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Intervention Engagement Moderates the Dose–Response Relationships in a Dietary Intervention

Sonia Lippke[1], Jana M. Corbet[2], Daniela Lange[2], Linda Parschau[2], and Ralf Schwarzer[3,4]

Abstract

Behavioral interventions could lead to changes in behavior through changes in a mediator. This dose–response relationship might only hold true for those participants who are actively engaged in interventions. This Internet study investigated the role of engagement in a planning intervention to promote fruit and vegetable consumption in addition to testing the intervention effect on planning and behavior. A sample of 701 adults (mean = 38.71 years, 81% women) were randomly assigned either to a planning intervention (experimental group) or to one of 2 control conditions (untreated waiting list control group or placebo active control group). Moderated mediation analyses were carried out. Significant changes over time and time × group effects revealed the effectiveness of the intervention. The effect of the intervention (time 1) on changes in behavior (time 3; 1 month after the personal deadline study participants set for themselves to start implementing their plans) was mediated by changes in planning (time 2; 1 week the personal deadline). Effects of planning on behavior were documented only at a moderate level of intervention engagement. This indicates an inverse U-shaped dose–response effect. Thus, examining participants' intervention engagement allows for a more careful evaluation of why some interventions work and others do not.

Keywords

moderated mediation, randomized controlled trial, intentions, planning, nutrition

The leading causes of morbidity and mortality in most countries are modifiable risk behaviors, such as physical inactivity or an unhealthy diet.[1] Developing effective behavior change interventions is therefore one of the key endeavors.[2] One target behavior that is considered crucial for preventive health interventions is a diet consisting mainly of low-energy, nutrient-dense food such as fruits and vegetables.[3] However, it is not clear how such recommendations can be communicated effectively to individuals and how the dose–response relationships transpire. Thus, the main purpose of this article is to test this in a longitudinal online study.

Behavior Change Interventions

Behavior change interventions are complex affairs comprising different components that can be clustered into 2 categories: techniques and implementation. Intervention techniques target constructs and variables, such as self-efficacy, change techniques, for example, model learning, and mode(s) of delivery, for example, puppets, video, brochures.[4] Theories of health behavior change provide guidance under which circumstances which variables should be addressed.[5] The intervention implementation process is composed of delivery fidelity (eg, compliance with protocol[6]), successful dissemination among the target population,[7] and intervention engagement.[8]

Often when evaluating the effectiveness of an intervention, researchers restrict their investigation to the techniques only[9] and conclude that depending on the outcome of the intervention

[1] Jacobs University Bremen, Bremen, Germany
[2] Freie Universität Berlin, Berlin, Germany
[3] Institute for Positive Psychology and Education, Australian Catholic University, Sydney, Australia
[4] University of Social Sciences and Humanities, Wroclaw, Poland

Corresponding Author:
Sonia Lippke, Jacobs Center on Lifelong Learning and Institutional Development, Department of Psychology & Methods, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany.
Email: s.lippke@jacobs-university.de

study, they addressed, more or less, the appropriate determinants of behavior change.[2] Examining factors concerning both the techniques and their implementation would allow for more sound conclusions as to why one intervention is more effective in modifying behavior than others. Thus, in the following, we will focus first on the techniques and second on their implementation.

Planning as the Target of Behavior Change Interventions

Behavior change interventions aim at modifying risk behaviors by addressing predictors of behavior change, and one such predictor is planning.[10,11] Through planning, individuals notice and create opportunities for engaging in intended behavior changes. As such, planning is a prospective self-regulatory strategy. In the Health Action Process Approach,[12] 2 types of planning are defined. Action planning refers to the precise specification of the situation in which the behavior will be performed. Coping planning refers to the anticipation of barriers that may hinder behavior performance and subsequently identifying strategies that help the individual cope with said barriers.[13] Action planning and coping planning work best in combination because they operate simultaneously as additive mediating processes and interactive counterparts.[14] In practice, this finding should result in the implementation of combined planning interventions. The simultaneous influence of these 2 types of planning should be accounted for.[14]

For a wide range of behaviors, it has been demonstrated that interventions prompting planning lead to changes in behavior.[13,15,16] The proposed mechanism here is that a planning intervention exerts its influence on changes in behavior via changes in behavioral predictors.[10] Planning involves linking situation parameters (when, where) to a predefined sequence of action (how). The mediating factors are cue accessibility and the strength of the cue–response linkage.[17] Action planning and coping planning are both important components of volitional planning interventions.[18]

