naturally provide some degree of need support through their practice, and thus the difference between this and the active intervention may be less exaggerated.

Coding SDT interventions using existing Behaviour Change Taxonomies

The process of coding SDT-based interventions according to existing taxonomies served to provide additional detail on how SDT has been operationalised in past work. Through using two existing taxonomies to code techniques at a more granular level than usually attempted, we identified 70 individual techniques that mapped to the 18 broader ‘strategies’ to which SDT-research typically refers. This process revealed the wide range of ways in which the same broad SDT strategies are operationalised, providing insight to others as to how they can be achieved. For example, the commonly stated strategy of ‘*providing a meaningful rationale*’ could encompass four techniques within the 93-item Behaviour Change Taxonomy’s Natural Consequences grouping (see Table 1), but also encompassed rationales unrelated to health outcomes that may be better described in relational terms (i.e., or the motivational interviewing technique of ‘*Coming alongside*’, or showing respect to a client by explaining processes). There were 21 techniques that we did not feel were adequately encompassed by these existing taxonomies for which we suggest SDT-specific descriptors are required. Further investigation would be useful to explore what this additional level of specificity adds to the efficacy of outcomes; for example going back to the example of *providing a rationale*, investigating whether it matters what type of rationale is provided, so long as a rationale of some sort is present. Similar breadth of techniques were observed for other SDT strategies.

As we coded a total of 70 different techniques across taxonomies (plus 18 SDT-specific techniques), this also brought challenges for analysis in relation to assessing which have a greater impact on intended outcomes. To manage this process we therefore grouped the techniques into the SDT broader ‘strategies’ for meta-regression analysis. This approach is not without its limitations, as it may mask effects (both negative and positive) of different individual techniques within each group. Nonetheless, some SDT strategies (such as *providing structure*) are necessarily broad descriptors to allow for specification as appropriate to the setting. For example, the structure you provide to children and adults for similar tasks would be different according to their experience and ability, and similarly the structure needed for simple versus complex tasks would differ. It is also possible that the coding of behaviour change techniques without concurrent verification that the techniques are delivered in a need supportive manner moves the coding process away from what is most pertinent to what SDT-based interventions are aiming to achieve; many behaviour change techniques (e.g., goal setting)

could be delivered in either a controlling or an autonomy supportive manner and thus the technique itself may not be relevant, instead the language and approach used. A similar tension exists in the coding of such techniques from a motivational interviewing perspective (see the separation of codes into relational vs content elements in the motivational interviewing taxonomy used in our coding process; Hardcastle et al., 2017). However, by not coding content-related elements we risk overlooking the compelling findings from meta-analyses predicting behavioural outcomes that show consistent support for some specific content techniques (e.g., Michie et al., 2011; Greaves, Shephard, Abraham et al, 2011), which may very likely contribute to participants' feelings of competence (e.g., Williams & French, 2011) and be a means of facilitating structured choice (i.e., choosing one's own goals). There may also be interactions between the amount of structure found acceptable, and people's preferences and expectations for choice and autonomy (i.e., their autonomy orientation). Taking each of these considerations into account, we felt that an initial exploration of the effect of techniques clustered into SDT strategies was the most theoretically coherent, inclusive and parsimonious means of dealing with the amount of data generated by the coding process.

Performance of SDT strategies in predicting need satisfaction

The findings relating to the performance of specific strategies in promoting need satisfaction and motivation demonstrated a limited effect. This is not unexpected as SDT proposes that interventions should create a need supportive climate in order to bring about the internalisation of behavioural regulations (Deci, Eghrari, Patrick, & Leone, 1994; Ryan & Deci, 2000b; Ryan & Deci, 2017), in which it is implicit that such a climate is achieved by a combination of actions and communication styles. As such, the meta-regressions were not conducted as a means to identify stand-alone successful strategies, but to explore whether certain strategies may be particularly important to include among those implemented. The finding of very few significant predictors among strategies further confirms the limitation to considering need supportive environments as something that can be brought about through individual strategies. There was also no evidence that simply increasing the number of strategies resulted in stronger outcomes. This finding is similar to the assumptions behind motivational interviewing, in that there is a certain 'spirit' of motivational interviewing that is important, that is more than just the sum of its parts.

Of the strategies that did significantly predict outcomes, two were as predicted by theory; *non-controlling language* significantly predicted autonomy satisfaction, and *provision of a rationale* predicted autonomous motivation. Conversely, *involvement* with participants (i.e., showing a personal interest in a person, use of affirmation etc) negatively predicted both autonomy and relatedness satisfaction. It is possible that this results from participants becoming reliant on that individual, or alternatively the finding may mask different effects of the 10 techniques subsumed within the strategy; this warrants further exploration. *Facilitating group co-operation* showed some contrasting effects; it loaded negatively onto competence satisfaction, but positively onto relatedness satisfaction. This suggests that participants experienced the positive feelings of belonging when taking part and interacting with others, but doing so may have undermined their individual sense of competence when apart from the group. Finally, the *provision of structure* and the *provision of information* both negatively predicted autonomous motivation. This may reflect that both of these strategies could be done in either an autonomy supportive or controlling manner (implying that in some studies in the present analysis they were experienced as controlling), and/or that they endorsed the feeling of the practitioner's position of authority in directing the behaviour change.

