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DEFINING WHAT WORKS IN TAILORING: A META-ANALYSIS OF COMPUTERTAILORED INTERVENTIONS FOR HEALTH BEHAVIOR CHANGE

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Abstract

Objective—Computer-tailored interventions have become increasingly common for facilitating improvement in behaviors related to chronic disease and health promotion. A sufficient number of outcome studies from these interventions are now available to facilitate the quantitative analysis of effect sizes, permitting moderator analyses that were not possible with previous systematic reviews.

Method—The present study employs meta-analytic techniques to assess the mean effect for 88 computer-tailored interventions published between 1988 and 2009 focusing on four health behaviors: smoking cessation, physical activity, eating a healthy diet, and receiving regular mammography screening. Effect sizes were calculated using Hedges *g*. Study, tailoring, and demographic moderators were examined by analyzing between-group variance and meta-regression.

Results—Clinically and statistically significant overall effect sizes were found across each of the four behaviors. While effect sizes decreased after intervention completion, dynamically tailored interventions were found to have increased efficacy over time as compared with tailored interventions based on one assessment only. Study effects did not differ across communication channels nor decline when up to three behaviors were identified for intervention simultaneously.

Conclusion—This study demonstrates that computer-tailored interventions have the potential to improve health behaviors and suggests strategies that may lead to greater effectiveness of these techniques.

MESH Keywords

behavioral research; exercise; smoking cessation; diet therapy; behavioral medicine; mammography; telemedicine

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Introduction

Health behaviors account for an estimated 60% of the risk associated with chronic illnesses such as diabetes, cardiovascular diseases, and some cancers (Institute of Medicine, 2001). With chronic illness responsible for the majority of deaths in the United States (Centers for Disease Control, 2008), effective strategies must be developed and disseminated for improving health-related behaviors on a population level. Computer-tailored interventions have become an increasingly common strategy for altering health risk behaviors such as tobacco use, poor diet, and lack of exercise that are linked to chronic disease. While early computer-tailored interventions relied largely on print materials as a communication channel, with more recent advances they can readily be provided via personal computer or even mobile phone, further reducing their cost and expanding their availability. Tailored messages are thought to foster behavior change by providing personally relevant feedback. For instance, a program could assess an individual's self-efficacy to quit smoking and suggest specific ways to increase confidence for dealing with the smoking cues they identified as most difficult.

As methods of computer tailoring have developed, numerous variations on the concept of tailoring have been employed in research trials, differing across number of contacts, communication channel, theory, number of contacts, and other intervention options. Such design decisions have usually been based on the assumption that each would contribute to the efficacy of an intervention, yet little research has compared these potential moderators of treatment efficacy across studies. These options have also led to confusion in distinguishing computer-tailored from computer-delivered interventions. While computer-delivery is a type of communication channel (such as printed letters), "computer-tailoring" is a method of assessing individuals and *selecting communication content* using data-driven decision rules that produce feedback automatically from a database of content elements. Computer tailoring is thus a form of tailored communications which involve a "combination of strategies and information intended to reach one specific person based on characteristics that are unique to that person, related to the outcome of interest, and derived from an individual assessment" (Kreuter and Skinner, 2000). This meta-analysis focuses on interventions that tailored feedback to individual users by means of computer algorithms, regardless of whether the feedback was delivered via print, telephone, or computer terminal.

Prior reviews of tailoring have drawbacks that limit their utility for advancing the effectiveness of this methodology. Reviews that focus solely on one behavior such as mammography (Sohl, 2007), smoking (Strecher, 1999), or nutrition (Brug, et al., 1999) may confuse effects of computer-tailoring with behavior-specific findings. Those that examine a specific intervention medium such as interactive computer (Norman, 2007, Portnoy, et al., 2008) or print (Noar, et al., 2007) limit tailoring to a single communication channel. Finally, those that have not employed meta-analytic data analysis methods (Kroeze, et al., 2006, Ryan and Lauver, 2002, Skinner, et al., 1999, Strecher, 1999) succumb to the drawbacks of significance testing and are limited in their ability to analyze moderators. This study extends and builds upon the most comprehensive meta-analytic review to date (Noar, et al., 2007) by examining both print and computer-delivered interventions, by modeling weighted group variance for statistical tests, and by systematically examining publication bias and study quality as is presently recommended (Lipsey and Wilson, 2001). Unlike past reviews, this meta-analysis also examines the effects of computer-tailored interventions across multiple outcome time points and examines the efficacy of employing dynamic tailoring (assessing intervention variables prior to each feedback) versus static tailoring (providing one baseline assessment on which to base all successive feedbacks), which are important analyses for informing future intervention design.

The present study accounts for these additional moderators and reports the efficacy of computer tailoring in facilitating health-related behavior change for smoking cessation, physical activity, healthy dietary practices, and regular mammography screening across multiple outcome time points. We hypothesize that non-engagement in each behavior as a participation criterion and comparison to assessment-only control groups will be related to larger effect sizes (Tunis, et al., 2003). Based on previous findings suggesting differences in study design, we also expect that studies completed outside of the United States (Noar, et al., 2007), and those lower study quality ratings (Moher, et al., 1998) will show larger effects. Additionally, we expect that interventions provided for multiple behaviors simultaneously will show comparable effect sizes to those that concentrate on one behavior alone (Prochaska, et al., 2008) and that dynamic tailoring will not differ from static tailoring (Heimendinger, et al., 2005, Strecher, et al., 2005). As demographic characteristics are often controlled for in randomization, we predict that age, gender, and minority representation will not be related to effect size.

Methods

Search strategy

A combination of search methods was used to locate all published and in-press studies that employed a tailored intervention. The electronic databases PsycInfo, PubMed, CINAHL, and the Cochrane library were searched for studies using following terms: “(tailor*) and (compute* OR feedback OR individualized)”, “expert system”, “e-health AND (tailor* OR feedback OR individualized)”. Reference lists from published studies were examined, and authors were contacted for additional information. Electronic databases were then re-searched for articles published by authors previously identified to locate studies that may have employed similar techniques.

Selection criteria

The search was inclusive of studies published from 1988 (the year of the first tailored feedback study) to March 2009. Studies selected for analysis met the following criteria: a) were “computer-tailored” in that they used computers to choose individual feedback based on decision algorithms; b) provided the intervention primarily via communication channels that did not use live counselors; c) included a non-tailored comparison group; and d) reported sufficient statistical information to calculate effect size (e.g. means, standard deviations, odds ratios, t- and p-values). The final analysis included smoking cessation, physical activity, dietary practices, and mammography screening because the largest number of studies have been completed focusing on these behaviors, thereby limiting heterogeneity and enabling stable comparisons across behaviors.

Outcome selection

As has been suggested for improving the interpretation of clinical trial data (Thompson and Schoenfeld, 2007, Tunis, et al., 2003), the minimal intervention (usually informational pamphlet; see Table 4), was chosen as the reference group for effect size calculation over assessment-only control groups where possible. When studies reported results at more than one time point, the final time point was used, which ensures independence of data and is consistent with procedures used by other reviews (Higgins and Green, 2009, Lancaster and Stead, 2006). For longitudinal analysis, effect sizes were grouped into discrete categories by final outcome time point from baseline with each study contributing no more than one effect size. We also controlled for intervention length by regressing months since intervention completion on effect size.

Effect size determination

We employ Hedges *g* as the effect size (*ES*) statistic. Hedges *g*, as defined by Borenstein et al. (2009), is a derivation of the mean difference (*d*) effect size that uses a pooled variance component and uses a correction factor (*J*) for underestimation of the population standard deviation such that

$$g = d \times J \quad \text{(eq. 1)}$$

where

$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}}} \quad \text{(eq. 2)}$$

and

$$J = \left(1 - \frac{3}{4df - 1}\right) \quad \text{(eq. 3)}$$

To combine outcomes with continuous and dichotomous formats, the odds ratio was transformed to a standardized mean difference (Lipsey and Wilson, 2001). Each effect size was weighted by its inverse variance weight in calculating mean effect sizes.

Variance modeling

Random and fixed effects estimates were calculated. A fixed effects model was employed for moderator analysis because this model increases statistical power for detecting heterogeneity; a random effects estimate assumes additional variance beyond the set of studies and facilitates generalizability of results. Variability of the variance component was tested with the *Q* test, the significance of which indicates that additional variance beyond that expected for the given *N* exists in the scores and implies the existence of moderators.

