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The Theory of Planned Behaviour and dietary patterns: a systematic review and meta-analysis

Mairtin S. McDermott

University of Wollongong, mairtin@uow.edu.au

Madalyn Oliver

University of Wollongong, mo987@uowmail.edu.au

Thomas Simnadis

University of Wollongong, ts057@uowmail.edu.au

Eleanor Beck

University of Wollongong, eleanor@uow.edu.au

Tim Coltman

University of Wollongong, tcoltman@uow.edu.au

See next page for additional authors

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The Theory of Planned Behaviour and dietary patterns: a systematic review and meta-analysis

Abstract

Objective Promoting adherence to healthy dietary patterns is a critical public health issue. Models of behaviour, such as the Theory of Planned Behaviour (TPB) allow programme designers to identify antecedents of dietary patterns and design effective interventions. The primary aim of this study was to examine the association between TPB variables and dietary patterns. **Methods** A systematic literature search was conducted to identify relevant studies. Random-effects meta-analysis was used to calculate average correlations. Meta-regression was used to test the impact of moderator variables. **Results** In total, 22 reports met the inclusion criteria. Attitudes had the strongest association with intention ($r = 0.61$) followed by perceived behavioural control (PBC, $r = 0.46$) and subjective norm ($r = 0.35$). The association between intention and behaviour was $r = 0.47$, and between PBC and behaviour $r = 0.32$. Moderator analyses revealed that younger participants had stronger PBC–behaviour associations than older participants had, and studies recording participants' perceptions of behaviour reported significantly higher intention–behaviour associations than did those using less subjective measures. **Conclusions** TPB variables were found to have medium to large associations with both intention and behaviour that were robust to the influence of key moderators. Recommendations for future research include further examination of the moderation of TPB variables by age and gender and the use of more valid measures of eating behaviour.

Disciplines

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Authors

Mairtin S. McDermott, Madalyn Oliver, Thomas Simnadis, Eleanor Beck, Tim Coltman, Donald C. Iverson, Peter Caputi, and Rajeev Sharma

The Theory of Planned Behavior and dietary patterns: A systematic review and meta-analysis.

McDermott MS ^a, Oliver M ^a, Simnadis T ^b, Beck EJ ^b, Coltman T ^c, Iverson D ^d, Caputi P ^e, Sharma R ^a.

^a School of Computing and Information Technology, Faculty of Engineering and Information Sciences, University of Wollongong, NSW 2522, Australia.

^b School of Medicine, Faculty of Science, Medicine and Health, University of Wollongong NSW 2522 Australia.

^c School of Management, Operations and Marketing, Faculty of Business, University of Wollongong, NSW 2522, Australia.

^d Faculty of Health, Arts and Design, Swinburne University of Technology, Victoria 3122, Australia.

^d School of Psychology, Faculty of Social Sciences, University of Wollongong, NSW 2522, Australia.

Corresponding author: Máirtín McDermott (mairtin@uow.edu.au)

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Abstract

Promoting adherence to healthy dietary patterns is a critical public health issue. Models of behavior, such as the Theory of Planned Behavior (TPB) allow program designers to identify antecedents of dietary patterns and design effective interventions. The primary aim of this study was to examine the association between TPB variables and dietary patterns. A systematic literature search was conducted to identify relevant studies. Random-effects meta-analysis was used to calculate average correlations. Meta-regression was used to test the impact of moderator variables. In total, 22 reports met the inclusion criteria. Attitudes had the strongest association with intention ($r_+ = 0.61$) followed by perceived behavioral control (PBC, $r_+ = 0.46$) and subjective norm ($r_+ = 0.35$). The association between intention and behavior was $r_+ = 0.47$, and between PBC and behavior $r_+ = 0.32$. These associations were robust to the influence of key moderators. However, analyses revealed that younger participants had stronger PBC-behavior associations than older participants, and studies recording participants' perceptions of behavior reported significantly higher intention-behavior associations than those using less subjective measures. Recommendations for future research include further examination of the moderation of TPB variables by age and gender and the use of more valid measures of eating behavior.