This mediation mechanism and, with that, the dose-response might differ in subgroups of participants (eg, the mediation might hold true for engaged individuals but not for unengaged one). This may account for some studies' failure to support the usefulness of a planning intervention for behavior change.[19,20] The given explanation represents a case of moderated mediation.[21,22] If a moderator variable is dichotomous (eg, gender), then mediation in one group (eg, in the group of women) and lack of mediation in the other (eg, in the group of men) reflect a moderated mediation. A moderated mediation can also be expressed as an interaction between the moderator and the predictor or between the moderator and the mediator, respectively.[21] Intervention engagement can be a putative moderator of the effect that a planning intervention exerts on changes in behavior via changes in planning.

Intervention Engagement as a Moderator

Over and above compliance with an assignment, the concept of engagement additionally comprises undivided attention (ie, the avoidance and disregard of distractions and the restraint from engagement in non–task-related activities), effort (engagement in the narrowest sense, as it shows that individuals are not merely "going through the motions"), and, to some degree, immersion in a given task or a health behavior intervention. As such, it is more than just being physically present; it is to utilize the provided time for its designated purpose. A proxy for intervention engagement can be the time actively used when participating in an intervention, although this taps only one component of the engagement concept.[8] However, the use of this term, conceptualization, and assessment methods have all been inconsistent in previous research.[8] In a review in children's mental health services, Lindsey et al[23] found 22 engagement practice elements—such as accessible promotion and modeling—and most of them with effect on adherence and cognitive preparation. Generally, there is evidence that engagement is predictive of intervention success.[8,24-27] For example, Glen and colleagues[28] could prove that higher engagement of patients treated for anxiety disorder with cognitive behavior therapy was associated with better outcomes.

Although numerous other studies could be found within clinical psychology and psychotherapy, very few research has focused on this in health psychology and lifestyle interventions. One of those few studies was the one by van den Berg and colleagues.[29] The researchers evaluated an individualized training in terms of engagement and its interrelation with physical activity. Although clear evidence was found that more engagement was associated with more physical activity, it remained unclear which psychological processes actually explained the effect of engagement on behavior. As no other study could be found on this either, the current research was conducted to shed light into these mechanisms by testing an Internet-based planning intervention (experimental group [EG]) against a placebo active control group (ACG) and a nontreated waiting list control group (WLCG).

Engagement is expected to moderate the effect that a health behavior intervention exerts on changes in behavior via changes in planning because the intervention should only lead to changes in cognitions (eg, action planning and coping planning) if participants engage in it.[8] This represents a case of moderated mediation in which the moderator interacts with the predictor.[23] In other words, the efficacy of the intervention is expected to depend on its successful change in behavioral predictors such as planning (mediation process), and this, in turn, depends on sufficient intervention engagement (moderation).

Aims and Hypotheses

The aim was to examine whether the Internet-based planning intervention (EG) would produce significantly more intervention engagement in comparison to an untreated control group (a WLCG), only filling in the questionnaire, but equally

engaged as a placebo-treated group (an ACG). Further, it was expected that the Internet-based planning intervention (EG) would perform better in terms of developing plans and adopting a healthy diet over time in comparison to both control groups (the nontreated WLCG and the placebo ACG).

Over and above replicating evidence for the planning mediation mechanism (ie, a question concerning intervention techniques), the aim of the current study was to examine the role of intervention engagement. Through this integrative approach, we aimed to evaluate a planning intervention's usefulness in increasing fruit and vegetable consumption in comparison to a standard placebo intervention and the nontreated group (WLCG). Our specific hypotheses were:

1. The ACG should be as engaged with working on the treatment as the EG receiving an individualized treatment. The 3 groups should exhibit differently in terms of changing their planning levels and behavior over time in favor of the EG in comparison to both control groups.
2. The effect of an intervention prompting action planning and coping planning on changes in fruit and vegetable consumption is mediated by changes in action planning and coping planning (mediation).
3. The mediation effect of the intervention on changes in behavior by changes in (a) action planning and (b) coping planning varies for different levels of intervention engagement (moderated mediation, ie, the dose-response depends on intervention engagement).