Moderator analysis

Categorical moderators were examined using a test appropriate for meta-analysis that employs weighted data and compares within and between groups heterogeneity (Lipsey and Wilson, 2001) using the *Q* statistic. Meta-regression was employed for analysis of continuous moderators using a necessary correction for standard errors and statistical test values (Biostat, 2006). With a sample size of 10 or more studies (the case for most comparisons in the present study), statistical power for detecting differences between groups was sufficient.

Sources of bias

If insufficient information was reported for effect size calculation, the study was excluded, but if the study indicated that the effect was simply “nonsignificant” it was included with the effect size entered as zero (which was needed only for one outcome). Mean effects were assessed for degree of publication bias using two techniques: Orwin’s fail safe N and trim and fill. Orwin’s fail-safe N calculates the number of studies with a null effect size needed to reduce the overall effect to clinical nonsignificance. Clinical significance was set to $g = 0.10$ ($OR = 1.18$), which would represent a difference in success rates about five percentage points higher in the treatment vs. control group, a minimum assumed to be a meaningful effect in population-based interventions (Rossi, 2003). Trim and fill is a technique developed by Duval and Tweedie

(2000) that assesses the symmetry of a plot of effect size by sample size (funnel plot) under the assumption that when publication bias exists, a disproportionate number of studies will fall to the bottom right of the plot. This technique determines the number of asymmetrical outcomes, imputes their counterparts to the left, and estimates a corrected mean effect size.

Coding and reliability

The primary author and trained master's level graduate student conducted the initial literature search and independently selected studies for inclusion. A coding manual was developed based on a prior meta-analysis of health behavior interventions (Hall and Rossi, 2008). To ensure data quality, a random subset of half the studies were coded by a trained masters-level graduate student and discrepancies resolved. In addition, the primary author coded all studies twice as a further check. Studies were assessed for quality using a 22-point coding scheme based on the CONSORT (Boutron, et al., 2008) and QUOROM guidelines (Moher, et al., 1999) (see Table 5). The primary database was created using the Comprehensive Meta-Analysis software package (Biostat, 2006).

Results

Search Results

The initial search retrieved 1,724 references. Of 173 potential studies that described an intervention, 85 were excluded (see Table 6). Of 13 unique behaviors intervened upon, only four were represented by a sufficient numbers of studies (at least 10) to include for analysis. These were smoking cessation (k = 32), dietary fat reduction (k = 26), increasing fruit and vegetable intake (k = 25) physical activity (k = 25), and mammography screening (k = 12). In sum, 88 unique studies and effect sizes were used to compute the overall effect size with 119 effect sizes in total included for behavior-specific analyses representing 106,243 participants (see Table 4).

Table 1 summarizes study attributes. Most studies used a proactive (vs. reactive) recruitment strategy that individually reached out to participants (70.4%), and of those, 33.0% used random sampling to identify the study population. Interventions were mainly delivered at home (81.8%), using print (75.0%) and computer (21.6%) communication channels. Medical institutions (38.6%), printed advertisements (such as in newspapers) (17.1%), and worksites (12.5%) were the most popular recruitment approaches. The majority of studies were conducted in the United States (72.7%), with 21.6% in Europe and the rest in Australia and New Zealand. Studies were characterized by moderate to high recruitment (61.4%, range = 9.1–98.0%) and retention rates (74.4%, range = 33.0–99.0). The average age of participants was 41.8 years (range = 12.1–74.9) and 69.4% were female (range = 17.0–100.0%). Studies recruited an average 23.2% of participants who identified as other than White with 10% being the median percentage of non-White participants.

Overall Mean Effect Size

The overall effect size for the 88 tailored interventions was g = 0.17 (95% CI = 0.14-0.19) using a fixed effects model and g = 0.17 using a random effects model (95% CI = 0.14-0.20). Orwin's fail safe N revealed that an additional 58 studies with null effects would be needed to reduce the overall effect size to a clinically nonsignificant outcome (g = 0.10). Trim and fill analysis for publication bias imputed eleven studies to the left of the mean, which would minimally reduce the fixed effect estimate to g = 0.15 (95% CI = 0.13-0.17) (see Table 2).

Effect Sizes by Behavior

Dietary Improvement—For dietary improvement behaviors, 26 studies reported dietary fat outcomes and 25 reported fruit and vegetable intake outcomes (see Table 4), which were analyzed separately. For dietary fat intake, the continuous variable of mean fat intake score was the preferred outcome (16 studies). Percent calories from fat (5 studies) and percent reaching Action or Maintenance stages (representing less than 30% of calories from fat) for fat reduction (5 studies) were used alternatively when fat intake scores were not reported (see Table 4). The mean effect size for dietary fat reduction was $g = 0.22$ (95% CI = 0.18-0.26), $p < .001$ (see Table 2).

Twenty-five studies assessed fruit and vegetable intake and reported results using three variables: a combined fruit/vegetable outcome (18 studies), separate fruit and vegetable outcomes (5 studies), and percent reaching Action or Maintenance stages for eating 5 fruits and vegetables (2 studies) (see Table 4). The combined measure was the preferred outcome and the mean of both outcomes was taken when fruit and vegetable consumption were reported separately. The mean effect size was $g = 0.16$ (95% CI = 0.10-0.21, $p < .001$) (see Table 2).

Physical Activity Promotion—The 25 studies focused on increasing levels of physical activity and reported a variety of outcomes, which were chosen in decreasing order of clinical importance: percent of participants reaching CDC physical activity criteria (10 studies), seven-day physical activity recall (11 studies), and percent increasing physical activity (4 studies) (see Table 4). The mean effect size was $g = 0.16$ (95% CI = 0.10-0.21, $p < .001$) (see Table 2).

Smoking Cessation—Studies reported smoking abstinence using various outcome measures including 24-hour, 7-day, 28-day, 10-week, 6-month, and 9-month point prevalence. Since 24-hour, 7-day, and 30-day point prevalence abstinence measures are highly correlated (Velicer and Prochaska, 2004) these outcomes were analyzed together to increase the number of included studies. Where studies reported more than one of these measures, 28-day abstinence was preferred (9 studies), followed by 7-day point prevalence (19 studies), and then by 24-hour point prevalence (4 studies) (Hughes, et al., 2003) (see Table 4). The mean effect for the 32 studies reporting point prevalence outcome was $g = 0.16$ (95% CI = 0.12-0.19, $p < .001$). Nine-month, six-month and 10-week sustained abstinence outcomes were analyzed separately to preserve similarly of measurement. Nevertheless, we calculated the mean effect for the 16 studies reporting prolonged abstinence measures and found a significant mean effect where $g = 0.24$ (95% CI = 0.20-0.31, $p < .001$).

Mammography Screening—Twelve studies reported the percentage of participants adherent to mammography recommendations. The mean effect size was $g = 0.13$ (95% CI = 0.08-0.18, $p < .001$).

Longitudinal Outcomes

Examination of effect size over time provides an important estimate of behavioral maintenance associated with tailored interventions. As shown in Table 2 and Figure 1, effects peak from 4-12 months post baseline with a mean effect size of $g = 0.20$, and while they decline after 12 months post-baseline, the mean *ES* at long-term follow-up ($g = 0.12$) remains statistically significant (95% CI = 0.08-0.16). To control for length of intervention, months since intervention completion were regressed on ES. A significant negative trend of decreasing effect size ($B = -0.006$, $p = .001$) was found, suggesting that after a year the average effect for computer-tailored interventions would decrease by an average of $g = 0.07$.

Moderator Analysis

Intervention characteristics—Number of intervention contacts was related to effect size (B = 0.01, p < .001) such that mean effect size increased by an average of g = 0.01 for every additional contact. Dynamic tailoring (i.e. iterative assessments and feedback) was associated with larger mean effect sizes (g = 0.19) than static tailoring (g = 0.14) p = .01 (see Table 2). Since some studies provided static feedback based on one baseline assessment at more than one time point, differences in mean effect size between numbers of contacts (1 vs. more than 1) of statically tailored materials was also assessed. Inclusion of more than one statically tailored communication was associated with larger effect sizes than use of only one contact (g = 0.20 vs. 0.13, p = .02). Interestingly, longitudinal examination of effect size trends for dynamic versus static tailoring (inclusive of multiple contacts) reveals a trend indicating that dynamic tailoring results in higher effects in three of four time point categories (see Figure 2 and Table 3). While effects for all interventions decrease over time, only the effect size for dynamic tailoring remains statistically significant at long-term follow-up past 12 months (g = 0.14), even though the time from final intervention to assessment was longer for dynamically tailored studies (5.3 months) versus statically-tailored studies (3.5 months).