Introduction

In 2012, one-quarter of all deaths globally were caused by ischemic heart disease and stroke (World Health Organisation, 2014). Improved diet quality has been consistently associated with decreases in the levels of risk factors associated with these conditions (Estruch et al., 2013; Ye et al., 2012). However, improving the quality of our diets is not easily achieved, particularly in countries of ubiquitous food supply. Individuals are faced with the difficult task of choosing from a wide range of food and beverages in order to meet nutritional requirements without excessive kilojoule intake. To facilitate this process, local authorities, such as the National Health and Medical Research Council in Australia, jointly by the Department of Health and Human Services/ Department of Agriculture in the US and National Health Service in the UK, translate scientific evidence into easily understandable dietary guidelines that promote healthy and nutritious dietary patterns. Based on these messages, 'healthy eating' revolves around consuming a variety of nutrient-dense foods and promoting dietary patterns that are conducive to reducing the risk of developing chronic diseases (National Health and Medical Research Council, 2013). However, despite general improvements in healthy eating patterns between 1990 and 2010, the incidence of unhealthy dietary patterns has also increased, resulting in a very small net change (Australian Bureau of Statistics, 2014; Imamura et al., 2015). Behavior change interventions that can increase adherence to health promoting eating patterns are clearly warranted.

Such interventions are more likely to be effective when based on theory (Michie and Johnston, 2012). The Theory of Planned Behavior (TPB) (Ajzen, 1991), which is an extension of the earlier Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) is amongst the models most commonly used to predict behavior. The TPB presents a parsimonious, rational view of behavior, and asserts that behavior can be adequately predicted by two variables: intention and perceived behavioral control (PBC). Intentions are viewed as the most proximal determinant of behavior and are considered to indicate the amount of effort an individual is likely to devote to performing that behavior. PBC represents an individual's perceptions of control, and is held to exert both a direct effect on behavior, and an indirect effect through intentions. Intentions in turn are also determined by attitudes, which represent an overall evaluation of the behavior, and subjective norms (SN), which represent an evaluation of whether an individual feels significant others think he/she should engage in the behavior. Thus, according to the TPB, individuals will have a strong intention to, for example, consume a healthy diet, when they hold more positive attitudes towards the

behavior, perceive social pressures from those whose opinions they value and feel capable of consuming a healthy diet without difficulty. This intention, along with their perceptions of capability, determines the likelihood that they will adhere to this dietary pattern. The effects of all other influences, for example, biological, social and environmental, are hypothesized to be mediated by these variables (Ajzen, 1985).

The TPB has proven to be a reliable predictor of a variety of health-promoting behaviors, explaining between 14 and 24% of the variance (McEachan et al., 2011). Previous meta-analyses (Godin and Kok, 1996; McEachan et al., 2011) have also demonstrated the capacity of the TPB to predict dietary behaviors. The most recent of these found that the TPB predicted 21.2% of the between-study variance in behavior. These reviews do not, however, allow us to draw conclusions on the association between the TPB and the overall dietary patterns that are associated with improvements in health. This is primarily due to the aggregation of a range of distinct eating behaviors; for example, dietary patterns such as ‘healthy eating’ in combination with discrete food choices such as eating fruit and vegetables or avoiding fast food. Thus, these analyses reveal high level associations only.

This is problematic for a number of reasons. First, from a theoretical standpoint, previous research has suggested that the association between the TPB and behavior may differ between more specific behaviors, such as discrete food choices, and broad categories of behaviors such as ‘healthy eating’ (e.g. Povey et al. (2000)). Second, from a practical standpoint, the clinical utility of studies examining discrete food choices is limited by the fact that positive dietary patterns are not adequately reflected through a single behavior. For example, consumption of foods, such as oats, which contain specific compounds (β -glucan) are associated with reducing serum cholesterol (Whitehead et al., 2014). However, in order to maintain optimum cholesterol levels, individuals must control several food choice behaviors, such as selecting foods rich in unsaturated, rather than saturated fats. In order to facilitate the necessary development of interventions based on the TPB that can impact upon health-promoting patterns of eating, a more nuanced examination of the literature is warranted. The primary aim of the current study is to examine the association between TPB variables and dietary patterns.