Methods

Procedure

Participants of this online study were recruited by personal invitations, press releases (radio, newspaper, TV), and advertisements posted on a university Web page. After providing informed consent, participants followed a link to a baseline questionnaire. The system then randomly allocated individuals to the waiting control group (questionnaires only), the active control condition, or the EG (all at time 1, T1). This randomization was performed using the software dynQuest, which provides such a random indicator.[30]

As part of the baseline questionnaire, participants were asked for their personal goal concerning fruit and vegetable intake (in portions per day, which was displayed by a human hand, and in addition, the information was given "1 portion = a 'handful,' eg, grapes or salad") and to specify a date by which they wanted to have attained this goal (participants were able to specify any date within 2 months of their baseline assessment). One week (time 2, T2) and 1 month (time 3, T3) after this personal deadline, participants received an e-mail invitation for the post- and follow-up assessments. As an incentive for study participation, individuals were able to take part in an optional raffle in which they could win attractive gift certificates for an online bookstore.

Participants

Inclusion criteria for this study were the completion of all 3 assessments. A total of 2306 individuals participated in T1; of these, 1160 (50.3%) also answered T2. Eight hundred sixty (37.3%) individuals participated in T3. The final study sample consisted of N = 701 individuals (30.40% of the initial sample). These study participants were on average mean = 38.52 years old (range = 15-77, standard deviation [SD] = 12.94) and mostly women (84.2%). The majority of the sample was highly educated (50.1% high school degree, 30.7% university degree), employed (61.3%), and in a steady relationship (60%). Dropout analyses for the 3 groups were computed, but no significant differences across the groups were found.

Interventions

An online intervention targeting fruit and vegetable consumption was administered. All material and techniques were developed using the intervention mapping approach.[31] Trial registration was conducted at ClinicalTrials.gov with ClinicalTrials.gov Identifier: NCT00986375.

Experimental Group

Participants in the EG received an online intervention prompting action planning and coping planning (see Table 1). In particular, participants were asked to commit to a specific personal goal with regard to fruit and vegetable consumption (eg, to eat 5 portions of fruits and vegetables daily by next month) and write it down. Individuals were then prompted to specify opportunities (where and when) for a smaller initial subgoal, such as 1 piece of fruit per day by the end of this week.

If participants' personal goal was already simple, they specified opportunities for that instead. Additionally, individuals were asked to identify opportunities for preparatory behaviors (such as buying and preparing foods) and to write everything in a calendar that they could print if desired.[32] Participants were encouraged to try their planned behavior and gain experience with it and then to review and potentially revise their self-imposed goals (blank calendars were provided). In small written vignettes, role models identified 5 common situations that may pose a challenge and provided solutions to overcome these obstacles. Subsequently, individuals were prompted to identify up to 3 personal barriers and find strategies to overcome them.[32]

Active Control Condition

Individuals in the active control condition received a different intervention that also targeted fruit and vegetable consumption. It was comparable in length, used equal strategies (eg, generating and writing down of ideas, reading about role models' experiences), and modes of delivery (Internet-based texts and pictures) but targeted different constructs that are typically addressed in standard care interventions on fruit and vegetable

Table 1. Contents of the Active Control Condition and the Experimental Condition.[a]

	ACG	EC
Risk perception	Yes	No
Information about connection between diet and blood vessel fitness		
Question to rate whether participants thought their blood vessels are rather clogged or in good shape		
Outcome expectancies	Yes	No
Question to indicate how participants would look if they would eat fruit and vegetables instead of high calorie and fatty products		
Statement was given, saying that this level of nutrition is doable		
Asked to think about the positive consequences (pros)		
Asked to generate 1 potential negative outcome		
Action planning	No	Yes
Instruction regarding commitment to a specific personal goal		
Asked to specify opportunities (where and when)		
Asked to think about opportunities for preparatory behaviors		
Question to write everything in a calendar that they could print		
Encouraged to try their planned behavior and gain experience with it and then to review and potentially revise their self-imposed goals		
Information about vignettes and role models		
Coping planning	No	Yes
Instruction to identify up to 3 personal barriers		
Asked to find strategies to overcome the personal barriers		

Abbreviations: ACG, active control group; EC, experimental condition.
[a] Adapted from Lippke et al.[13]

consumption (eg, risk perception and outcome expectancies, see Table 1).