We noted during the process of extracting the techniques from intervention descriptions that there was a lack of detail in the reporting of some studies, and as a result it is likely that some techniques were present in the intervention but not identified as such in the description provided (e.g., the provision of social support). This will have reduced the specificity of our analysis. Nevertheless, we believe it is still useful to attempt to identify the most useful components within interventions to better understand how need supportive climates can be fostered, and improve the match between theory and practice in SDT-based research. The recent interest in using motivational interviewing as a means to provide need support (Markland et al., 2005; Patrick & Williams, 2012; Vansteenkiste & Sheldon, 2006) illustrates that there is demand for a defined, testable and trainable approach with which to deliver interventions that promote autonomous motivation in practice. The approach has been shown to be effective in bringing about change in variety of health behaviours (Armstrong et al, 2011; Lundahl et al., 2013; O'Halloran et al., 2014; VanBuskirk, 2014), and is attractive as it is a recognised clinical approach for which regulated training programmes are available. That is, it is clear

what is being delivered, and people delivering interventions can be required to demonstrate a level of skill or qualification that helps to ensure minimum standards are met. The same systematic and consistent level of training is not typically provided by research studies implementing other behaviour change or SDT-based techniques. Limitations with the use of motivational interviewing include its lack of a theoretical foundation, such that the interpersonal contexts that promote positive outcomes through motivational interviewing may be better understood via the processes within SDT (e.g., basic need satisfaction and autonomous motivation; Ryan & Deci, 2017), and challenges in delivering it outside one-to-one settings and longer-term interventions (e.g., during school lessons, in group-based interventions). Thus, the results of this review aim to contribute towards a similarly standardised set of styles and techniques that could be reliably taught and understood by people working to promote health behaviours.

Limitations

This meta-analysis was limited by the comparability of studies. The intensity of interventions varied widely, ranging from experimental lab-based studies involving just one contact, to weekly group based treatment sessions lasting up to 12 months. The behaviours targeted varied from a comprehensive lifestyle change for weight loss, to tooth brushing or participation in physical education classes. With sufficient numbers, separate analyses differentiating health behaviour and setting would be informative; this is particularly the case for exploring the efficacy of the types of strategy most effective for each.

We explored the impact of risk of bias on outcomes through two sensitivity analyses, however there are other practical markers of study quality that we could have used that may have been insightful. For example, quality in terms of the treatment that participants receive could be assessed through taking account of the implementation of interventions according to their fidelity to protocol, participant attendance, or skill level of delivery teams. However, although this type of information is important, it is typically less reliably reported. Finally, the quality of reporting of the techniques used was often weak. For example, some researchers assume that there is tacit understanding of what terms such as ‘autonomy support’ mean, so provided only examples of the types of strategies used rather

than a full list, and other authors did not report them at all. While every attempt was made to contact authors for clarification, we were not able to obtain this information for all studies.

Conclusion

This review is the first to examine the techniques delivered within interventions to promote need satisfaction and autonomous motivation for health behaviour change, and examine their efficacy, based on literature spanning five decades. The analysis of 74 intervention studies shows that the techniques in current use have the potential to bring about changes in the theoretical mediators of health behaviour change of a small (relatedness satisfaction and autonomous motivation), moderate (competence satisfaction) and large effect size (autonomy support and satisfaction). Positive effects are achievable in both children and adults and across a wide range of health domains. Moderation effects for the satisfaction of competence highlight that there may be particular need to bolster the focus of this need support provided in group settings and in interventions delivered to children in particular. Within the limits of the research available, there was little evidence that any individual techniques are independently predictive of successful need support, endorsing the suggestion that a need supportive environment requires the combination of multiple co-acting techniques.

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Table 1: Frequency of strategies reported to promote need satisfaction

SDT strategies	Descriptor	Codes included	K studies per technique	Formal description of BCTs from other taxonomies	k studies per strategy (one or more codes)	Primary target*
SDT1: Choice	Client is given choices and options	MIT 24	16	Emphasise autonomy: The counsellor provides a statement that directly expresses motivational support, acknowledging the client's ability for choice and self-determination	44	Autonomy
		MIT 32 SDT 1 [±]	3 43	Consider change options <i>Provide choice</i>		
SDT2: Acknowledge participant's perspective	Practitioner takes time to understand the Client's perspective and recognise their challenges	MIT 2	14	Affirmation: The counsellor provides a statement of affirmation that acknowledges the client's difficulties, efforts and self-worth	32	Autonomy
		SDT 2	28	<i>Acknowledge participant's perspective</i>		
SDT3: Provide a rationale	Practitioner provides a rationale for undertaking an activity	BCT 4.2	2	Information about antecedents	38	Autonomy
		BCT 5.1	26	Information about health consequences [of behaviour]		
		BCT 5.2	2	Salience of consequences		
		BCT 5.3	4	Information about social and environmental consequences		
		BCT 5.6	4	Information about emotional consequences		
		SDT 3	24	<i>Provide a rationale</i>		
SDT4: Use of non-controlling language	Practitioner uses language that emphasises the client's right to choose	SDT 4	22	<i>Use of non-controlling language</i>	23	Autonomy

SDT5: Intrinsic goal orientation	Practitioner encourages identification of intrinsic (self-concordant) goals	SDT 5	13	<i>Intrinsic goal orientation</i>	13	Autonomy
SDT6: Structure	Practitioner sets parameters within which choice and agency can take place and provides support to initiate action	BCT 1.1 BCT 1.3 BCT 1.4 BCT 4.1 BCT 6.1 BCT 8.1 MIT 33 SDT 6	34 1 8 15 6 8 4 17	Goal setting (behaviour) Goal setting (outcome) Action planning Instruction on how to perform the behavior Demonstration of the behaviour Behavioural practice/rehearsal Develop a change plan: (CATs) C - Commitment, A - Activation, T - Taking steps. <i>Provide structure</i>	48	Autonomy
SDT7: Emphasise responsibility	Practitioner encourages the client to take on responsibility in decision making and/or leadership	BCT 12.2 MIT 24 SDT 7a SDT 7b SDT 9	7 16 12 6 13	Restructuring the social environment Emphasise autonomy Provide opportunities to take the lead <i>Facilitate active participation in decision making</i> <i>Give responsibility</i> <i>Motivational interviewing</i>	32	Autonomy
SDT8: Explore reasons	Practitioner explores client's reasons for changing behaviour	MIT 12 SDT 8	5 3	DARN questions - The counsellor uses open-ended questions that seek to elicit four subtypes of client motivational talk: Desire, Ability, Reason and Need. <i>Explore participant's reasons for change</i>	7	Autonomy