This review also has a number of secondary aims. Firstly, to facilitate the development of targeted interventions, we will also examine the impact of several moderator variables. We

will examine the impact of participants' age and gender, as dietary patterns have been found to vary by these characteristics both in Australia (Australian Bureau of Statistics, 2014) and worldwide (World Health Organisation, 2004). It is possible therefore that the relationships between the determinants of behavior specified in the TPB differ between males and females and between older and younger age groups. These differences have important practical implications for public policy initiatives.

Secondly, we will look at whether the associations within the TPB vary between different dietary patterns. Specifically, between those studies that examined the association between the TPB and a healthy dietary pattern, such as 'healthy eating', and those that examined the association with a restricted dietary pattern, such as 'eating a low fat diet'. These behaviors are distinguished by their prospective associations with important health outcomes. Research has demonstrated that adherents to healthy dietary patterns achieve lower waist circumference over time, whereas those attempting to restrict their diets face increased body weight (Ritchie et al., 2007; Savage and Birch, 2010). Furthermore, it is arguable that this latter category of behavior might be determined more by alternative psychological processes such as self-regulation or self-control (Johnson et al., 2012; Strack and Deutsch, 2004).

Finally, the current review will also examine the impact of important measurement artefacts not addressed by previous reviews. Although McEachan and colleagues looked at differences between the associations derived from TPB variables and objective, as opposed to self-reported behavior, studies using objective measurement of eating behavior are rare. The current review, therefore, will test for moderation for those TPB variables hypothesized to have a direct association with behavior, intention and PBC, and the type of self-report measure used. Specifically, we will examine whether the strength of association differs between studies that have employed *perceptions* of eating behavior versus those that have used less subjective methodologies such as food frequency questionnaires (FFQs) or food diaries (FDs). These dietary measurement tools report the frequency of food consumption and food intake (respectively) at time of consumption and may therefore represent a more valid assessment of actual behavior.

Methods

The design, conduct and reporting of this systematic review were informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA, Moher et al. (2009a)). As the study involved the secondary analysis of existing datasets, ethical approval was not sought. The funding organization for this study had no role in the collection, analysis and interpretation of data, or the right to approve the finished manuscript prior to publication. As the current study was conducted as part of a larger program of research, no study protocol was produced.

Selection criteria

In accordance with PRISMA, the PICOS (population, intervention, comparison, outcome, study design) approach was used to formulate the selection criteria. Studies, published in English, that explicitly applied the TRA or the TPB to dietary patterns, were included. Studies were not included where the dietary behavior was a de facto medical treatment, for example following a gluten-free diet. Studies that investigated the consumption of dietary supplements or where the target behavior was weight control, which can include activities such as physical activity, were also not included. Studies where participants were drawn from a **population** with a current or former psychiatric or medical condition, for example eating disorders or diabetes were excluded, as the psychological determinants of eating behaviors in these populations may not be generalizable to the community at large. Studies where participants received an **intervention** were also excluded as the receipt of intervention components could moderate the associations between variables. Studies were not selected based on any **comparison** between conditions. In keeping with theoretical models, TRA studies must at minimum have reported correlations between the following **outcomes**: attitudes and SN with intention, and intention with behavior. TPB studies must have additionally reported correlations between PBC, intention and behavior. Any quantitative **study design** was included provided the other inclusion criteria were met.