Measures

Intervention Engagement

Intervention engagement was measured immediately after participants finished their intervention (T1, for means and SDs, see Table 2). The construct was assessed with the validated task engagement scale.[8] Example items are "I completed all set tasks," "I was preoccupied with other things; my mind was not in it" (reverse recoded), "I put a lot of effort into completing the tasks," and "I was so immersed, I completely forgot everything else around me." All statements were rated on a 6-point Likert scale ranging from (1) not at all true to (6) exactly true. Cronbach α was .97.

Action Planning

Action planning was assessed with 3 items at T1, T2, and T3. Items read "I have planned precisely... (1)... which fruits and vegetables I will eat, (2) ... at which occasions (in which situations) I will eat fruits and vegetables, and (3) ... how I will eat my fruits and vegetables (eg, cooked, cut up)."

Participants rated these statements on a 6-point Likert scale ranging from (1) not at all true to (6) exactly true. Homogeneity of the items was high with Cronbach α being .88. Scale means for T1, T2, and T3 were calculated (for means and SDs, see Table 2), and difference scores (ie, T1 − T2) were obtained subsequently (for means and SDs as well as intercorrelations, see Table 3).

Coping Planning

Coping planning was assessed with 2 items at T1, T2 and T3. Items read "I have planned precisely ... (1) ... in which situations I need to be especially careful so as to succeed in eating sufficient amounts of fruit and vegetables and (2) ... what I can do in difficult situations so as to succeed in eating sufficient amounts of fruits and vegetables."

Statements were rated on a 6-point Likert scale ranging from (1) not at all true to (6) exactly true, and the 2 items correlated significantly with $r = .69$, $P < .01$. Scale means for T1, T2, and T3 were calculated (for means and SDs, see Table 2), and difference scores (ie, T1 − T2) were obtained subsequently (for means and SDs as well as intercorrelations, see Table 3).

Fruit and Vegetable Consumption

Fruit and vegetable consumption was measured at T1, T2, and T3. In an open-answer format, participants were asked: "How many servings of (a) fruit... and (b) vegetables..... .do you eat on average per day?" One serving was defined and visualized as a "handful." Sum scores for T1, T2, and T3 were calculated (for means and SDs, see Table 2), and difference scores (ie, T1-T3) were obtained subsequently (for means and SDs as well as intercorrelations, see Table 3). All items were piloted, used, and validated in previous studies.[8,12,33]

Analytical Procedure

Computations were performed with SPSS 23. Analyses of variance in addition, were used to test the differences between the Waiting List Control Group (WLCG), the Active Control Group (ACG) and the Experimental Group (EG) over time (with a RM-ANOVA). Testing the mechanisms of the intervention in comparison to an ACG and a nontreated, WLCG, was done with the PROCESS macro by Hayes.[34] First, a simple mediation model was carried out. With the latter, it was tested whether the effect of the intervention on changes in fruit and vegetable consumption was mediated by changes in action planning and coping planning. The rationale was to first compare all the groups, as comparing the intervention to an ACG is much stronger than only to a passive WLCG. Second, only the mechanism explaining the effectiveness in the intervention group to both control groups should be tested.

Subsequently, for each mediator separately, it was tested whether engagement functions as a moderator of these mediations. To test the interactions, variables were z-standardized.[35] Confidence intervals (95%) were generated by bootstrapping with 5000 resamples. The moderated mediation is expressed by

Table 2. Means (Standard Deviation).[a]

		Waiting List Control Group (WLCG)	Active Control Group (ACG)	Experimental Group (EG)	
Intervention engagement	T1	0.70 (1.54)	4.10 (1.42)	3.97 (1.27)	$F_{T1(2,698)} = 431.54^b$; WLCG < EG; ACG < EG
Action planning	T1	3.47 (1.15)	3.34 (1.25)	3.30 (1.21)	$F_{Time(2,696)} = 28.03^b$; $\eta^2 = .08$
	T2	3.65 (1.13)	3.64 (1.16)	3.85 (1.12)	$F_{T \times G(2,697)} = 6.56^b$; $\eta^2 = .02$
	T3	3.57 (1.16)	3.65 (1.27)	3.72 (1.12)	
Coping planning	T1	2.85 (1.14)	2.85 (1.30)	2.71 (1.16)	$F_{Time(2,696)} = 74.57^b$; $\eta^2 = .18$
	T2	3.15 (1.25)	3.30 (1.27)	3.45 (1.22)	$F_{T \times G(2,697)} = 8.09^b$; $\eta^2 = .02$
	T3	3.29 (1.18)	3.41 (1.32)	3.40 (1.19)	
Fruit and vegetable consumption	T1	3.37 (1.43)	3.18 (1.58)	3.20 (1.52)	$F_{Time(2,695)} = 91.66^b$; $\eta^2 = .21$
	T2	3.82 (1.37)	3.82 (1.52)	4.05 (1.35)	$F_{T \times G(2,696)} = 4.67^b$; $\eta^2 = .01$
	T3	3.92 (1.36)	3.99 (1.51)	4.03 (1.34)	