SDT9: Motivational Interviewing	Author describes the intervention as based on, or delivered through motivational interviewing	BCT 3.3 SDT 9	19 13	Social support (emotional) <i>Motivational Interviewing</i>	25	Autonomy
SDT10: Task climate	Facilitation focuses on completing the process of the task, matched against one's own standards, rather than the outcomes of the task	SDT 10	9	<i>Provide a task oriented climate</i>	9	Competence
SDT11: Provide optimal challenge	Practitioner matches/tailors the level of the task to an individual client	BCT 8.7 SDT 11a SDT 11b	8 7 7	Set graded tasks <i>Provide optimal challenge</i> <i>Set challenging tasks</i>	16	Competence
SDT12: Provide informational feedback	Practitioner provides feedback providing information of <i>how</i> a person achieved/did not achieve a desired outcome, rather than generic praise/criticism	BCT 1.5 BCT 1.7 BCT 2.2 BCT 2.3 BCT 2.4 BCT 2.6 BCT 2.7 MIT 37 SDT 12	11 3 22 11 2 1 3 2 19	Review behaviour goals Review outcome goals Feedback on behaviour Self-monitoring of behaviour Self-monitoring of outcome Biofeedback Feedback on outcomes Review outcome goals <i>Provide informational feedback</i>	40	Competence
SDT13. Provide information	Practitioner provides information to the client relevant to their needs and situation	BCT 4.2 BCT 5.1 BCT 5.3 BCT 5.6 SDT 13	2 26 4 4 18	Information about antecedents Information about health consequences [of behaviour] Information about social and environmental consequences Information about emotional consequences <i>Provide personalised information (when not coded as any of the above)</i>	36	Competence

SDT14. Barrier identification	Practitioner works with the client to identify barriers to behaviour change	BCT 1.2	20	Problem solving	23	Competence
		MIT 19	2	Brainstorming		
		MIT 20	3	Trouble shooting: The counsellor prompts the client to think about potential barriers and identify ways of overcoming them in order to strengthen motivation		
		SDT 14	8	<i>Barrier identification</i>		
SDT15: Provide support and encouragement	Practitioner provides general support and encouragement (i.e., social support from the practitioner him or herself)	BCT 15.1	3	Verbal persuasion about capability	25	Competence
		MIT 2	14	Affirmation		
		MIT 35	3	Support change/persistence: The counsellor functions as a partner or companion, collaborating with the client's own expertise.		
		MIT 36	7	Offer emotional support		
		SDT 15a	3	<i>Express confidence</i>		
		SDT 15b	8	<i>Provide support and encouragement</i>		
SDT16: Involvement	Express a personal interest in the individual and take time to develop a rapport	MIT 1	2	Open-ended questions	30	Relatedness
		MIT 2	14	Affirmation		
		MIT 3	3	Reflective statements		
		MIT 12	5	DARN questions		
		MIT 21	7	Values exploration (open or structured)		
		MIT 27	2	Coming alongside		
		MIT 35	4	Support change/persistence		
		MIT 36	7	Offer emotional support		
		SDT 16a	9	<i>Show personal involvement</i>		
		SDT 16b	10	<i>Listening to participants</i>		
SDT17. Encourage social support seeking	Practitioner encourages client to seek social support from others	BCT 3.1	14	Social support (unspecified)	34	Relatedness
		BCT 3.2	9	Social support (practical)		
		BCT 3.3	19	Social support (emotional)		
		SDT 17	10	<i>Encourage social support seeking from others</i>		

SDT18: Group co-operation	Practitioner establishes interdependence within a group, or encourages cooperative peer-to-peer activities	SDT 18	11	<i>Facilitate group co-operation</i>	11	Relatedness
SDT19: Use of incentives**		BCT 10.1	1	Material incentive (behaviour)	3	**Autonomy (negative)
		BCT 10.2	0	Material reward (behaviour)		
		BCT 10.3	2	Non-specific reward		
		BCT 10.10	1	Reward (outcome)		

* We acknowledge that the three needs are interrelated, and thus, techniques may support more than one need. However, we have highlighted the primary need targeted by each; it is also implied that strategies fostering need support would also foster autonomous motivation. ** Incentives are not typically an SDT-based technique, but have been coded as these can be theoretically associated with *decreased* autonomy support. [±] Techniques labelled as “SDT(N)” refer to occasions when the technique is described by authors as in column 2, the technique is listed again in column 3 to allow inclusion of the number of times the technique was listed to compare alongside techniques listed by other taxonomies.

Table 2: Weighted mean effect sizes and degree of homogeneity for outcomes according to study characteristics

	Outcome variables									
	autonomy k=26		competence k=34		relatedness k=19		motivation k=60		Autonomy support k=19	
	ES (95% CI)		ES (95% CI)		ES (95% CI)		ES (95% CI)		ES (95% CI)	
All studies	0.81 ^a (0.45, 1.16)		0.63 (0.35, 0.90)		0.28 (0.01, 0.54)		0.41 (0.25, 0.57)		0.84 (0.51, 1.17)	
	Q=608.00**		Q=815.80**		Q=161.78**		Q=1020.60**		Q=470.75**	
	I ² =96%		I ² =96%		I ² =89%		I ² =94%		I ² =96%	
RCTs only	0.54 (0.17, 0.91)		0.51 (0.24, 0.78)		0.15 (-0.23, 0.53)		0.39 (0.21, 0.58)		0.82 (0.42, 1.23)	
	k=17		k=25		k=11		k=46		k=15	
Intention to treat	1.13 (0.22, 2.25)		0.93 (0.09, 1.76)		-0.00 (-.73, 0.73)		0.71 (0.36, 1.06)		1.17 (-0.82, 3.17)	
only	k=8		k=11		k=5		k=19		k=3	
Moderator analyses:	<i>Q^b</i>	<i>ES (CI)</i>	<i>Q</i>	<i>ES (CI)</i>	<i>Q</i>	<i>ES (CI)</i>	<i>Q</i>	<i>ES (CI)</i>	<i>Q</i>	<i>ES (CI)</i>
Length of intervention	Q = 0.28		Q = 1.40		Q = 0.04		Q = 0.49		Q = 0.98	
≤ 1 month	<i>k=9</i>	0.94 (0.33, 1.54)	<i>k=13</i>	0.41 (-.05, 0.87)	<i>k=4</i>	0.33 (-0.25, 0.91)	<i>k=27</i>	0.35 (0.11, 0.58)	<i>k=10</i>	1.01 (0.54, 1.48)
> 1 month	<i>k=17</i>	0.74 (0.29, 1.18)	<i>k=21</i>	0.76 (0.40, 1.13)	<i>k=15</i>	0.26 (-0.06, 0.58)	<i>k=31</i>	0.46 (0.24, 0.69)	<i>k=9</i>	0.66 (0.16, 1.17)