Study identification

Initial scoping searches were conducted by MO in PsycINFO and SCOPUS using the search terms *healthy eating, low fat, diet, theory of planned behavior, theory of reasoned action, attitude* and *intention* to inform the development of the formal search strategy and gauge the number of eligible studies. The results of these initial searches were then verified by a second author (MSMcD) using a formal search strategy (see Supplementary File 1) in PsycINFO,

MEDLINE (both via Ovid), Web of Science and CINAHL (via EBSCOhost). ProQuest Dissertations & Theses were also reviewed to locate unpublished studies (Rosenthal, 1979). Initial scoping searches were conducted in January 2013, with final searches conducted in October 2014. Reference lists of all studies selected for inclusion and the reference list of a key systematic review (McEachan et al., 2011) were also searched manually.

Two authors (MO & MSMcD) independently pre-screened one half of the database containing all titles and abstracts for possible inclusion. These studies were then selected for inclusion independently by the same two authors. Cohen's kappa was used to determine agreement between the two raters for selecting studies at the full-text screening stage. Agreement between the two raters was substantial ($\kappa = .802$, $p < .001$) (Landis and Koch, 1977). Data from each study was extracted primarily by one author (MO), the accuracy of which was checked by MSMcD. Any discrepancies were resolved by consensus.

Data extraction

In addition to correlation data and sample size, data on participant characteristics including both gender (the percentage of the sample that were female) and age (coded into three categories: ≤ 17 ; 18-29 and ≥ 30) were extracted. In addition the type of dietary pattern investigated in the study was also coded into one of two categories: a healthy dietary pattern, e.g. *eating a healthy diet*, *healthy eating* etc...; or a restricted dietary pattern, e.g. *eating a low-fat diet* or *watching your diet*. Finally, details of the measures used to assess the dietary pattern were coded as either a perception of eating behavior (e.g. over the past 2 weeks, how healthy has your eating been? Not at all healthy/ to very healthy) (Baker, 2001) or a more objective measure, such as a FFQ or FD. One study (Louis et al., 2007) used an objective measurement of behavior that was not comparable with other measures and was excluded from moderator analyses examining differences between behavior measures. Again, coding was completed independently by two authors (MO & MMD) and agreement was substantial ($\kappa = .673$, $p < .001$). Where necessary, the authors of the primary studies were contacted to obtain additional information about measures used. All data were extracted into a specially designed electronic database.

A number of studies included in each meta-analysis provided multiple effect sizes that were eligible for inclusion. The decision of how to handle these data was guided by Borenstein et al. (2009) and Sharma et al. (2009). In instances where multiple effect sizes were due to data

being presented for independent samples (e.g. based on gender or ethnicity) or where data were presented from two or more time points using the same participants, these were treated as individual data points for analysis. A small number of studies measured ‘higher-order’ TPB variables separately, e.g. *instrumental* and *affective* attitudes (Hagger and Chatzisarantis, 2005; Payne et al., 2004), *injunctive* and *descriptive* norms (Conner et al., 1996; Hagger and Chatzisarantis, 2005) and *self-efficacy* and *perceived controllability* (Armitage and Conner, 1999; Hagger and Chatzisarantis, 2005). As there was not enough data to test for differences between these variables, these were combined to yield a single effect size. Where multiple measurements of behavior eligible for inclusion in the meta-analysis were reported in the same study, each was retained provided they yielded distinct information. For example, we retained a measure of healthy eating behavior measured using a FFQ in addition to a perception of healthy eating behavior from Armitage and Conner (1999) but clustered data from Brouwer (2012) which had collected overlapping data using both a FFQ and a FD.

