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ORIGINAL ARTICLE

Perceived Control and Intrinsic vs. Extrinsic Motivation for Oral Self-Care: A Full Factorial Experimental Test of Theory-Based Persuasive Messages

Liam Staunton, M.Sc · Paul Gellert, Ph.D. · Keegan Knittle, Ph.D. · Falko F. Sniehotta, Ph.D.

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Abstract
Background Correlational evidence suggests that perceived control (PC) and intrinsic motivation (IM), key constructs in social cognitive and self-determination theories, may interact to reinforce behavior change.
Purpose This proof-of-principle study examines the independent and synergistic effects of interventions to increase PC and IM upon dental flossing frequency.
Methods University students (n=185) were randomized in a 2×2 full factorial design to receive two computer-based interventions: one to either increase or decrease PC and another to increase either IM or extrinsic motivation. These constructs were measured immediately post-intervention; flossing behavior was measured 1 week later.
Results The interventions to increase PC and PC/IM had main and interaction effects on flossing, respectively. The PC/IM interaction effect was mediated by increases in PC and IM.
Conclusions Combining interventions to increase PC and IM seems to be a promising avenue of research, which has implications for both theory and intervention development.

Keywords Self-determination theory · Social cognitive theory · Perceived control · Intrinsic motivation · Full factorial design · Dental flossing

L. Staunton
School of Psychology, University of Aberdeen, Aberdeen, UK

P. Gellert · K. Knittle · F. F. Sniehotta
Health Psychology Group, Institute of Health & Society, Newcastle University, Newcastle upon Tyne, UK

P. Gellert
Institute of Medical Sociology, Charité–Universitätsmedizin Berlin, Berlin, Germany

K. Knittle
MoveLab, Institute of Cellular Medicine, Newcastle University, Newcastle upon Tyne, UK

F. F. Sniehotta
Fuse Centre for Translational Research in Public Health, Newcastle University, Newcastle upon Tyne, UK

F. F. Sniehotta (✉)
Institute of Health & Society, Faculty of Medical Sciences, Newcastle University, Baddiley-Clark Building, Richardson Road, Newcastle upon Tyne NE2 4AX, UK
e-mail: falko.sniehotta@ncl.ac.uk

Introduction

Health behavior theories provide conceptual frameworks for empirical research into health behavior change. They summarize relevant evidence and suggest hypotheses about future observations, making them amenable to empirical tests [1]. Where theoretical hypotheses conflict with one another, empirical research can be used to identify which theory best accounts for actual observations. In 2005, Noar and Zimmerman [2] reviewed empirical studies of health behavior theories and found only 19 studies that tested theories against one another—all using correlational designs.

Experimental tests of the effects of manipulating theory-based variables can provide for more stringent tests of theories [3, 4], and factorial designs allow for comparisons between competing theory-based hypotheses. In addition, factorial experimental tests allow for examinations of how theory-based interventions interact and can provide evidence for the utility of integrating and combining theoretical approaches.

This study aims to test two dominant explanations of motivation in health behavior theory. More specifically, perceived control (the seminal determinant in social

cognitive theories) and intrinsic and extrinsic motivation (important theoretical concepts suggested by self-determination theory) will be manipulated in a full factorial design to examine whether the integration of social cognitive theory and self-determination theory holds promise for future interventions.

Perceived Control in Social Cognitive Theories

One of the two dominant explanations for motivation in health behavior is that individuals are more likely to enact behaviors over which they feel they have control. This perceived control is a crucial construct in social cognitive theories: perceived behavioral control within the theory of planned behavior (TPB) [5] and self-efficacy in social cognitive theory [6]. Correlational studies and intervention research both support the hypothesis that perceived control is positively related to behavioral performance [7, 8], although its working mechanisms are not entirely clear. In a rare experimental test of perceived control, Fisher and Johnston [9] found that manipulating the perceived control of chronic back pain sufferers influenced their ability to perform a lifting task. In another study, Sniehotta [3] manipulated that the TPB constructs perceived control, attitudes, and social norms for physical activity within a 2×2×2 full factorial experimental design. While the perceived control intervention did change physical activity behavior, this change was not mediated by any of the TPB cognitions. There is therefore more to be known about the role of perceived control in initiating and sustaining behavior change efforts.

Intrinsic vs. Extrinsic Motivation in Self-determination Theory

According to self-determination theory [10, 11], the motivation to fulfill basic psychological needs is held to lie at some point between perceived intrinsic and extrinsic motivation [12]. Behaviors that are engaged in spontaneously and for their inherent interest and enjoyment are characterized as intrinsically motivated (self-determined), whereas those that are engaged in to please others are characterized as extrinsically motivated. According to the theory and a growing body of evidence, autonomous and intrinsically motivated behaviors are more likely to be undertaken than those that are extrinsically motivated [13, 14]. While self-determination theory focuses on the contextual contingencies and orientations inherent to the individual that give rise to motivational states and subsequent behavior, it does not chart the exact process by which motivational orientations lead to the formation of intentions and subsequent behavior [12].