In terms of communication channel (i.e. print, computer, telephone, etc), effect sizes ranged from 0.16-0.21 with no significant difference noted (p = .89). A trend was found for increasing effect sizes across studies that intervened on one (g = 0.15), two (g = 0.21), and three (g = 0.24) behaviors, but this trend did not continue with the one study at intervened on four behaviors (g = 0.12).

Recruitment Strategies—No differences were found between studies employing proactive (g = 0.18) and reactive (g = 0.17) recruitment strategies (p = .85). A nonsignificant trend (p = .10) was found favoring studies that recruited participants who were currently not engaging in a particular behavior (g = 0.18) versus studies that did not screen out participants who may be already engaging in the behavior (g = 0.15).

Demographic Moderators—Studies conducted in the U.S. (g = 0.18) did not differ from those based in other countries (g = 0.14), p = .12. When regressed on mean effect size, no significant relationships were found by age, proportion of non-White participants, and gender after controlling for the relationship between gender and behavior by excluding mammography studies (see Table 2).

Study Quality and Design—Study quality (B = 0.01, p = .07) and retention rate (B = 0.06, p = .33) were not related to mean effect size (see Table 2). Overall, 49 studies compared a tailored intervention to a minimal intervention and 39 compared tailoring to an assessment-only group, but effect sizes between study designs did not differ significantly (g = 0.18 vs. g = 0.15, p = .20).

Discussion

This study computed a mean effect size for 88 studies that provided computer-tailored feedback based on individual assessments using computer, print, or telephone communication channels. We also examined moderators that were hypothesized to influence the effects of tailored interventions. A significant effect size (g = 0.17) was found for tailored interventions averaged across four health behaviors. The overall effect for tailored interventions represents a small to medium-size effect for population-based interventions (Rossi, 2003) (where g = 0.15, 0.20, and 0.25 for small, medium and large effects) and a 36% increase (OR = 1.36) over the control conditions to which the interventions were compared. In addition, significant effects were found for each of the behaviors examined individually. It appears that systematic differences

in tailoring methods is an unlikely explanation for the range of effect sizes across behaviors since the same research groups conducted interventions for each behavior and many tailoring techniques were shared across groups. Other possibilities are base rates and differences in the nature of the behaviors. Population rates of mammography (the lowest effect size reported) are the highest (>66%) compared to the other behaviors, which may produce a ceiling effect. Each behavior also presents a unique set of barriers to adherence and it is difficult to make conclusions regarding the relative difficulty of changing distinct behaviors.

These data show that computer-tailored interventions would have clinically significant impact on rates of behavioral risk factors. First, in terms of smoking cessation, the average point prevalence abstinence was 20% at final follow-up versus 14% in the comparison group, a clinically significant absolute increase of 6% in quit rates, and a rate comparable to that observed with 4-8 individual in-person counseling sessions (Fiore, 2008). Second, for physical activity, 43% of participants receiving computer-tailored communications were adherent to physical activity recommendations (World Health Organization, 2002) at follow-up versus only 34% in the comparison groups. With up to 40% of people in industrialized countries not engaging in any regular physical activity (Bauman, et al., 2009), increasing rates of physical activity by the rate produced by these interventions would have an important impact on health outcomes. Third, since an estimated 27% of people eat five or more fruits or vegetables per day (Centers for Disease Control and Prevention, 2007), increasing this rate by the effect size found in this study for fruit and vegetable intake (*OR* = 1.36) would increase the absolute rate of fruit and vegetable consumption to 37%, a meaningful change that is highly recommended to prevent and control obesity and multiple chronic diseases (Centers for Disease Control and Prevention, 2009). Finally, for receipt of least bi-annual mammography screening, computer-tailored interventions resulted in 56% adherence versus 50% in control groups, an important difference given that a secular trend reflecting a reduction of 4% in mammography screening rates existed during the period in which most of these studies were conducted (Breen, et al., 2007).

In terms of moderators of effect size, dynamically-tailored interventions outperformed statically-tailored interventions, especially upon examination of longitudinal effects. The larger effect size for dynamically tailored interventions could be explained by increased number of overall contacts that dynamic tailoring necessitates, and indeed static tailoring with more than one contact showed similar effects (g = .20) compared to dynamic tailoring (g = .19). When examined longitudinally, however, greater intervention effects for dynamic tailoring as compared to static tailoring with multiple contacts were seen in three of four outcome time point categories (1-3, 4-6, and 13-24 months) and only dynamic tailoring remained significant at long-term follow up, an important finding in terms of intervention maintenance. These results suggest that more than just providing additional contact, updating feedback to reflect a person's changes may increase information relevance and depth of processing (Petty and Elster, 1981). The addition of systematic qualitative data as a complement to studies of dynamically tailored interventions would help to clarify the processes involved in this observed effect.

No significant differences were found by communication channel (print, computer, or automated phone). While conclusions cannot be drawn regarding automated phone intervention delivery with only three studies, the lack of difference between print and computer terminal-based feedback channels suggests that both channels can be effective means of health communication.

It also appears that intervening on up to three multiple behaviors at the same time does not negatively impact behavioral outcomes, with suggestion of a trend for larger effects as number of behaviors increased from one to three. Individual studies also support the feasibility of multiple behavior interventions (Vandelanotte, et al., 2008). The effectiveness of multiple

behavior change could reflect an underlying general health orientation that influences engagement in behaviors (Noar, et al., 2008, Prochaska, et al., 2008). Common change patterns have also been found across behaviors for both decisional balance (Hall and Rossi, 2008) and self-efficacy (Grembowski, et al., 1993) constructs, suggesting that similar principles can be applied to changing distinct behaviors.

In terms of study design characteristics, a nominally significant ($p = .10$) trend was found suggesting that including only participants not engaging in a behavior may mitigate intervention effects. It was also predicted that reactive recruitment would result in larger effect sizes under the assumption that participants responding to ads and actively volunteering would be more ready to change. This hypothesis was not upheld, possibly because studies using reactive strategies made efforts to recruit people who were less ready to change (Hageman, et al., 2005, Prochaska, et al., 1993). Results did not favor non-U.S based studies as previously found by Noar. Whereas their sample of studies conducted outside the U.S. used shorter follow up time points, which likely explained this difference, our samples were similar in that non-U.S. studies followed up at 8.9 months on average and U.S. studies did so at 9.3 months. Study quality was also not related to effect size, which may be due to restricted range for the measure given a standard deviation of 1.6 on the 22-point scale. Differences in effect size were not found for mean age, percentage of minority participants, or gender likely attributable to efforts in most studies to randomize by demographic characteristics.

Study Strengths and Limitations

This study has a number of strengths that enhance its contribution to the study of computer-tailored interventions. First, it is the most representative and current review of studies that employed computer tailoring. We included studies using three different communication channels and searched multiple databases drawing from over 20 years of research. While publication bias has been cited as a problem in meta-analysis, it is likely minimal given that almost all intervention studies were large-scale funded projects. The fail-safe N suggests that a large number of studies would be needed to lower the average effect size to clinical nonsignificance. Second, this study distinguishes tailoring methodology from communication channels as has not been done previously. Third, we employed well-established meta-analytic techniques for effect size estimation and moderator analysis. Finally, we conducted novel moderator analyses not covered in previous reviews, examining effect sizes across outcome time points, intervention channels, multiple behaviors, design characteristics, and study quality.

On the other hand, methodological considerations necessarily limit the conclusions able to be drawn from the present work. First, given that effects decrease after intervention completion, using the final assessment from each study may underestimate the potential of tailored-interventions. If participant contact can be maintained, intervention effects may be higher than found here. Second, this study reported primary analyses of computer-tailored interventions and more work is needed to examine the relationship between effect size and additional intervention variables. We are currently preparing an analysis that focuses on the utility of tailoring options such as tailoring using specific constructs, use of theory, depth of tailoring, cultural tailoring, etc. (Rimer and Kreuter, 2006).

Conclusion

The current analysis of computer tailoring indicates that this intervention technique can be effective for supporting health-related changes across a number of behaviors linked to chronic diseases. Dynamic tailoring using iterative assessment and feedback is an important intervention strategy, and print, telephone, and computer-based communication channels are

all effective for delivering intervention content. In addition, results demonstrate that multiple behaviors can be targeted simultaneously without hindering intervention effectiveness.