Data analysis

Calculation of the pooled mean effect size (r_+) was conducted using inverse-variance weighted random effects meta-analysis. The inverse-variance method, in which each included effect size is given a weight equal to the inverse of its variance, allows more weight to be given to more precise studies (Borenstein et al., 2009). Random-effects meta-analysis was used as significant heterogeneity between effect sizes was expected due to variation in, for example, settings, participants and the methods used to measure variables (Borenstein et al., 2009). Additionally, use of random-effects meta-analysis allows the results of the meta-analysis to be generalized beyond the included studies (Hedges and Vevea, 1998). We also estimated the heterogeneity across studies, using both the Q (a significant result indicates significant heterogeneity (Borenstein et al., 2009)) and I^2 (values of 25%, 50% and 75% indicate low, moderate and high heterogeneity respectively (Higgins et al., 2003)) statistics. To test for moderation we employed the protocol for random effects meta-regression recommended by Borenstein et al. (2009) with the correlation between TPB variables and intention or behavior as the criterion variable, the moderator as the predictor variable and studies being weighted by their inverse variance weights. All analyses were performed using Comprehensive Meta-Analysis (CMA) Version 3.0 (Borenstein et al., 2014).

Results

Search results

The electronic search strategy retrieved 10,238 unique records. A further five were identified through screening the reference lists of a related meta-analysis (McEachan et al., 2011) and 31 through screening the reference lists of included articles. Some of these studies were selected based on different search criteria and will be reviewed elsewhere. In total, 16 journal articles and six dissertations met the inclusion criteria. Data from two studies were reported in more than one article (Nejad, 2005; Nejad et al., 2004) and (Hagger and Chatzisarantis, 2006; Hagger et al., 2006a, b). Relevant data were extracted from either article as appropriate. Nineteen studies were therefore included with a total n of 6117. Full details of the screening process can be seen in the PRISMA Flow-Chart (Figure 1). A list of all included studies can be found in Supplementary File 2.

Figure 1: PRISMA flow chart

Description of included data

Details of the variables extracted from each study and entered into meta-analyses can be found in Supplementary File 3. Most studies were conducted in the UK (n=8), followed by the USA (n=5) and Australia (n=2) with the remainder conducted in Canada, the Netherlands Norway and Thailand (all n=1). Sample sizes ranged between 77 and 764. Included articles were published between 1990 and 2012. Most studies (n=17) examined the association between the TPB and behavior with only two examining the TRA.

Overall association of TPB variables with intention and dietary patterns

Table 1 summarizes the random-effects average correlations between TPB variables across studies. TPB variables were found to have medium to large associations with both intention and behavior. Attitudes had the strongest association with intention ($r_+ = 0.61$) followed by PBC ($r_+ = 0.46$) and SN ($r_+ = 0.35$). The association between intention and behavior was $r_+ = 0.47$ and between PBC and behavior was $r_+ = 0.32$. Forest plots for each association can be found in Supplementary File 4.

Because a certain amount of variation in observed effect size is to be expected we conducted tests to determine if the true effect size varies from study to study. Both the Q - and I^2 -statistics revealed significant heterogeneity for each effect size (see Table 1) supporting the use of meta-regression to search for moderators.

Table 1: Random-effects average correlation and heterogeneity statistics for TPB associations and dietary patterns

Association	<i>n</i>	<i>k</i>	r_+	CI	Q	I^2
Attitude-intention	6117	19	0.61	0.54-0.68	341.72***	94.73
SN-intention	6117	19	0.35	0.27-0.42	193.75***	90.71
PBC-Intention	5926	18	0.46	0.36-0.55	374.09***	95.46
PBC-Behavior	5554	22	0.32	0.24-0.40	234.78***	91.06
Intention-Behavior	6417	24	0.47	0.37-0.56	563.62***	95.92
<i>n</i> = number of participants, <i>k</i> = number of effect sizes included in the analysis, CI = 95% confidence interval, Q and I^2 = tests of heterogeneity, r_+ = random effects average correlation, *** $p < .001$.						

Moderator analyses: participant characteristics

Four of the included studies included participants with a mean age of less than or equal to 17, seven included participants aged 18-29 and eight included participants aged 30 or above. The proportion of female participants in each sample ranged between 0 and 100% (see

Supplementary File 3). Participants' age moderated the PBC-behavior association ($\chi^2(2)=11.40, p<0.01$), accounting for 39% of the between-study variance. Studies in which participants had a mean age of less than or equal to 17 reported a significantly higher correlation ($r_+ = 0.59$) than those in which participants were aged 18-29 ($r_+ = 0.24$) or 30+ ($r_+ = 0.35$). No other significant differences were found. Table 2 shows the breakdown of mean effect sizes by participants' age. There was no evidence that gender moderated any of the associations within the TPB.