Age of participants	Q = 0.17		8.18**		0.13		0.00		0.03	
Children	<i>k</i> =13	0.87	<i>k</i> =13	0.11	<i>k</i> =10	0.23	<i>k</i> =32	0.41	<i>k</i> =10	0.83
		(0.36, 1.41)		(-0.34, 0.56)		(-0.14, 0.60)		(0.19, 0.63)		(0.33, 1.32)
Adults	<i>k</i> =13	0.73	<i>k</i> =21	0.95	<i>k</i> =9	0.33	<i>k</i> =26	0.41	<i>k</i> =9	0.89
		(0.21, 1.26)		(0.59, 1.31)		(-0.08, 0.74)		(0.17, 0.66)		(0.36, 1.42)
Mode of delivery	Q = 1.01		5.58		0.04		0.73		0.00	
			*							
One-to-one	<i>k</i> =10	0.57	<i>k</i> =17	0.96	<i>k</i> =5	0.32	<i>k</i> =20	0.31	<i>k</i> =4	0.84
		(-0.02, 1.17)		(0.57, 1.36)		(-0.22, 0.87)		(0.03, 0.59)		(0.10, 1.58)
Group	<i>k</i> =16	0.96	<i>k</i> =17	0.28	<i>k</i> =13	0.26	<i>k</i> =38	0.46	<i>k</i> =15	0.85
				(-0.11, 0.68)		(-0.07, 0.58)		(0.26, 0.67)		(0.47, 1.24)
Control group	Q = 5.30 (p=0.07)		5.70 [±]		0.57		15.34		6.64	
							**		*	
Standard care/ no	<i>k</i> =14	0.51	<i>k</i> = 20	0.62	<i>k</i> =11	0.18	<i>k</i> =30	0.19	<i>k</i> =8	0.60
intervention		(0.00, 1.03)		(0.26, 0.99)		(-0.19, 0.55)		(-0.03, 0.41)		(0.08, 1.12)
Neutral alternative ^c	<i>k</i> =10	0.96	<i>k</i> = 13	0.49	<i>k</i> =8	0.40	<i>k</i> =25	0.52	<i>k</i> =9	0.79
		(0.35, 1.56)		(0.05, 2.16)		(-0.02, 0.82)		(0.28, 0.76)		(0.31, 1.27)

Undermining	<i>k</i> =2	2.16	<i>k</i> =1	-	<i>k</i> =0	-	<i>k</i> =3	1.59	<i>k</i> =9	2.12
autonomy		(0.80, 3.52)						(0.89, 2.30)		(1.08, 3.17)

Notes: [±] *p*=0.05, * *p*<.05, ** *p*<.01, *** *p*<.001; *g* = weighted effect size (Hedges' *g*); *k* = number of studies; *Q* stat is the between group statistic; ^a the first point of assessment post intervention was used in each case (range 0 [i.e., immediately post intervention] to 104 weeks); ^b between group; ^c an alternative intervention provided without autonomy/need support. Where cells are empty, too few studies were available for meaningful comparison for that particular analysis.

Table 3: Meta-regression for strategies to promote need satisfaction and autonomous motivation

	Autonomy satisfaction (<i>k</i> =26)		Competence satisfaction (<i>k</i> =34)		Relatedness satisfaction (<i>k</i> =19)		Autonomous motivation (<i>k</i> =59)	
	Mean ES: 0.81, R ² : 0.82		Mean ES: 0.63, R ² : 0.56		Mean ES: 0.30, R ² : 0.99		Mean ES: 0.42, R ² : 0.32	
Strategy	B (SE)	95% CI	B (SE)	95% CI	B (SE)	95% CI	B (SE)	95% CI
SDT1: Choice	-0.59 (0.54)	-1.64, 0.47	-0.35 (0.59)	-1.51, 0.80	-	-	-0.10 (0.27)	-0.62, 0.42
SDT2: Acknowledge participant's perspective	0.54 (0.79)	-2.09, 1.01	0.47 (0.63)	-0.77, 1.700	-	-	0.59 (0.39)	-0.16, 1.35
SDT3: Provide a rationale	0.15 (0.91)	-1.64, 1.94	0.21 (0.70)	-1.15, 1.58	-	-	1.07** (0.41)	0.26, 1.89
SDT4: Use of non-controlling language	1.86* (0.82)	0.26, 3.47	0.70 (0.88)	-1.02, 2.43	-	-	-0.27 (0.34)	-0.94, 0.41
SDT5: Intrinsic goal orientation	-0.58 (0.75)	-2.1, 0.89	-0.73 (0.79)	-2.28, 0.82	-	-	-0.14 (0.38)	-0.90, 0.61
SDT6: Structure	-1.00 (0.82)	-2.60, 0.61	0.63 (0.58)	-0.51, 1.76	-	-	-0.85** (0.32)	-1.47, -0.23
SDT7: Emphasise responsibility	-0.26 (0.58)	-1.40, 0.89	-0.31 (0.50)	-1.29, 0.67	-	-	-0.17 (0.26)	-0.67, 0.33
SDT8: Explore reasons	-	-	-	-	-	-	0.58 (0.46)	-0.32, 1.48
SDT9: Motivational Interviewing	0.01 (0.95)	-1.86, 1.88	-0.85 (0.66)	-2.14, 0.45	-	-	-0.32 (0.35)	-1.00, 0.36
SDT10: Task climate	0.02 (0.59)	-1.1, 1.17	0.64 (0.67)	-0.67, 1.95	-	-	-0.23 (0.39)	-1.00, 0.54
SDT11: Provide optimal challenge	1.06 (1.23)	-1.36, 3.48	-0.29 (0.93)	-2.12, 1.54	-	-	-0.54 (0.36)	-1.25, 0.17
SDT12: Provide informational feedback	0.04 (0.77)	-1.15, 1.86	0.60 (0.56)	-0.48, 1.69	-	-	0.38 (0.28)	-0.18, 0.93