This study also highlights areas for improvement with regard to intervention design as well as study reporting. Regardless of tailoring method, intervention effects overall were found to decline after intervention completion, suggesting the need for innovative techniques to help participants maintain changes. In addition, while these programs produce clinically significant effects, little data is available as to whether the interventions themselves are being sustained, as would be necessary to decrease disease burden among populations. Further work needs to analyze their cost-effectiveness and possibly investigate methods for integrating these methods into clinical care systems in ways that they will be maintained over time and available to the populations that would most benefit from them (Stellefson, et al., 2008). In addition, few studies sufficiently reported methods for how assessments and feedback were integrated and no study examined or even mentioned graphic/visual and human factors design issues, which may be important moderators of effect in these communication modalities.

This study demonstrates that computer-tailored interventions have the potential to impact health behaviors to a meaningful extent and suggests strategies that may lead to greater effectiveness of these techniques. Further work is needed to improve intervention maintenance and to define specific mechanisms, such as content and depth of tailoring, that promote optimal effectiveness of computer-tailored interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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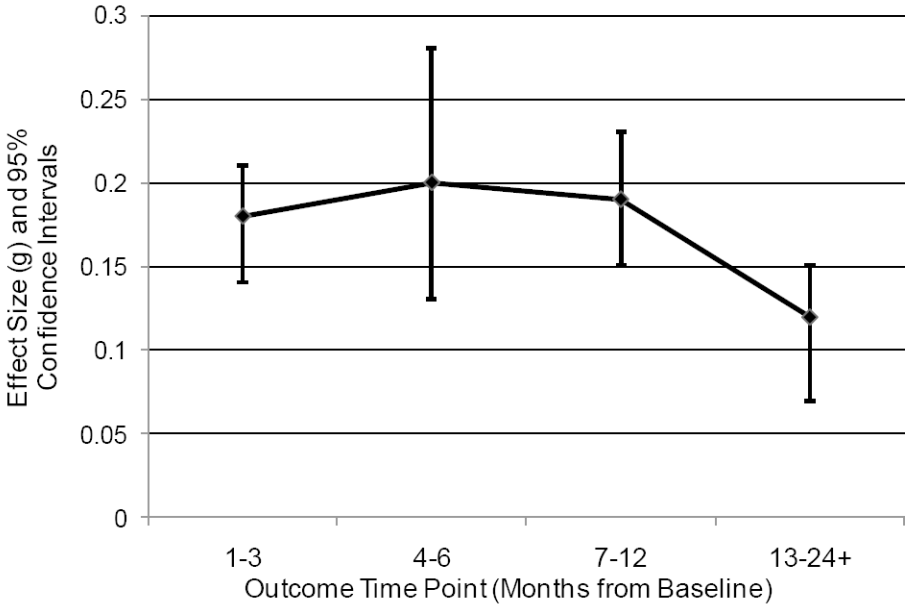

Figure 1.
Trends in effect size over outcome time point

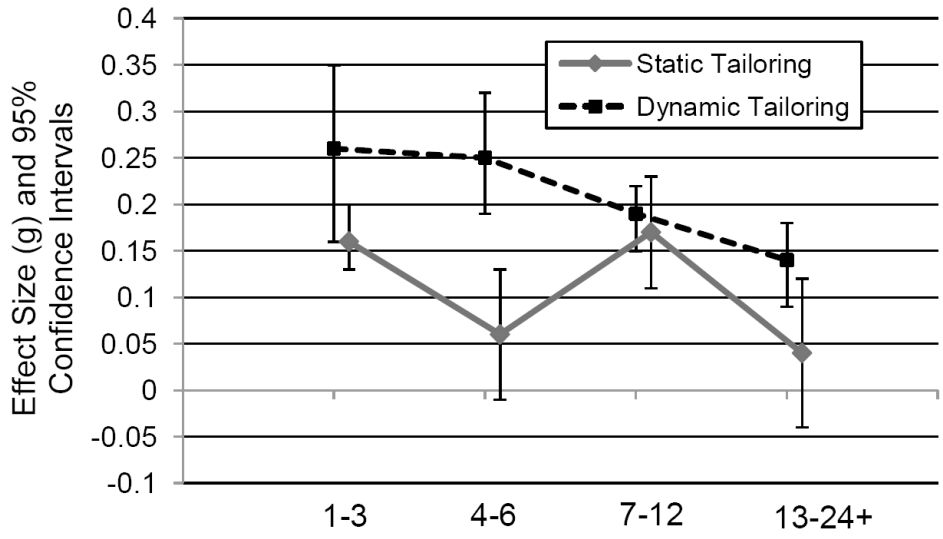

Figure 2.
Trends in effect size over outcome time point by tailoring method

Table 1

Study Attributes (Studies published 1988-2009)

Attribute	k	%
Recruitment Strategy		
Proactive	62	70.4
Reactive	26	29.6
Random Sampling	29	33.0
Delivery Site		
Home	72	81.8
Home + Clinic	1	1.1
Clinic	6	6.8
Store	1	1.1
School	4	4.7
University Lab	1	1.1
Worksite	2	2.3
Community Center	1	1.1
Intervention Method		
Computer	19	21.6
Print	66	75.0
Automated Phone	3	3.4
Recruitment Strategy		
Medical Clinic	18	20.4
HMO insurer lists	16	18.2
General Advertisements	15	17.1
Worksite	11	12.5
Random Dial or Mailing	8	9.1
School	8	9.1
Call in Center	6	6.8
Community Center	3	3.4
Church	2	2.3
Website	1	1.1
Country		
United States	64	72.7
Europe	19	21.6
Australia	4	4.6
New Zealand	1	1.1
Behaviors Intervened Upon		
One	65	73.9
Two	16	18.2
Three	6	6.8
Four	1	1.1
	Mean (SD)	**Median**

Attribute	k	%
Recruitment Rate (%)	61.4 (23.1)	68.0
Retention Rate (%)	74.4 (14.7)	75.0
Mean Age	41.8 (12.0)	41.1
% Female	69.4 (20.4)	67.3
% Minority	23.2 (30.5)	10.0

Table 2

Effect Sizes and Moderator Analyses (Studies published 1988-2009)

Moderator	*k*	*g*	95% CI	*p*
Mean Effect Size				
Fixed	88	0.17	0.14-0.19	< .001*
Random	88	0.17	0.14-0.20	< .001*
Homogeneity	Q (87) = 148.8, $p < 0.001$			
Health Behavior				
Smoking Cessation	32	0.16	0.12-0.19	< .001*
Dietary Fat Reduction	26	0.22	0.18-0.26	< .001*
Fruit/Veg	25	0.16	0.10-0.21	< .001*
Mammography	12	0.13	0.08-0.18	< .001*
Physical Activity	25	0.16	0.10-0.21	< .001*
Tailoring Method				
Static	51	0.14	0.11-0.16	.01
Dynamic	37	0.19	0.16-0.21	
Number of contacts (static tailoring only)				
1	34	0.13	0.09-0.17	.02
1+	18	0.20	0.15-0.24	
Recruitment Strategy				
Reactive	26	0.17	0.13-0.21	.85
Proactive	62	0.18	0.16-0.20	
Communication Channel				
Computer	19	0.16	0.12-0.21	.89
Print	66	0.17	0.14-0.19	
Automated Phone	3	0.21	0.01-0.42	
Longitudinal Effects				
1-3 months	27	0.18	0.14-0.21	.04+
4-6 months	16	0.20	0.13-0.27	
7-12 months	25	0.19	0.16-0.23	
13-24+ months	19	0.12	0.08-0.16	
Engagement in Behavior at Baseline				
No	49	0.18	0.15-0.22	.10
Yes	39	0.15	0.13-0.18	
Comparison Group				
Assessment Only	39	0.18	0.15-0.21	.19
Minimal Intervention	49	0.15	0.12-0.18	
Country				
U.S.	64	0.18	0.15-0.20	.12
Non-U.S.	24	0.14	0.10-0.18	
Number of Behaviors Intervened Upon				

Moderator	***k***	***g***	**95% CI**	***p***
1	65	0.15	0.13-0.17	.01
2	16	0.21	0.16-0.26	
3	6	0.24	0.18-0.31	
4	1	0.12	-0.04-0.29	
Demographics	***B***	***p***		
Mean Age	-0.01	.84		
% Female (excluding mammography)	-0.06	.27		
% Minority	0.03	.35		
Study Quality	0.01	.07		
Retention Rate	0.06	.33		
Publication Bias				
Orwin's Fail Safe N	58			
Trim and Fill	11 imputed to left of mean, g = 0.15 (0.13-0.17)			

*Indicates significance of mean effect size

+Final outcome with each study was included once to ensure independence of observations

Table 3

Comparison of Effect Sizes for Static and Dynamic Tailoring Method by Outcome Time Point (Studies published 1988-2009)

Time Point	Static			Dynamic			*p*-value*
	k	*g*	95% CI	*k*	*g*	95% CI	
1-3 months	30	0.16	0.13-0.20	9	0.26	0.16-0.35	.05
4-6 months	14	0.06	-0.01-0.13	17	0.25	0.19-0.32	< .001
7-12 months	13	0.17	0.11-0.23	23	0.19	0.15-0.22	.61
13-24 months	7	0.04	-0.04-0.12	14	0.14	0.09-0.18	.03

Mean intervention length was 4.5 months (range = 0-18).