Table 2: Random-effects average correlation and heterogeneity statistics by age of participants

Association	≤17				18-29				≥30			
	<i>n</i>	<i>k</i>	r_+	I^2	<i>n</i>	<i>k</i>	r_+	I^2	<i>n</i>	<i>k</i>	r_+	I^2
Attitude-intention	1359	4	0.58	97.38	1833	7	0.68	87.52	2925	8	0.56	90.97
SN-intention	1359	4	0.41	53.58	1833	7	0.38	93.74	2925	8	0.28	88.46
PBC-Intention	1168	3	0.53	98.96	1833	7	0.45	70.48	2925	8	0.29	94.97
PBC-Behavior	418	2	0.59	97.24	1852	11	0.24	74.24	3284	9	0.35	86.52
Intention-Behavior	1281	4	0.36	98.61	1852	11	0.53	94.52	3284	9	0.44	91.46
<i>n</i> = number of participants, <i>k</i> = number of effect sizes included in the analysis, CI = 95% confidence interval, I^2 = tests of heterogeneity, r_+ = random effects average correlation.												

Moderator analyses: Type of dietary pattern

Included articles were roughly evenly split between those examining healthy dietary patterns (n=10) and those examining restricted dietary patterns (n=9). Table 3 shows the breakdown of mean effect sizes by dietary pattern, which was not found to moderate any of the associations within the TPB.

Table 3: Random-effects average correlation and heterogeneity statistics by type of dietary pattern

Association	Healthy eating pattern				Restricted eating pattern			
	<i>n</i>	<i>k</i>	<i>r</i> ₊	<i>I</i> ²	<i>n</i>	<i>k</i>	<i>r</i> ₊	<i>I</i> ²
Attitude-intention	3034	10	0.56	93.59	3083	9	0.66	95.33
SN-intention	3034	10	0.34	67.72	3083	9	0.35	95.16
PBC-Intention	2843	9	0.50	97.11	3083	9	0.42	89.13
PBC-Behavior	2398	8	0.39	94.17	3156	9	0.27	81.85
Intention-Behavior	3261	13	0.40	96.02	3156	11	0.55	92.88
<i>n</i> = number of participants, <i>k</i> = number of effect sizes included in the analysis, CI = 95% confidence interval, <i>I</i> ² = tests of heterogeneity, <i>r</i> ₊ = random effects average correlation.								

Moderator analyses: method used to measure behavior

A total of nine studies reported data on participants' perceptions of their eating behavior only; eight used less subjective measures; and the remaining two reported data from both types of measure (see Supplementary File 5). The type of behavior measure used moderated the intention-behavior association ($B=0.37$ [95% CI: 0.17 – 0.57], $p<0.001$) accounting for 42% of the between-study variance. Studies that recorded a perception of eating behavior reported a significantly higher intention-behavior association ($r_+ = 0.61$) than those using a less subjective measure ($r_+ = 0.33$). There was no evidence of moderation for the PBC-behavior association (see Table 4).

Table 4: Random-effects average correlation and heterogeneity statistics by method used to measure behavior

Association	Less subjective measure				Perception of eating behavior			
	<i>n</i>	<i>k</i>	<i>r</i> ₊	<i>I</i> ²	<i>n</i>	<i>k</i>	<i>r</i> ₊	<i>I</i> ²
PBC-Behavior	2278	8	0.25	16.82	3023	12	0.39	93.54
Intention-Behavior	3141	10	0.33	88.43	3023	12	0.61	94.71
<i>n</i> = number of participants, <i>k</i> = number of effect sizes included in the analysis, CI = 95% confidence interval, <i>I</i> ² = tests of heterogeneity, <i>r</i> ₊ = random effects average correlation.								