Integrating the Theories

Recently, researchers have sought to integrate self-determination theory and social cognitive models because these approaches provide complementary explanations of the unexplained processes within each theory [12]. For instance, Chatzisarantis et al. [15] demonstrated that perceived control to engage in health behavior was based on the influence of intrinsic or extrinsic motives. Additionally, intrinsic motivation has been shown to mediate the relationship between perceived control and pro-environmental behaviors such as recycling [16] and to contribute to increased self-regulatory efforts across behaviors [14]. To this point, the evidence base in support of theoretical integration is however largely correlational, and there is a clear lack of stringent experimental tests.

The hypothesis that people are more likely to perform behaviors they perceive as controllable might be particularly powerful when individuals have a strong intrinsic motivation to perform the behavior, as individuals might be more willing to invest self-regulatory resources to exercise control for behaviors they are intrinsically motivated to perform. As the sources of motivation are insufficiently addressed in social cognition models, an integration of both lines of theorizing might be fruitful, and it appears plausible to hypothesize that when motivation is intrinsic (self-determined) rather than extrinsic, control beliefs are more likely to predict behavior change [10].

Oral Self-Care, Perceived Control, and Self-Determination Theory

In the present study, both theories are applied to oral self-care behavior (i.e., dental flossing). The American Dental Association (ADA) [17] and British Dental Association (BDA) [18] both recommend an oral health regime which includes daily flossing and brushing to remove interdental plaque and prevent calculus (tartar) formation, periodontal disease, and gingivitis [19]. Despite evidence that the combination of flossing and tooth brushing prevents gingivitis more effectively than tooth brushing alone [20], daily flossing rates are low [21].

Previous research has shown that psychosocial variables predict oral hygiene behavior [22–24], and that interventions informed by social cognitive approaches may change oral self-care behaviors [25]. Some studies have successfully applied self-determination theory to flossing behavior using experimental study designs [26, 27]. In the present research, we evaluate individuals' responses to persuasive messages for oral self-care behaviors, manipulating participants' control beliefs and types of motivation.

Aims and Hypotheses

The aim of this study is to test the effects of manipulating perceived control and motivational focus within persuasive messages for oral self-care behavior using a 2×2 full factorial experimental design, with immediate post-intervention measurement of the proposed mediators, and flossing behavior measured 1 week later. It was hypothesized that:

1. Manipulating perceived control would have a significant main effect on perceived control and subsequent flossing behavior.
2. Manipulating motivational focus would have a significant main effect on intrinsic and extrinsic motivation and on subsequent flossing behavior.
3. The interaction of manipulating perceived control and motivation would yield synergistic effects on flossing, such that the intervention to increase perceived control and intrinsic motivation would show the highest levels of follow-up flossing.

Additionally, we hypothesized the presence of several mediation effects:

1. The main effect of the perceived control intervention would be explained by post-experimental perceived control as a putative mediator between the perceived control intervention and flossing behavior.
2. The main effect of the motivation intervention was hypothesized to consist of intrinsic and extrinsic motivation working as two parallel mediators between the motivation intervention and flossing behavior.
3. Finally, all three putative mediators (perceived control, intrinsic motivation, and extrinsic motivation) would explain the interaction effect of the perceived control and intrinsic motivation intervention on flossing behavior.

Method

Design

Participants were randomly assigned to one of four conditions following a 2×2 factorial design with factors manipulating control beliefs (increasing perceived control vs. decreasing perceived control) and motivation (increasing intrinsic motivation vs. increasing extrinsic motivation) delivered via a computer. Self-report measures of flossing behavior were assessed via computer at baseline and 1 week after receiving the intervention. Perceived control, intrinsic motivation, and extrinsic motivation were assessed via computer immediately following the intervention. The study was approved by the School of Psychology Ethical Board of Aberdeen University (PEC: 1810060780).

Participants

To be eligible for participation in the study, individuals had to be students of Aberdeen University. Participants were recruited predominantly not only from first year psychology tutorials but also from other undergraduate and postgraduate degree programs by email.

Intervention Conditions

The intervention manipulations are briefly described below, along with the appropriate codes from the v1 taxonomy of behavior change techniques (BCTs) [28]. The full text of the manipulations appears in Fig. 1.