SDT13. Provide information	-0.20 (1.03)	-2.23, 1.82	-1.16 (0.82)	-2.77, 0.45	-	-	-1.17** (0.35)	-1.85, -0.49
SDT14. Barrier identification	-0.23 (0.95)	-2.09, 1.62	0.20 (0.72)	-1.20, 1.61	-	-	0.26 (0.29)	-0.32, 0.83
SDT15: Provide support and encouragement	1.21 (0.88)	-0.53, 2.95	0.86 (0.66)	-0.43, 2.14	-	-	0.45 (.35)	-0.23, 1.14
SDT16: Involvement	-2.56** (1.03)	-4.59, -0.53	-0.64 (0.88)	-2.38, 1.09	-0.69* (0.23)	-1.15, -0.24	-0.39 (0.37)	-1.12, 0.33
SDT17. Encourage social support seeking	0.08 (0.67)	-1.24, 1.40	0.23 (0.60)	-0.94, 1.40	0.12 (0.24)	-0.34, 0.58	-0.06 (0.32)	-0.70, 0.57
SDT18: Group co-operation	-	-	-1.52* (0.66)	-2.82, -0.22	0.58* (0.24)	0.12, 1.05	0.17 (0.36)	-0.55, 0.88

Notes: Only strategies implemented in five or more studies were included in the analysis for all outcomes. For Relatedness, only the primary strategies loading onto Relatedness (see Table 1) were used due to the lower number of studies. * $p < .05$, ** $p < .001$

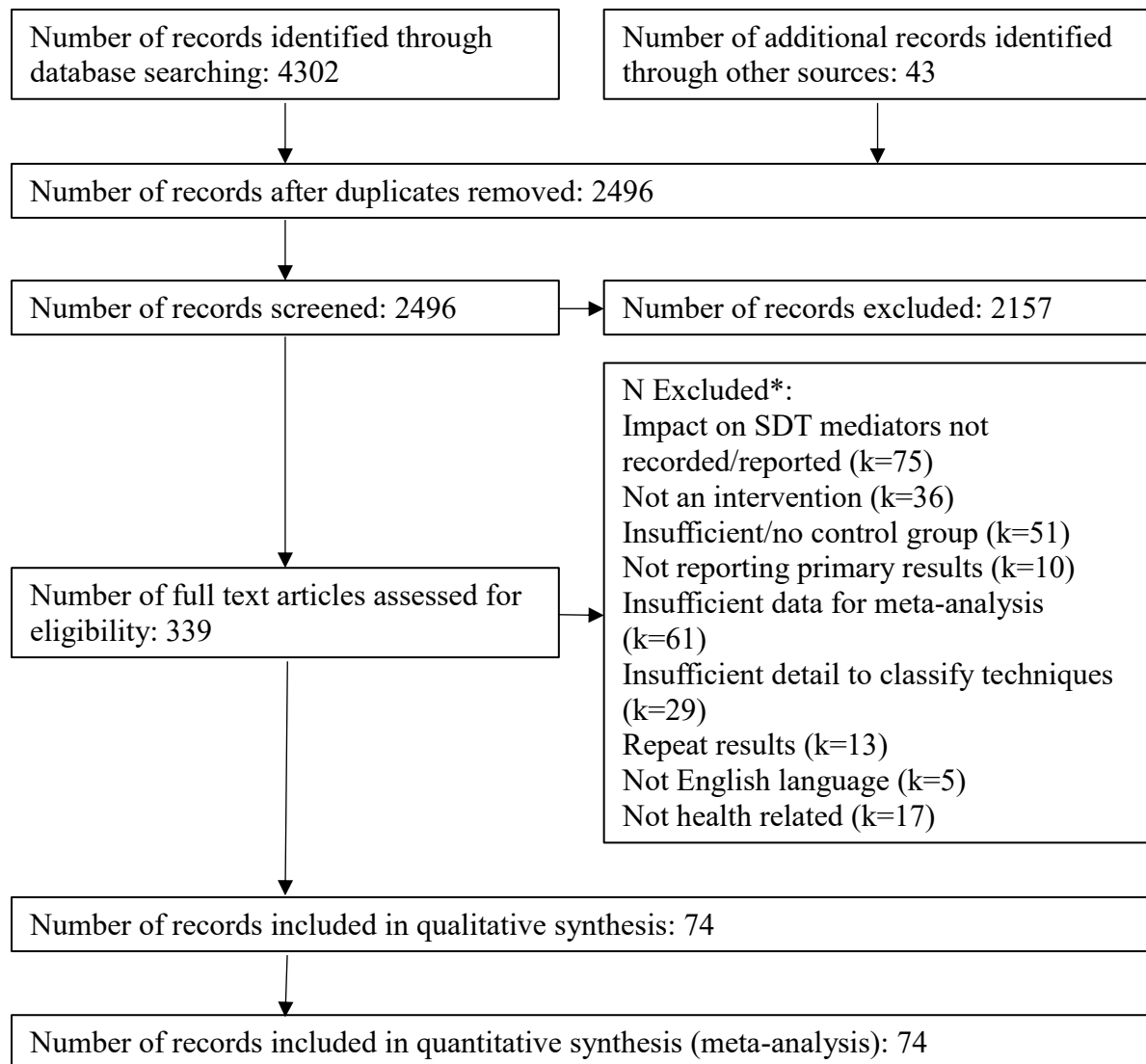


Figure 1. Study selection process (* studies could be excluded for more than one reason).