*If studies reported outcomes at more than one time point, they were entered once into each category. Comparisons between static and dynamic methods are thus independent within time point category.

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Table 4

Description of Studies Included for Analysis of Effect Size (Studies published 1988-2009)

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Anderson, Winett, Wojcik, Winett, & Bowden, 2001	Diet[a,c]	464	Up to 15 dynamically feedbacks[+] or no treatment[*] delivered at grocery store	General population proactively recruited in person at grocery store	15	4	6	45.0	16
Armitage & Conner, 2001	Diet[b]	801	Behavioral feedback[+] or brochure[*]	Employees proactively contacted at worksite	1	1	5	64.5	15
Ausems, Mesters, van Breukelen, & De Vries, 2004	Smoking[h]	2,376	3 tailored letters[+], tailored letters plus in-school lessons, in-school lessons only, or assessment-only control group[*]	Vocational secondary school students in the Netherlands	3	2.5	18	75.4	16
Aveyard, Griffin, Lawrence, & Cheng, 2003	Smoking[g]	2,471	3 dynamically tailored feedbacks[+], counseling, brochure[*] or manual-only conditions	Random sample proactively recruited from medical clinic	3	6	12	50.0	16
Bastani, Maxwell, Bradford, Das, & Yan, 1999	Mammography[i]	902	Behavioral feedback + manual[+] or brochure only[*]	Proactive random digit dial of general population	1	1	12	84.0	15
Becona & Vasquez, 2001	Smoking[g]	300	6 weekly non- tailored pamphlets, 6 pamphlets plus 2 tailored letters[+], or manual only control group[*]	Respondents to advertisements in newspapers, radio, and local television	6	2	12	82.0	17
Block & Wakimoto et al., 2004	Diet[c]	481	One-time experience with tailored CD- OM[+], CD-ROM plus two reminder telephone calls, or a stress management CD-ROM control condition[*]	Respondents to fliers posted in state agencies serving low- income persons	1	1	2	98.0	18
Bock, Marcus, Pinto, & Forsyth, 2001	Phys Activity[j]	194	4 dynamically tailored letters and manual[+] or brochure only[*] delivered at home	Respondents to fliers and announcements	4	6	12	33.0	16

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Borland, Balmford, & Hunt, 2004	Smoking[g]	1,058	3 dynamically tailored letters[+] or brochure-only[*] delivered at home	Callers to cancer info line	5	12	12	70.0	17
Borland, Balmford, Segan, Livingston, & Owen, 2003	Smoking[g]	1,578	3 dynamically tailored reports[+], counseling calls, or manual-only[*] conditions delivered at home	Callers to cancer info line	3	6	12	76.6	17
Brug, Glanz, van Assema, Kok, & Van Breukelen, 1998	Diet[b,d,e]	762	2 dynamically tailored letters, tailored letter, or brochure-only[*] conditions delivered at home	Respondents to fliers and announcements	2	2	3	91.8	17
Brug, Steenhuis, van Assema, Glanz, & DeVries, 1999	Diet[b,d,e]	347	Tailored report[+] or behavioral feedback-only[*] delivered at home	Proactively recruited employees from worksite	1	1	2	91.0	12
Brug, Steenhuis, van Assema, & de Vries, 1996	Diet[b,d,e]	507	Tailored letter [+] or brochure[*] delivered at home	Proactively recruited employees from worksite	1	1	2	51.0	15
Bull, Jamrozik, & Blanksby, 1999	Phys Activity[L]	763	Tailored report[+], brochure[*], or assessment-only plus physician advice delivered at home and clinic	Proactively recruited patients from clinic list	1	1	12	57.0	17
Bull, Kreuter, & Scharff, 1999	Phys Activity[L]	272	Tailored report[+], personalized feedback, brochure[*] or assessment only delivered at home	Proactively recruited patients from clinic list	1	1	3	75.0	17
Burnett, Magel, Harrington, & Taylor, 1989	Diet[b]	77	Tailored letters[+] or informational brochure only[*] delivered at school	Proactively recruited students from high schools	3	3	3	99.0	12
Campbell & Bernhardt et al., 1999	Diet[c]	459	Tailored [+], culturally tailored bulletin, or assessment-only[*] conditions delivered at home	Proactively recruited from church attendees	1	10	12	82.0	16

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Campbell & Carbone et al., 2004	Diet[b,c]	410	Tailored interactive computer feedback[+] or assessment-only[*] condition delivered at clinic	Proactively recruited patients from clinic list	1	0	2	74.8	18
Campbell, DeVellis, Strecher, & Ammerman, 1994	Diet[b,c]	558	Tailored letter[+], brochure[*], or assessment-only conditions delivered at home	Proactively recruited patients from medical clinic	1	1	4	82.0	18
Campbell & Honess et al., 2004	Diet[b]	526	Tailored feedback or assessment-only[*] condition delivered via computer at clinic	Proactively recruited patients from medical clinic	1	1	3	72.0	17
Campbell & James et al., 2004	Diet[a,c] Phys Activity[j]	850	4 tailored newsletters[+] and targeted videotapes or lay health advisor (LHA) [*] conditions	Proactively recruited church attendees	4	9	12	69.0	19
Campbell & Tessaro et al., 2002	Diet[b,c] Phys Activity[k] Smoking[g]	859	2 dynamically tailored letters[+] or assessment-only[*] conditions delivered at home	Proactively recruited employees for worksite intervention	2	6	18	63.0	18
Cardinal & Sachs, 1995	Phys Activity[m]	113	Tailored letter[+] or behavior feedback[*] conditions delivered at home	Proactively recruited employees for worksite intervention	1	1	7	75.0	10
Champion & Skinner et al., 2002	Mammography[i]	1,390	Tailored letter[+], counseling calls, or assessment-only[*] conditions delivered at home	HMO members contacted via mail and phone	1	1	2	71.0	16
Champion & Skinner et al., 2007	Mammography[i]	1,245	Tailored letter[+], counseling calls, or assessment-only[*] conditions delivered at home	HMO members contacted via mail and phone	1	1	4	91.8	16
Clark & Rakowski et al., 2002	Mammography[i]	1,324	2 dynamically tailored letters[+], brochure[*], or assessment-only conditions delivered at home	HMO members contacted via mail and phone	2	6	20	77.0	16

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Curry, McBride, Grothaus, Louie, & Wagner, 1995	Smoking[g]	1,317	Tailored report +manual [+], tailored report +manual +call, or manual-only[*] conditions, delivered at home	Proactive random digit dial of general population	1	1	21	76.0	15
Curry, Wagner, & Grothaus, 1991	Smoking[g]	1,217	3 dynamically tailored letters[+] or brochure[*] delivered at home	Respondents to fliers and announcements	3	3	12	95.0	16
Delichatsios & Friedman et al., 2001	Diet[a,d] Phys Activity	298	Automated calls[+] or physical activity control[*] conditions delivered at home	HMO members contacted via mail and phone	11	6	6	50.0	18
Demark-Wahnefried & Clipp et al., 2007	Diet[a,c] Phys Activity[k]	543	Tailored mailed print materials[+] or nontailored mailed materials[*] delivered at home	Proactively recruited cancer survivors from registries via letters	7	10	12	95.6	21
DiNoia & Contento et al., 2008	Diet[c]	549	4 CD-ROM tailored feedback interventions[+] or assessment-only[*] conditions delivered at youth agencies	Students proactively recruited from after school programs	4	1	2	92.0	17
Dijkstra, 2005	Smoking[f]	202	Personalized feedback delivered through interactive computer[+] or brochure[*] delivered at university	Students proactively recruited through school	1	1	4	70.0	15
Dijkstra & DeVries et al., 1998	Smoking[g]	1,546	Self-efficacy and outcome tailored information[+], self-efficacy tailored information, outcome-tailored information, or no information[*] conditions delivered at home	Respondents to advertisements in newspapers in the Netherlands	1	1	14	64.0	15
Dijkstra, De Vries, & Roijackers, 1999	Smoking[g]	843	3 tailored letters, 1 tailored letter[+], manual-only[*] or assessment-only conditions delivered at home	Respondents to fliers and announcements	1	1	6	89.0	13
Elder & Ayala et al., 2006	Diet[b]	357	Tailored newsletters[+], or tailored letters	Proactive random digit dial of general population	12	3	12	79.0	17