[a] *F* statistics are Roy's largest root. [b] $P \leq .01$.

Table 3. Means (M), Standard Deviations (SDs), and Intercorrelations for Study Variables.[a]

	Engagement (T1)	Changes in Action Planning (T2)	Changes in Coping Planning (T2)	Changes in Fruit and Vegetable Consumption (T3)
M	4.26	0.29	0.45	0.64
SD	0.68	1.21	1.26	1.57
Changes in action planning (T2)	.06[b]	–	–	–
Changes in coping planning (T2)	.14[c]	.51[c]	–	–
Changes in fruit and vegetable consumption (T3)	.01	.16[c]	.15[c]	–

[a] N = 701.
[b] $P < .01$.
[c] $P < .001$.

an interaction between engagement and intervention on changes in planning.[21] Missing data (less than 5%) were imputed using the expectation–maximization algorithm in SPSS.[36]

Results

Intervention Effects

Significant effects for experimental conditions were only found for intervention engagement, indicating that the 3 groups spent significantly different amounts of time with the intervention (see Table 2 for means and SDs as well as the *F* statistic from the ANOVA). However, running post hoc paired comparisons, significant differences between the groups revealed only for the WLCG versus the ACG and WLCG versus the EG. In other words, the 2 treated groups spent about the same amount of time with working on the pages and its contents.

When conducting repeated-measure ANOVAs with action planning, coping planning, and behavior, it revealed that all time effects as well as all time × group effects were significant. When comparing the changes from T1 to T2 for action planning and coping planning, the WLCG was significantly different from the EG as well as the ACG from the EG (all $P < .05$, not reported in Table 2). For fruit and vegetable consumption, significant differences revealed only for WLCG versus EG, both with changes from T1 to T2 ($P < .01$) as well as marginally from T1 to T3 ($P = .07$, not reported in Table 2).

Summarizing the intervention effects, the 3 groups exhibited differently in terms of changing their planning levels and behavior over time in favor of the EG, with fewer differences between the WLCG and the ACG than between the ACG and the EG. Thus, in the following, WLCG and ACG (both without including a planning intervention) were lumped together to compare against the EG (including a planning intervention).

Mediation Processes

Having received a planning intervention (ie, being in the EG vs one of the control groups) at T1 emerged as a significant predictor of changes in action planning at T2 ($\beta = .31$, $P < .001$). Changes in action planning in turn predicted changes in fruit and vegetable consumption ($\beta = .15$, $P < .001$). There was a direct effect of the planning intervention (EG vs in one of the control groups) on changes in fruit and vegetable consumption ($\beta = .27$, $P < .001$). This could indicate that in addition to eliciting changes in action planning, there were other mechanisms via which the intervention led to changes in behavior. Having received a planning intervention (being in the EG vs one of the control groups) also emerged as a significant predictor of changes in coping planning ($\beta = .28$, $P < .001$). Changes in coping planning in turn predicted changes in fruit and vegetable consumption ($\beta = .16$, $P < .001$).