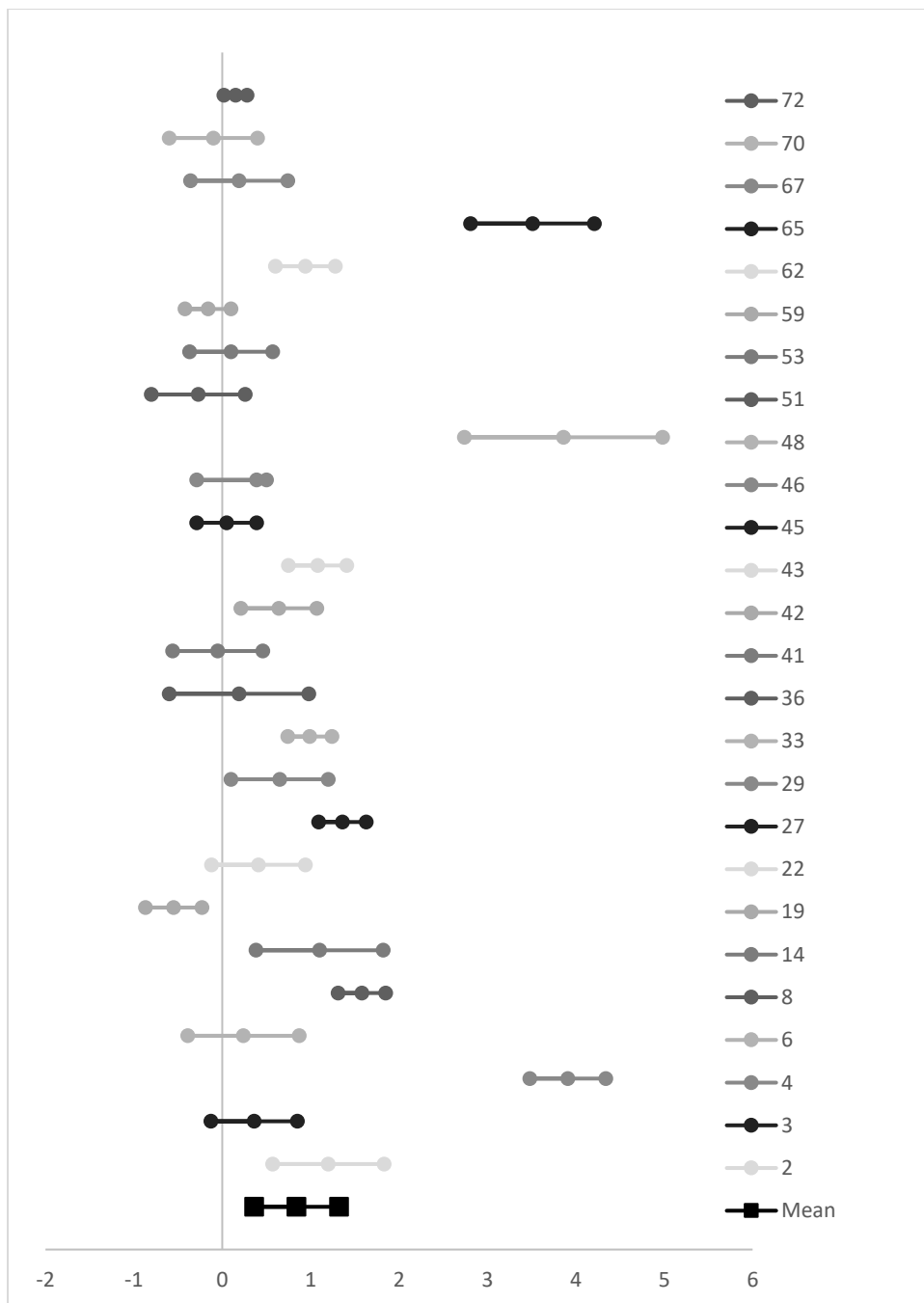


Figure 2. Effect sizes and confidence intervals for individual studies (k=26) that measure autonomy satisfaction and overall mean.