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
			+counseling, or targeted brochure*, conditions delivered at home						
Etter & Perneger, 2004	Smoking[h]	2,934	4 dynamically tailored letters+, brochure* or assessment-only conditions delivered at home	Proactively recruited random sample of general population contacted by mail	4	12	24	82.2	12
Etter, 2005	Smoking[g]	11,969	Tailored feedback+ or information-only* conditions delivered through computer over Internet	Respondents to smoking cessation website	1	2	3	35.0	17
Frenn & Malin et al., 2005	Diet[a] Phys Activity[k]	132	Eight-session Internet/ video intervention in school+ or assessment-only* conditions	Students recruited via consent form sent to parents	8	1	1	77.0	15
Greaney & Riebe et al., 2008	Phys Activity[n]	1,274	Dynamically tailored letters+brief calls+manual+ or assessment-only* conditions delivered at home	Respondents to fliers and announcements	12	12	24	76.0	15
Haerens & Deforche et al., 2007	Diet[b]	307	Computer-tailored interactive intervention+ or assessment only* conditions	Students recruited from secondary school classes	1	1	3	91.0	18
Hageman & Walker et al., 2005	Phys Activity[k]	31	3 tailored+ or nontailored* online newsletters	Respondents to ads placed in newspapers	3	2	3	90.0	17
Heimendinger & Oneil et al., 2005	Diet[c]	3,402	4 dynamically tailored+, 4 tailored, 1 tailored letters, or brochure-only* conditions delivered at home	Proactively recruited callers to cancer info line	4	5	12	57.0	18
Irvine & Ary et al., 2004	Diet[b,c]	517	Tailored intervention at workstation+ or wait-list control* conditions	Employees recruited via advertisements/fliers	3	1	2	90.0	17
Johnson, Driskell, Johnson,	Diet[n] Phys Activity[n]	404	3 dynamically tailored letters + manual+ or assessment-only*	Proactive random digit dial of general population	3	6	18	58.0	14

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Dyment et al., 2006			conditions delivered at home						
Johnson & Paiva et al., 2008	Diet[n] Phys Activity[n]	1,277	4 tailored letters[+] or assessment-only[*] conditions delivered at home	Proactive random digit dial calls or respondents to advertisements	4	9	12	66.0	13
Jones & Edwards, 2003	Diet[n] Smoking[n]	1,029	Multiple tailored letters[+] or brief physician advice[*] conditions delivered at home and clinic	Respondents to posters in clinics and newspapers	12	12	12	77.7	16
King & Friedman et al., 2007	Phys Activity[j]	218	Tailored automated telephone feedback[+], tailored human advice, or health education group[*] conditions	HMO members contacted via mail and phone	15	12	6	86.7	18
Kosma, Cardinal, & McCubbin, 2005	Phys Activity[k]	151	4 tailored interactive website interventions[+] or assessment-only[*] conditions	Respondents to fliers and announcements	4	1	1	49.6	16
Kreuter & Strecher, 1996	Diet[b] Phys Activity[j] Mammography[i] Smoking[g]	1,317	Tailored letter[+], behavioral feedback or assessment-only[*] conditions delivered at home	Proactively recruited medical clinic patients	1	1	6	86.0	15
Kreuter & Sugg-Skinner et al., 2005	Diet[c] Mammography[i]	416 720	Tailored[+], culturally tailored letters, or assessment-only[*] conditions delivered at home	Proactively recruited medical clinic patients	6	18	18	71.8	16
Kristal, Curry, Shattuck, Feng, & Li, 2000	Diet[b,c]	1,459	Tailored letter+manual +brief calls[+] or assessment- only[*] conditions delivered at home	Proactively recruited HMO members	2	12	12	87.0	18
Kypri & McAnally, 2005	Diet[n] Phys Activity[j]	218	Web-based assessment and feedback[+] or assessment only[*] conditions delivered at school	Patients recruited from college health service	1	1	2	86.0	16

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Lennox & Osman et al., 2001	Smoking[h]	2,553	Tailored letter[+], personalized information or assessment-only[*] conditions delivered at home	Patients proactively recruited from medical clinic	1	1	6	78.1	15
Lipkus, Lyna, & Rimer, 1999	Smoking[h]	266	Tailored letter + advice + counselor call, tailored letter + brief advice[+], or advice-only[*] conditions delivered at home and clinic	Random sample of medical clinic patients	2	1	16	62.2	17
Lipkus, Rimer, Halabi, & Strigo, 2000	Mammography[i]	1,934	Tailored letter[+], counselor call, or reminder[*] delivered at home	Sample of HMO members	1	12	12	96.0	16
Lutz & Ammerman et al., 1999	Diet[c]	710	4 tailored letters[+], nontailored letters, or assessment-only[*] conditions delivered at home	Proactively recruited from random sample of HMO members	4	4	6	80.8	18
Marcus & Bock et al., 1998a	Phys Activity[m]	1,559	2 tailored letters[+] or brochure conditions delivered at home	Reactively recruited employees from worksite	2	1	3	73.0	16
Marcus & Napolitano et al., 2007	Phys Activity[k]	239	Telephone-based individualized feedback, print-based individualized feedback[+], or contact control[*] conditions	Reactively recruited employees via newspaper and workplace advertisements	14	12	12	85.4	17
McKay & King et al., 2001	Phys Activity[k]	65	8-week online tailored intervention[+] or internet information-only[*] conditions	Respondents to e-mail postings to diabetes specific UseNet groups, listserves, web sites, and on-line community groups	5	2	2	87.0	18
Meyer & Ulbricht et al., 2008	Smoking[h]	1,499	3 tailored letters[+], brief physician advice, or assessment-only[*] conditions	Proactively recruited patients in primary care clinics	3	6	18	61.9	16
Napolitano & Fotheringham et al., 2003	Phys Activity[k]	65	12 weekly tip sheets plus 3 months of access to an interactive web-based program[+] or assessment-	Employee respondents recruited from worksite advertisements	12	3	3	80.0	15

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
			only conditions* delivered at home						
Nitzke & Kritsch et al., 2007	Diet[c]	2,024	2 tailored reports plus newsletters+ or mailed non-tailored pamphlet* conditions delivered at home	Respondents to advertisements directed at low-income persons	4	6	12	62.0	19
Oenema, Tan, & Brug, 2005	Diet[b,d,e]	782	2 tailored feedback sessions delivered by CD-ROM+, brochure*, or assessment-only conditions delivered at home	Proactively recruited employees from worksite	2	1	1	79.0	15
Owen, Ewins, & Lee, 1989	Smoking[g]	208	4 tailored letters+, brochure*, or assessment-only conditions delivered at home	Respondents to fliers/announcements	4	1	9	88.0	13
Papadaki & Scott, 2005	Diet[d,e]	72	4 tailored dietary and psychosocial feedbacks+ or brochure* conditions delivered via internet	Respondents to advertisements in newsletters, flyers, postings on the worksites' Intranet and email	4	6	6	80.0	19
Patrick & Sallis et al., 2001	Diet[b,c] Phys Activity[k]	148	2 tailored feedbacks + follow up letters or calls+ or tailored feedback* only conditions delivered at clinic and home	Proactively recruited students from high schools	2	4	4	79.0	17
Peterson & Aldana, 1999	Phys Activity[k]	784	Tailored letter+, brochure*, or assessment-only conditions delivered at worksite	Proactively recruited employees from worksite	1	1	2	67.0	10
Pinto & Friedman et al., 2002	Phys Activity[j]	298	6 dynamically tailored automated calls+ or assessment-only* conditions delivered at home	Proactively recruited HMO members via mail and phone	6	6	6	79.8	18
Prochaska & Sallis, 2004	Phys Activity[k]	138	Tailored feedback provided via computer in school+ or assessment-only* conditions	Proactively recruited middle school students	1	1	3	99.0	14