The effect of intervention on changes in fruit and vegetable consumption was fully mediated by changes in action planning and coping planning. That is, the direct effect of intervention on changes in fruit and vegetable consumption was reduced from

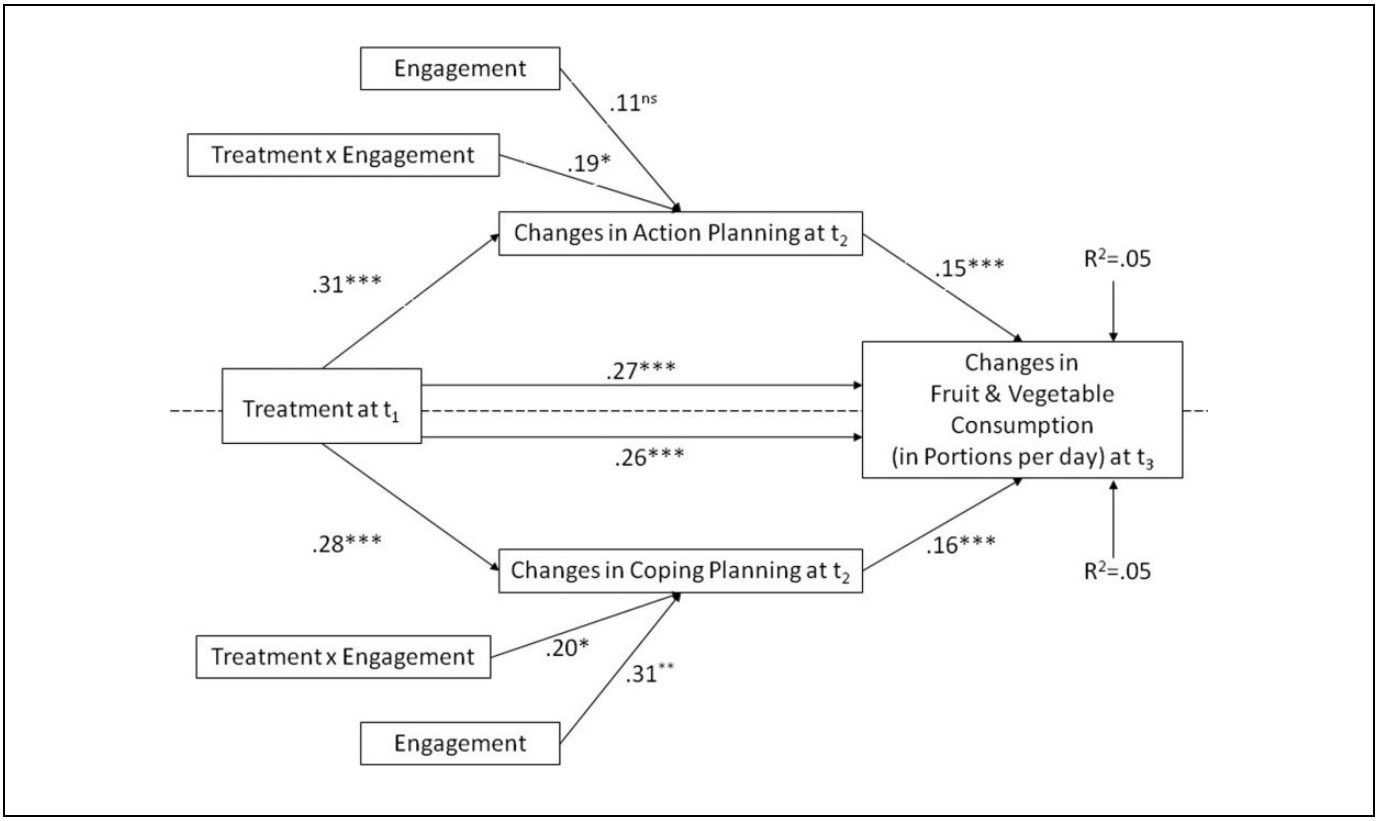

Figure 1. Two separate moderated mediation models for changes in fruit and vegetable consumption in N = 701 individuals. The top part shows the model for changes in action planning as mediator, and the bottom part of the figure shows the model for changes in coping planning as mediator. ***$P < .001$, **$P < .01$, *$P < .05$. Treatment was coded: 0 = waiting list control group and active control group (combined), 1 = experimental group.

$\beta = .21$, $P < .001$ to $\beta = .16$, $P > .05$ after controlling for changes in action planning and coping planning. The contrast test of the specific indirect effects for changes in action planning ($\beta = .03$, $P < .05$) and coping planning ($\beta = .03$, $P < .05$) did not become significant (contrast <.01, $P > .05$). This is suggesting that both variables are equally important mediators. The mediator model accounted for 5% of the variance in changes in fruit and vegetable consumption ($P < .05$).