Discussion

To our knowledge, the current study is the first to estimate the associations between the TPB and dietary patterns. Intentions were most strongly associated with attitudes, followed by PBC and SN. Behavior was most strongly associated with intention followed by PBC. These findings are broadly in line with those reported by McEachan et al. (2011) suggesting that these associations might be similar across a range of dietary behaviors. The current review provides further novel information with regard to the identification of important moderator variables. Although in general associations were robust to the impact of moderators, the key associations between PBC, intention and behavior were found to differ significantly based on variables with important practical and methodological implications.

Moderation by participant characteristics

Participants' age was found to moderate associations within the TPB, with PBC being more strongly associated with behavior for those participants who were aged 17 or younger compared to older age groups. According to the TPB, PBC influences behavior directly to the extent that it reflects actual control (Ajzen and Madden, 1986). It may be that older age groups have inaccurate perceptions of control over their dietary patterns compared to younger age groups, possibly due to their dietary patterns being more ingrained and driven by habit (Ouellette and Wood, 1998). This contrasts with previous work however. McEachan et al. (2011) found PBC to have *stronger* associations with intentions in older compared to younger age groups, a trend not apparent here. Elsewhere, it has been suggested that the TPB may be *less* likely to predict consumption behaviors, such as dietary patterns, in younger age groups due to the fact that they are more likely to live at home with less control over what they consume (Cooke et al., 2014; Kothe and Mullan, 2014). Although the current finding is tempered by the fact that there were only two studies contributing to this younger age category, the moderation of TPB variables by age within dietary patterns requires further examination.

We did not find any evidence that associations were moderated by participants' gender. This is in spite of research suggesting that men and women differ in their dietary patterns. For example, recent research from Australia showed that men were more likely to consume unhealthy foods such as soft drinks or burgers than women (Australian Bureau of Statistics, 2014). Previous research has also found that associations in the TPB are moderated by gender for snack food (Branscum and Sharma, 2014) and fruit and vegetable consumption (Lien et

al., 2002). It is possible that differences by gender in the predictors of consuming specific foods are masked when overall patterns of consumption are considered, but again, this is a matter for further empirical work.

Moderation by type of dietary pattern

We also found no evidence that associations in the TPB were moderated by the type of dietary pattern investigated. Theoretically, one might have expected that a rational model of behavior such as the TPB would better predict adherence to healthy dietary patterns than more restricted patterns involving avoiding certain foods or limiting consumption. We hypothesized that this latter dietary pattern might be governed more by alternative psychological processes such as self-regulation or self-control (Johnson et al., 2012; Strack and Deutsch, 2004). However, this does not appear to be the case based on the current analysis. If anything, given the trend towards *stronger* associations between intentions and behavior for restricted dietary patterns, it is possible that the direction of our original hypothesis was incorrect, and that these behaviors may be under *greater* intentional control than healthy eating. Against this, those studies examining restricted dietary patterns were more likely to report data from participants' perceptions of their eating behavior (see Supplementary File 5), meaning that this trend could be confounded. Alternatively, it may be that participants don't distinguish between 'healthy eating' and 'dieting', as has been demonstrated in adolescents (Stevenson et al., 2007).

Moderation by method used to measure behavior

We found that the intention-behavior association was significantly moderated by the type of measure used to record behavior. There are three possible explanations for this finding. First, the higher average correlation evident in those studies that recorded participants' perceptions of their eating behavior may be due to these measures being matched more closely with the intentions based on the '*principle of compatibility*'. The principle, which according to Ajzen & Fishbein (1977) must be adhered to in order to maximize the predictive power of cognitive antecedents of behavior, states that two measures of a given disposition can be considered compatible with each other so long as their *target*, *action*, *context* and *time* elements are assessed at *identical* levels of generality and specificity. This is likely to be more easily achieved using researcher-designed measures targeting participants' perceptions, compared to less subjective measures assessing the consumption of specific foods. Second, for those studies that used less subjective measures of behavior, it may be that participants' and