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
Prochaska, DiClemente, Velicer, & Rossi, 1993	Smoking[f]	756	4 dynamically tailored letters[+], dynamically tailored letters + manual + counselor call, brochure[*], or manual conditions delivered at home	Respondents to fliers/announcements	4	6	18	70.0	12
Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001a	Smoking[g]	4,144	3 dynamically tailored mailed reports[+] or assessment only[*] conditions delivered at home	Proactive random digit dial of general population	3	6	18	67.0	15
Prochaska & Velicer et al., 2001b	Smoking[h]	1,447	3 dynamically tailored letters[+], dynamically tailored letters + manual, dynamically tailored letter + manual + counselor call, or assessment-only[*] conditions delivered at home	Proactively recruited HMO members via mail and phone	3	6	18	62.9	14
Prochaska & Velicer et al., 2005	Diet[n] Smoking[f] Mammography[i]	5,407	3 dynamically tailored letters + manual[+] or assessment-only[*] conditions delivered at home	Proactively recruited patients from medical clinic	3	12	12	75.0	16
Prochaska & Velicer et al., 2004	Diet[n] Smoking[g]	2,460	3 dynamically tailored letters + manual[+] or assessment-only[*] conditions delivered at home	Proactively recruited parents of participants in related student study	3	12	12	70.0	17
Rakowski & Ehrich et al., 1998	Mammography[i]	1,864	2 dynamically tailored letters[+], brochure, or assessment-only[*] conditions delivered at home	Proactively recruited HMO members from list of enrollees	2	5	20	75.0	19
Rakowski & Lipkus et al., 2003	Mammography[i]	2,023	Tailored letter at either 2 mos or 10[+] mos post-assessment or reminder letter[*] delivered at home	Proactively recruited HMO members from list of enrollees	1	10	15	80.0	18
Rimer & Halabi et al., 2002	Mammography[i]	1,287	2 dynamically tailored letters[+], tailored letter + counselor calls, or	Proactively recruited HMO members from list of enrollees	2	13	24	96.0	17

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
			reminder letter* delivered at home						
Saywell, Champion, Skinner, Menon, & Daggy, 2004	Mammography[i]	1,390	Tailored letter+, tailored letter + counselor calls, or assessment-only* conditions delivered at home	Proactively recruited HMO members from list of enrollees	1	1	2	75.0	13
Schumann & John et al., 2008	Smoking[g]	485	3 tailored letters+ or assessment-only* conditions delivered at home	Proactively recruited from hospital population survey	3	6	24	71.4	18
Shiffman, Paty, Rohay, Di Marino, & Gitchell, 2001	Smoking[h]	4,209	Tailored print feedback + nicotine patch+, or manual + nicotine patch* conditions delivered at home	Callers to quit line asked to participate	6	3	1	63.9	18
Skinner, Strecher, & Hospers, 1994	Mammography[i]	489	Tailored letter+ or brochure-only* conditions delivered at home	Proactively recruited medical clinic patients	1	5	8	89.0	12
Smeets & Brug et al., 2008	Phys Activity[j]	936	Tailored letter+ or assessment-only* conditions delivered at home	Random population-based mailing	1	1	3	52.0	17
Strecher, Kreuter, Den Boer, & Kobrin, 1994a	Smoking[g]	296	Tailored letter or brochure-only* conditions delivered at clinic	Proactively recruited medical clinic patients	1	1	4	70.8	14
Strecher, Kreuter, Den Boer, & Kobrin, 1994b	Smoking[g]	1,588	Tailored letter+ or assessment-only* conditions delivered at clinic	Proactively recruited medical clinic patients	1	1	6	67.0	14
Strecher & Marcus et al., 2005	Smoking[g]	1,978	4 tailored print feedbacks + nicotine patch+ or manual + nicotine patch * delivered at home	Recruited callers to cancer info line	4	6	12	43.9	17
Strecher, Shiffman, & West, 2005	Smoking[h]	3,971	3 tailored newsletters plus support email sent via email+ or informational	People who purchased nicotine patch and logged onto to suggested website	3	3	3	53.3	15

Study	Health Behaviors and Outcome Measures	N (Baseline)	Intervention Methods	Sample and Recruitment Characteristics	Number of Treatment Contacts	Length of Treatment (months)	Final Assessment (months from baseline)	Retention Rate (%)	Quality Rating (out of 22)
			website only* conditions delivered at home						
Velicer & Friedman et al., 2006	Smoking[g]	2,054	Tailored letter+, tailored letters + call, or manual-only* conditions in combination with patch delivered at home	Proactively contacted from VA hospital population	1	1	30	61.0	16
Velicer, Prochaska, Fava, Laforge, & Rossi, 1999	Smoking[h]	2,882	2, 3, or 6 dynamically tailored letters, 1 tailored letter+, or manual-only* conditions delivered at home	Proactively recruited from HMO member list	1	1	18	74.0	17

[a] = % kCalories from fat;

[b] = Fat FFQ;

[c] = Fruit and Vegetable Servings/Day;

[d] = Fruit Servings/day;

[e] = Veg Servings/day;

[f] = 24 hr point prevalence smoking abstinence;

[g] = 7 day point prevalence smoking abstinence;

[h] = 28 day point prevalence smoking abstinence;

[i] = % adherent to mammography screening;

[j] = % adherent to CDC physical activity recommendations;

[k] = recalled minutes of physical activity;

[L] = % increasing physical activity;

[m] = % making progress in stage of change for physical activity;

[n] = % reaching action or maintenance stages.

* Indicates group to which intervention was compared

[+] Indicates treatment group outcome used for analysis

Table 5

Study Quality Rating Criteria

Topic	Item	Descriptor
Introduction	1	Provides scientific background and explanation of rationale.
Methods Participants	2	- Eligibility/exclusion criteria for participants clearly described. - Settings and locations where the data were collected.
Interventions	3	- Precise details of intervention intended for each group and how and when interventions were actually administered and standardized. - Details of how adherence to protocol was assessed or enhanced.
Objectives	4	Is the hypothesis/objective of the study clearly described?
Outcomes	5	Are the main and secondary outcomes clearly defined?
Measures	6	Was actual data or reference provided on reliability and validity of outcome measures?
Sample size & power	7	Description of systematic methods to determine sample size – specifically, mention that power analysis was done in study planning.
Randomization	8	Were study participants *randomized* to intervention/control groups?
Implementation	9	Reporting of who enrolled participants and assigned them to groups?
Statistical methods	10	Were statistical methods used for main outcomes reported (e.g. ANOVA) and appropriate?
Adjustments	11	Was there adequate adjustment for confounding in the analyses or mention of moderator analyses including clustering by provider when appropriate?
Results Participant flow	12	For each group report the numbers randomly assigned, receiving intended treatmnet, completing the study, and analyzed for the primary outcomes.
Recruitment	13	Specifies dates of recruitment and follow-up.
Baseline data	14	Baseline demographic and clinical characteristics of each group (age, gender, race) along with difference analysis on outcome variables based on potential moderators.
Numbers reported	15	- Number of participants (numerator and denominator) in each group (e.g. 10/20 not 50%) are reported so that reader can check major findings. - Type of analysis (ITT or not).
Outcomes and estimation	16	For all results, a summary of results including - Summary of results for each group - Actual p-values (e.g. $p = .035$ not $p < .05$) - Estimates of variability (confidence intervals or SE, SD).
Ancillary analysis	17	Were any results based on data mining or comparisons that were not planned?
Adverse events	18	Have all important adverse events that may be a consequence of intervention been reported? Should be answered yes if study mentions intent to measure such events.
Discussion	19	Interpretation of results taking into account study hypotheses, sources of potential bias or imprecision and the dangers associated with multiplicity of analyses or outcomes.
External validity	20	Generalizability of the findings – mention as to what extent were subjects and intervention representative of populations to which this intervention may be used.
Overall evidence	21	General interpretation of the results in the context of current evidence.
Funding	22	Acknowledgment of funding source/sponsorship or conflicts of interest.