Moderated Mediation

Engagement moderates the mediation effect of intervention on changes in behavior via changes in action planning. There was a significant interaction between the intervention and the intervention engagement on changes in action planning ($\beta = .19$, $P < .05$), indicating that the partial mediation of the intervention on changes in fruit and vegetable consumption via changes in action planning was moderated by engagement. Figure 1 visualizes the results indicating a dose-response. In particular, participants needed an engagement score between 3.2 and 5 on the 1- to 6-point scale to allow for a significant mediation effect, as identified by the Johnson-Neyman technique.[34]

Engagement moderates the mediation effect of intervention on changes in behavior via changes in coping planning. There was also a significant interaction between the intervention and the intervention engagement on changes in coping planning ($\beta = .20$, $P < .05$), indicating that the partial mediation of intervention on changes in fruit and vegetable consumption via changes in coping planning is moderated by engagement (see Figure 1). Participants needed an engagement score between 2.0 and 4.5 on the 1- to 6-point scale to allow for a significant mediation effect. In other words, the intervention response depended on the right medium dose of intervention engagement, meaning that too little engagement and too high engagement, was not effective in improving coping planning to actually facilitating behavior change.

To summarize, the effect of intervention on changes in fruit and vegetable consumption was fully mediated by changes in action planning and coping planning. Engagement emerged as a moderator in the way that intervention led to changes in action planning and coping planning, only if engagement in the intervention was at a certain level (3.2 and 5 on the 1- to 6-point scale for action planning and 2.0 and 4.5 on the 1- to 6-point for coping planning). In other words, the intervention response depended on the right medium dose of engagement, meaning that too little and too high engagement, was not

effective in improving action planning or coping planning. Thus, it is a nonlinear relationship between the intervention, engagement, and its effect on the 2 different planning outcomes clearly indicating a dose–response effect of the intervention on the behavioral outcomes.

Discussion

Changing health behaviors such as fruit and vegetable consumption requires self-regulatory efforts, which can be addressed in planning interventions. This study replicated findings (eg,[11,13,15-17,33,37-41]) that show the effect of interventions on engagement, planning, and behavior. In this online study, N = 701 individuals were assigned to an untreated control group (WLCG), a placebo ACG, or an EG. Results showed changes over time and interactions between time and group clearly in favor of the EG. However, the novelty about this study lies in the analyses of the psychological mechanisms how an intervention translates into behavior change depending on potential mediators and moderators. Therefore, the 2 control groups (the WLCG and the ACG) were combined and compared with the EG.

So far, only little was known about the specific nonlinear mechanisms of how behavioral interventions translate into behavior change. In the present study, we aimed at adding to the understanding by explicitly investigating the mechanisms between the intervention and behavior change. Therefore, we experimentally manipulated action planning and coping planning to investigate whether the effect of the intervention on changes in fruit and vegetable consumption could be accounted for by changes in planning. Moreover, we examined the role of intervention engagement in the process of behavior change to discover whether this mediation mechanism varies for different levels of intervention engagement. In our approach, we aimed at integrating aspects of intervention techniques and intervention implementation. This allows for a more complex evaluation of a behavior change intervention and subsequently provides a possible explanation for previous ambivalent research findings concerning the role of planning in the behavior change process (cf,[13,15,16,19,26,37,38,41]).

The effect of intervention on changes in fruit and vegetable consumption was fully mediated by changes in action planning and coping planning. The finding corroborates previous research[37,38] and supports the value of simultaneously including action planning and coping planning in health behavior interventions that address fruit and vegetable consumption. Moreover, engagement in the intervention emerged as a moderator of this effect in the way that intervention led to changes in action planning and coping planning, respectively, only if engagement in the intervention was at a moderate level (3.2 and 5 on the 1- to 6-point scale for action planning and 2.0 and 4.5 on the 1- to-6 point for coping planning).