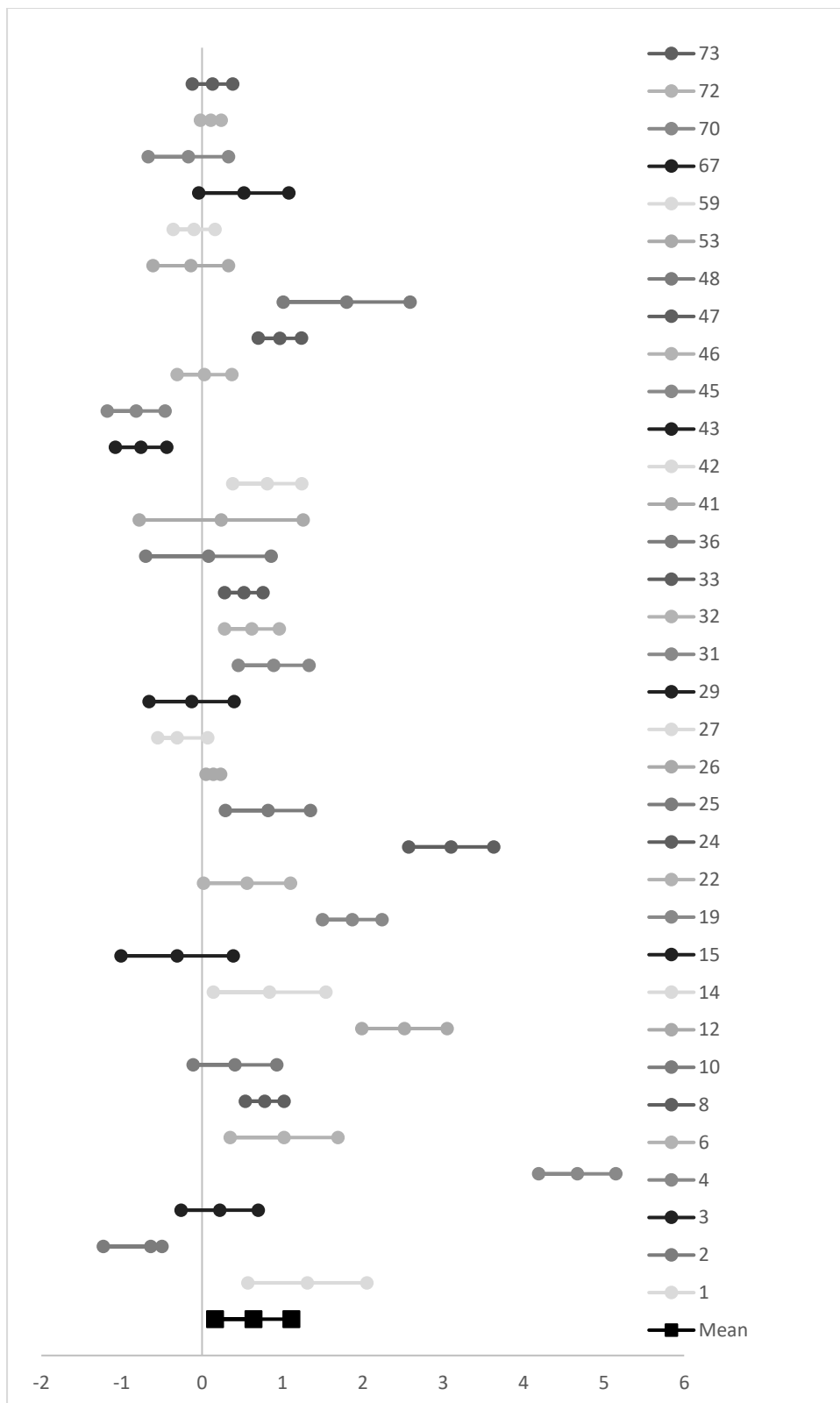


Figure 3. Effect sizes and confidence intervals for individual studies (k=34) that measure competence satisfaction and overall mean.

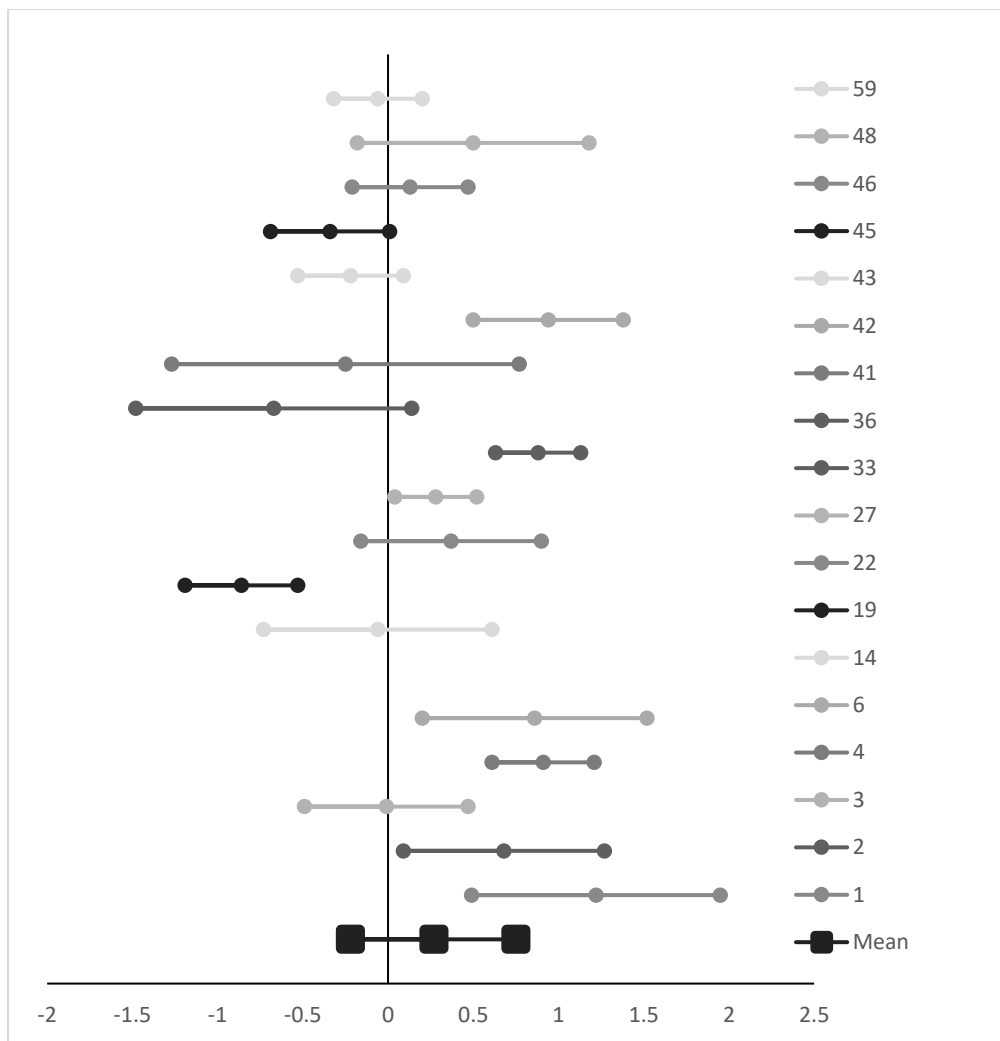


Figure 4. Effect sizes and confidence intervals for individual studies (k=19) that measure relatedness satisfaction and overall mean.