researchers' perceptions of what comprised the specific dietary pattern did not match. Only half of those studies that reported using complex measures of behavior reported that they provided participants with a definition of their targeted behavior (see Supplementary File 5). Finally, based on the assumption that more complex measures of behavior give a more accurate estimate of *actual* behavior, it may be that the lower value provides a more accurate estimate of the true intention-behavior association. Previous reviews (Armitage and Conner, 2001; McEachan et al., 2011) have demonstrated that the intention-behavior association is lower for objective, compared to self-report measures. The current review demonstrates that even within self-report measures of behavior, an important gradient may also be evident that is worthy of further examination (Sharma et al., 2009).

Strengths and limitations

Strengths of the present study include the broad search strategy, targeting both published and unpublished research, the rigorous screening and selection process and the use of established criteria (Moher et al., 2009b) to guide the design, conduct and reporting of the meta-analysis. It is worth noting, however, that despite the inclusion of a sample of studies that were largely homogenous, reported heterogeneity remained high for all associations. This indicates the presence of other moderators not accounted for here. Furthermore, our review and meta-analysis employed a relatively small sample of studies, which may have limited our ability to detect significant differences in moderator analyses. Even with this small sample, however, we did find evidence of moderation for key associations between PBC, intention and behavior that have important practical and methodological implications.

Practical implications

Understanding the drivers of behavior in relation to dietary patterns is an invaluable resource for health practitioners, manufacturers and policy makers. By identifying the key influences, there is an opportunity to work through these channels to encourage consumption of foods that are nutritious and healthy to help build healthy communities. Given the medium-to-large mean associations evident in the current analyses, it is suggested that the TPB may provide a solid foundation for those seeking to increase adherence to health-promoting dietary patterns. This recommendation, however, must be accompanied by some important caveats. First, the results indicate that individuals' perceptions of their dietary intake may be prone to bias, meaning that the reported associations between cognitive variables and behavior may be

overestimated. Researchers should be careful to include more objective measures of eating, such as FFQs when designing future studies.

Following on from this, a fundamental issue associated with healthy dietary patterns is whether participants understand what actually constitutes such behaviors. Participants may have intended to eat healthily and followed this pattern, but the measurement of behavior was evaluated according to researcher-defined criteria, which may have been different. As an extension to designing interventions targeting participants' cognitions, it may also be pertinent for researchers and intervention designers to provide information regarding, for example, national dietary guidelines in order to embed the concept of healthy eating behavior in participants.

Finally, whilst the current findings are informative, and provide valuable information for which variables intervention designers could target in interventions, ultimately they do not allow us to judge the *utility* of the TPB. The main two reasons for this are: (a) the relationships suggested by correlational data do not always match those uncovered in experimental studies, e.g. small effects in correlational analyses do not necessarily imply small effects in experimental studies (Sheeran et al., 2014); and (b) such evidence leaves open the possibility that the relationship is spurious and that an unknown, unmeasured variable has a causal impact on both intention and behavior. Clearly, experimental research aiming to facilitate a change in dietary patterns targeting TPB variables is warranted.

Conclusions

Adhering to health promoting dietary patterns is vital, not only to provide adequate nutrition for our bodies, but also to reduce the risk of developing non-communicable diseases that contribute most heavily to mortality worldwide. Our main finding is that TPB variables have medium to large associations with both intention and dietary patterns and may therefore provide program designers with a guide for designing effective interventions. The results further suggest that it may be worthwhile for those who wish to develop targeted interventions to focus on PBC for younger compared to older age groups. Finally, given the significant moderation of the key intention-behavior association by the type of behavior measure used, the value of further research testing the association between TPB variables and behavior measured using more objective measures of food consumption, linked to evidence-based dietary guidelines, is clearly justified.

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Conflict of Interest Statement

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