Although previous research has suggested a positive linear relationship between engagement and intervention effects (cf,[8,26]), results of this study point toward a nonlinear relationship. In particular, we found that the mediation mechanism only held true for medium levels of engagement. That is, when participants were too little or too highly engaged in the intervention, the effects of intervention on changes in fruit and vegetable consumption were not mediated via changes in action planning and coping planning, respectively. This result is in agreement with 2 studies that suggest a similar, inverted U-shaped relationship between number of plans and changes in behavior[42] or number of lifestyle recommendations and success rate of translating those recommendations into behavior.[43] The authors of the latter study concluded that this effect is due to the interventions enabling the necessary threshold of motivation to translate the recommendation into their lifestyle. Thereby, the compliance was increased with the intervention-based goals, while the intervention did not become too demanding. The previous and the current finding are arguing that cognitive demands increase with the number of recommendations to change or plans that are generated in an intervention. Although making plans is not equal to engagement, it may be seen as an indicator of effort and may explain why the mediation mechanism did not work for high levels of engagement.

Regarding engagement, too little is an indicator of not really participating. Two reasons may count for this: (1) the intervention might not be matched to the participant's need or (2) the participant did not have the resources for adequately participating because of other distractors. This was found in a meta-analysis by Rooke et al[44] when analyzing computer-delivered interventions for alcohol and tobacco use. When individuals participated at home, the effects were smaller ($d = 0.20$) than if they participated in a research setting (in the laboratory with $d = 0.25$).

Too high engagement might also be associated with too high expectations, which then might turn into disappointment and lead to ineffective planning, for example, when participants are overly optimistic and do not feel a need for careful and deliberate planning. However, this should be investigated further in future research.

Limitations

In this study, only one possible aspect of self-regulation was focused on: planning as mediator between the intervention and its effect on behavior change. Research suggests, however, that other social cognitive variables, such as self-efficacy and social support, are also useful determinants of behavior change.[13,32] This is in line with our finding that only 5% of the variance in changes in fruit and vegetable consumption were explained. Subsequently, models accounting for additional predictors may be favored in future research.

Although recruitment was broad so as to obtain a representative sample, study participants were predominantly highly educated women. In addition, the time frame that individuals chose for attaining their goal (and inevitably, the time of their follow-up dates) might be confounded with the difficulty of their goal. Since only those participants who had

already completed all 3 assessments were included in the study, this may have resulted in a sample that is skewed toward lower or easier goals. Although no significant differences regarding dropout within the 3 groups revealed, the results of this study should be generalized with caution, and replication should be attempted in a more representative sample. However, studying a mechanism within an intervention program does not require a nationally representative sample because a generalization to all Germans, for example, is not an aim of the study.

Fruit and vegetable consumption was assessed with a self-report measure because the online format of the study did not allow for more objective measures. Unintentional or intentional misreporting (for example, due to social desirability) might have occurred. Therefore, in the analyses, we only investigated mechanisms and misreporting at the different measurement points might have leveled out. However, the recall of the behavior is just an approximation with some subjective deviations from the actual behavior. This has to be kept in mind when interpreting the results. In future studies, a validation procedure would be desired, for instance, by assessing objective measures additionally and computing the validity of the subjective data.

Although we used a computer-based approach, we were not able to measure additional objective data on engagement (such as login times) because the ethical agreements constrained us from saving such data. However, such an approach should be considered in the future because this would provide multiple further options.

In terms of the engagement construct, our focus was limited to the user experience, and we did not identify objective design characteristics (eg, gamification) or behavior change techniques (eg, process motivators) that generate engagement. Thus, not the determinants of online engagement but only their effect was at stake here.

When testing the psychological mechanisms, analyzing difference scores was the method of choice in this study, as we were interested in predicting change rather than discrete follow-up scores. Our assumption was that the intervention would generate changes in planning and that those changes in planning would subsequently lead to changes in dietary behaviors. Alternative procedures such as baseline-controlled follow-up scores or residualized change scores are also possible. Future studies should validate the present findings with more reliable measures such as objective assessments (instead of subjective reports), latent change scores and with other health behaviors such as physical activity.

Outlook

This study shows that the intervention effects were successfully translated via planning when moderate intervention engagement was present. The findings thereby demonstrate that the dose–response of the intervention is dependent on the right dose of engagement: That means too little and too high engagement was not effective in improving action planning and coping planning to actually facilitating behavior change. Questions concerning the nature of intervention engagement should be addressed in the future: For example ''What predicts engagement?'' and ''How can we manipulate engagement to optimize intervention effects?'' should be explored further. This requires an examination of the treatment design characteristics and the behavior change techniques that facilitate a motivating user experience. In future studies, the findings need to be replicated in other samples and settings, with longer follow-ups, analytical techniques and with other behaviors.

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