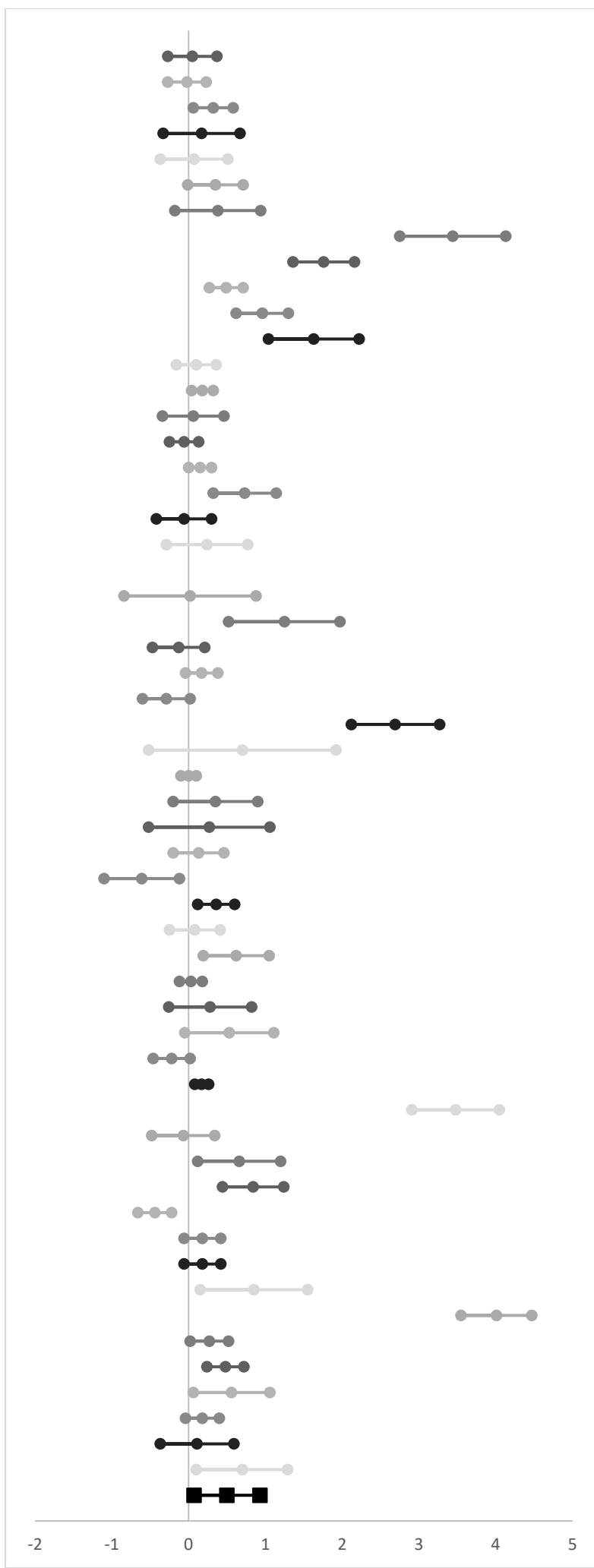


Figure 5. Effect sizes and confidence intervals for individual studies (K= 56) that measure autonomy satisfaction (including study numbers 74, 73,71,70,69,68,66,65,64,63,62,60,59,58,57,56,55,54,52,51, 50, 49,48,46,44,43,42,40,38,37,36,35,34,33,32,31,30,29,28,27,26,24,23,22,21,19,16,15,14,11,10, 8,7,5,3,2, Overall Mean)

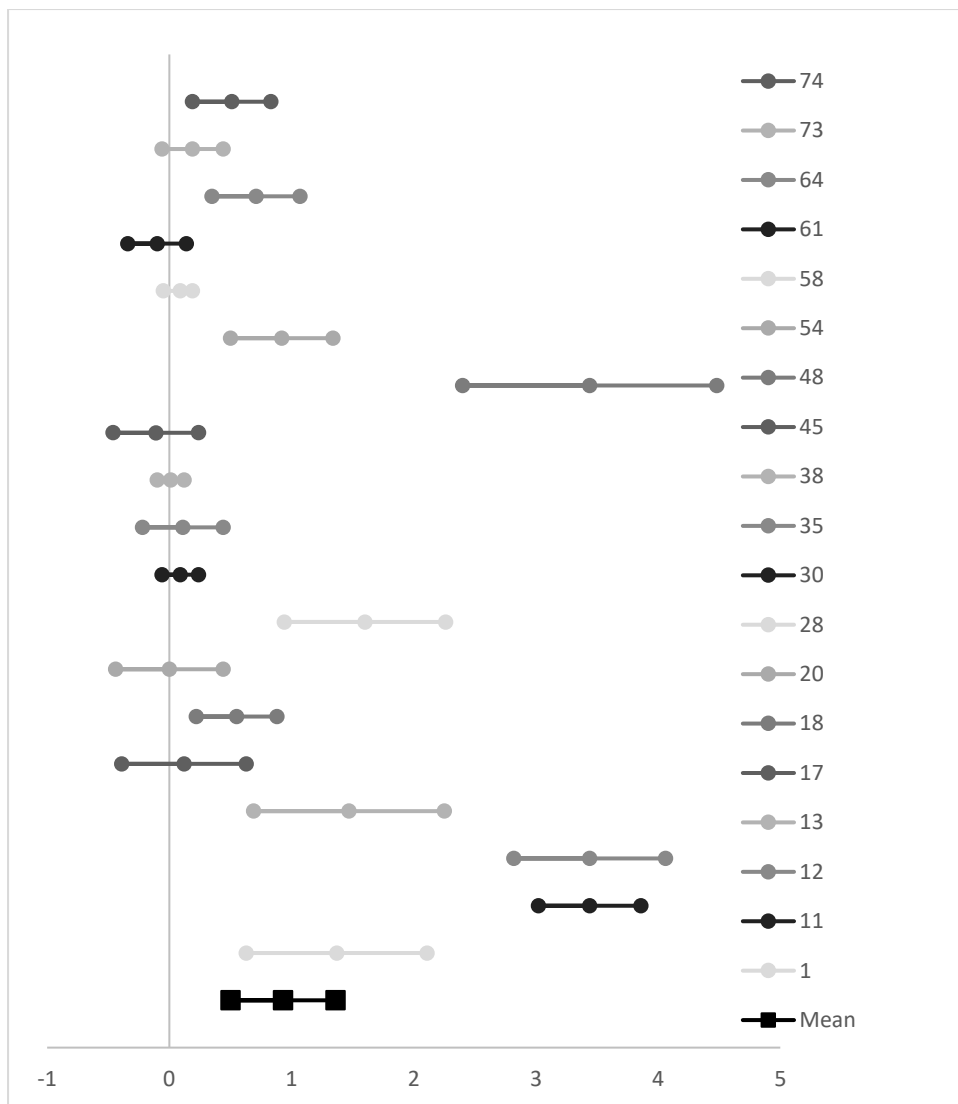


Figure 6. Effect sizes and confidence intervals for individual studies (k=19) that measure autonomy support and overall mean.