Table 6

Studies Excluded from Analysis

Behavior	Citation	Exclusion Criteria
Diet	Blalock, DeVellis, & Patterson et al., 2002[1]	Insufficient data reported
Diet	Brinberg & Axelson, 1990[2]	Counselor based
Diet	Brinberg, Axelson, & Price, 2000[3]	Counselor based
Diet	Brug & van Assema, 2000[4]	Results reported in Brug et al, 1998
Diet	Brug, Glanz, & Kok, 1997[5]	No intervention provided
Diet	De Bourdeaudhuij, Brug, Vandelanotte, & Van Oost, 2002[6]	Randomization and analysis according to family, not individual
Diet	de Vet, de Nooijer, de Vries, & Brug, 2008[7]	No control group
Diet	Esters, Boeckner, & Hubert et al., 2008 [8]	No behavioral outcomes reported
Diet	Glanz, Murphy, & Moylan, et al., 2006[9]	No control group
Diet	Glasgow, Toobert, Hampson, & Strycker, 2002[10]	Counselor based
Diet	Gould & Anderson, 2002[11]	No control group
Diet	Jantz, Anderson, & Gould, 2002[12]	No behavioral outcomes reported
Diet	King, Estabrooks, & Strycker et al., 2006[13]	Counselor based
Diet	Oenema & Brug, 2003[14]	No behavioral outcomes reported
Diet	Oenema, Brug, & Lechner, 2001[15]	No behavioral outcomes reported
Diet	Sorensen, Thompson, & Glanz et al., 1996[16]	Community intervention, no tailored component
Diet	Stevens, Glasgow, & Toobert et al., 2002[17]	Counselor based
Diet	Stevens, Glasgow, & Toobert et al., 2003[18]	Counselor based
Diet	Veverka, Anderson, & Auld et al., 2003[19]	No behavioral outcomes reported
Diet	Winett, Wagner, & Moore et al., 1991[20]	Not theoretically tailored
Diet	Kreuter, Bull, Clark, & Oswald, 1999[21]	No behavioral outcomes reported
Diet	Tate, Wing, & Winett, 2001[22]	Employed manually tailored intervention
Diet	Tate, Jackvony, & Wing, 2003[23]	Employed manually tailored intervention
Diet Phys Activity	Glasgow, Boles, & McKay et al., 2003[24]	Counselor based
Diet Phys Activity	Clark, Hampson, Avery, & Simpson, 2004[25]	Counselor based
Diet Phys Activity	Booth, Nowson & Matters, 2008[26]	No control group
Diet Phys Activity	Plotnikoff, McCargar, & Wilson et al., 2005[27]	Not tailored
Diet Phys Activity	Vandelanotte, Reeves, & Brug et al., 2008[28]	Results reported in Vandelanotte et al., 2005 study
Diet Phys Activity	Vandelanotte, De Bourdeaudhuij, & Sallis et al., 2005[29]	Insufficient data reported
Mammography	Allen & Bazargan-Hejazi, 2005[30]	Counselor based
Mammography	Champion, Maraj, & Hui et al., 2003[31]	Counselor based
Mammography	Gustafson, McTavish, & Stengle et al., 2005[32]	No tailored feedback provided

Behavior	Citation	Exclusion Criteria
Mammography	Jibaja-Weiss, Volk, & Kingery et al., 2003[33]	Not theoretically tailored
Mammography	McCaul & Wold, 2002[34]	Employed manually tailored intervention
Mammography	Meldrum, Turnbull, & Dobson et al., 1994[35]	Targeted intervention, not theoretically tailored
Mammography	Rimer, Halabi, & Skinner et al., 2001[36]	Reported in Rimer et al., 2002
Mammography	Stoddard, Fox, & Costanza et al., 2002[37]	Counselor based
Mammography	Williams-Piehota, Pizarro, & Schneider, et al., 2005[38]	Lacked sufficient control group
Mammography	Ryan, Skinner, & Farrell et al., 2001[39]	No intervention provided
Phys Activity	Brownson, Hagood, & Lovegreen et al., 2005[40]	Results confounded with multilevel community intervention
Phys Activity	Castro, King, & Brassington, 2001[41]	Focused on maintenance
Phys Activity	Demark-Wahnefried, Clipp, & McBride et al., 2003[42]	Results reported in Demark et al., 2007
Phys Activity	Hurling, Fairley, & Dias, 2006[43]	Insufficient data reported
Phys Activity	Jacobs, Ammerman, & Ennett et al., 2004[44]	Examined maintenance only
Phys Activity	Marshall, Leslie, & Bauman et al., 2003[45]	No control group
Phys Activity	Marcus, Emmons, Simkin-Silverman et al., 1998[46]	Results reported in Bock et al., 2001
Phys Activity	Marcus, Lewis, & Williams et al., 2007[47]	Results not reported
Phys Activity	Purath, Miller, & McCabe et al., 2004[48]	Counselor based
Phys Activity	Van Sluijs, Van Poppel, & Twisk et al., 2005[49]	Counselor based
Smoking	Burling, Marotta, & González et al., 1989[50]	Not behaviorally tailored
Smoking	Carpenter, Watson, & Raffety et al., 2003[51]	Intervention focused on provider training
Smoking	Chouinard & Robichaud-Ekstrand, 2005[52]	Counselor based
Smoking	Cobb, Graham, & Bock et al., 2005[53]	No control group
Smoking	Gilbert, Nazareth, & Sutton et al., 2008 [54]	Results not reported
Smoking	Klesges, DeBon, & Vander et al., 2006[55]	Counselor based
Smoking	Lenert, Munoz, & Perez et al., 2004[56]	No control group. Non-randomized design
Smoking	Levinson, Glasgow, & Gaglio et al., 2008[57]	No behavioral outcomes reported
Smoking	Orleans, Boyd, & Bingler et al., 1998[58]	Counselor based
Smoking	Pallonen, Veliver, & Prochaska et al., 1998[59]	No control group
Smoking	Rimer, Orleans, & Fleisher et al., 1994[60]	Counselor based
Smoking	Shegog, McAlister, & Hu et al., 2005[61]	No behavioral outcomes reported
Smoking	Shiffman, Rolf, Hellesbush et al., 2002[62]	No tailored intervention
Smoking	Stoddard, Delucchi, & Munoz et al., 2005[63]	No control group
Smoking	Wang & Etter, 2004[64]	No control group
Smoking	Webb, Simmons, & Brandon, 2005[65]	No behavioral outcomes reported
Smoking	Wiggers, Oort, & Dijsktra et al., 2005[66]	No behavioral outcomes reported
Smoking	Velicer & Prochaska 1999[67]	No behavioral outcomes reported

Behavior	Citation	Exclusion Criteria
Alcohol Use	Butler, Chiauzzi, & Bromberg et al., 2003[68]	Insufficient number of same behavior for comparison
Alcohol Use	Kypri, Saunders, & Williams et al., 2004[69]	Insufficient number of same behavior for comparison
Injury Prevention	McDonald, Solomon, & Shields et al., 2005[70]	Insufficient number of same behavior for comparison
Injury Prevention	Nansel, Weaver, & Donlin et al., 2002[71]	Insufficient number of same behavior for comparison
Organ Donation	Reubsaet, Brug, & Kitslaar et al., 2004[72]	Insufficient number of same behavior for comparison
Pain	Nicholson, Nash, & Andrasik, 2005[73]	Insufficient number of same behavior for comparison
Pain	Wilkie, Huang, & Berry et al., 2001[74]	No intervention provided
Risk Perception	Kreuter & Strecher, 1995[75]	Insufficient number of same behavior for comparison
Risk Perception	Emmons, Wong, & Puleo et al., 2004[76]	Insufficient number of same behavior for comparison
Cancer screening	Kreuter, Skinner, & Steger-May et al., 2004[77]	Behavior change not reported
Cancer screening	Marcus, Mason, & Wolfe et al., 2005[78]	Insufficient number of same behavior for comparison
Cancer screening	de Nooijer, Lechner, & de Vries, 2002[79]	Behavior change not reported
Sexual Risk Prevention	Bellis, Grimley, & Alexander, 2002[80]	No intervention provided
Sexual Risk Prevention	Chesney, Koblin, & Barresi et al., 2003[81]	Baseline data only
Sexual Risk Prevention	Scholes, McBride, & Grothaus et al., 2003[82]	Insufficient number of same behavior for comparison
Stress reduction	Evers, Prochaska & Johnson et al., 2006[83]	Insufficient number of same behavior for comparison
Sun Protection	Bernhardt, 2001[84]	Insufficient number of same behavior for comparison
Sun Protection	Hornung, Lennon, & Garrett et al., 2000[85]	Insufficient number of same behavior for comparison