Factor 1—Increasing Perceived Control vs. Decreasing Perceived Control

Interventions to alter perceived control were adapted from an earlier study [9]. In the increasing control condition, participants were prompted to recall previous mastery experiences in changing behavior and to describe these using bullet points (BCTs: information about antecedents (4.2); salience of consequences (5.2); focus on past success (15.3)). In the decreasing control condition, participants were prompted to recall previous failures in changing behavior and to describe these using bullet points (BCTs: information about antecedents (4.2); focus on past failures (unlisted); barrier identification alone (unlisted)).

Factor 2—Increasing Intrinsic Motivation vs. Increasing Extrinsic Motivation

The manipulation to increase intrinsic motivation asked participants to reflect on how regular flossing would be in line with their current values system (BCTs: salience of consequences (5.2); information about others approval (6.3); credible source (9.1); valued self-identity (13.4)), and the manipulation to increase extrinsic motivation asked participants to reflect on why the BDA would want the participant to floss regularly (BCTs: salience of consequences (5.2); credible source (9.1)).

Measures

Flossing behavior was measured at baseline and 1 week after the intervention by asking participants the free-response question "How many times have you flossed your teeth in the past seven days?" [22, 23].

Fig. 1 Verbatim full text of intervention content in each factor. Manipulations in the left column were hypothesized as more likely to increase flossing behavior than those in the right column

Factor Manipulating **Perceived Control**	**Increase** Perceived Control	**Decrease** Perceived Control
	Learning how to use dental floss successfully and adding flossing to your daily routines requires conscious efforts. In this study we are interested in learning how people successfully manage to adopt regular flossing. As a background for your experience over the period of this study, we would like you to recall some past experiences with behaviour change. We know that one of the things that influences how well people do in attempt of adopting new healthy practices is your sense of control over making these changes. The more control you believe you have, the better you will succeed at the things you try and do. If you feel optimistic and able to make the changes you intend to, you will do very well. Please reflect briefly and tell us about times when you **successfully made changes** in health practices and achieved things well (e.g., adopting regular tooth brushing, physical activity, changed your diet or stopped smoking). Please give us some examples in bullet points, describing **how you managed** to make this changes and **how it felt to succeed**.	Learning how to use dental floss successfully and adding flossing to your daily routines requires conscious efforts. In this study we are interested in learning what barriers people encounter while trying to make these changes and what makes it difficult to realise these changes. As a background for your experience over the period of this study, we would like you to recall some past experiences with behaviour change. We know that one of the things that influences how well people do in attempt of adopting new healthy practices is the number of obstacles and difficulties they experience when trying to integrate new practices in their everyday life. Often, so many things require one's attention that it is easy to forget new ideas or one simply cannot be bothered. Please reflect briefly and tell us about times when you felt **unable to stick** to the changes in health practices you set out to achieve (e.g., failed to maintain planned levels of daily tooth brushing, regular physical activity, healthy diet or restarted smoking)? Please give us some examples in bullet points, focussing on the difficulties that **prevented you from** successfully **making these changes**.
Factor Manipulating **Motivation**	Increase **Intrinsic** Motivation	Increase **Extrinsic** Motivation
	In this study we are interested in learning the reasons why people would use dental floss. The British Dental Association (2005) recommends daily flossing for all adults. A recent study shows that more and more people in the UK are using dental floss regularly. You might have been using dental floss yourself or might be interested in trying as part of this study. Why would regular dental flossing be attractive to you? How would regular flossing be in line with **your values** and the things that are **important for you** as an individual?	In this study we are interested in learning the reasons why people should use dental floss. The British Dental Association (2005) recommends daily flossing for all adults. Please tell us why you think the BDA makes this recommendation? What would be the **main reasons for** them **to want you to use dental floss** regularly? Please tell us what you assume to be the main reasons for this recommendation in bullet points. The British Dental Association would want me to floss regularly because....

Perceived control was assessed by taking the mean score of five items measuring aspects of perceived behavioral control, each measured on a seven-point unipolar scale (range=1–7; Cronbach's alpha=0.80). Example item: "How much control do you think you have over whether or not you use dental floss everyday over the next seven days?" [29].

Intrinsic and extrinsic motivation were measured by taking the mean of five items measured on seven-point unipolar scales (range, 1–7) with anchors of "not at all true of me" and "very true of me" [30]. Each item begins with the stem "I (would) floss my teeth regularly because…." Example completions of the items for intrinsic motivation include "I personally believe that flossing will improve my oral health" and "I've thought carefully about flossing my teeth and believe it's the right thing to do" (Cronbach's alpha=0.68). Example completions of the items for extrinsic motivation include "other people would expect me to" and "the British Dental Association recommends it" (Cronbach's alpha=0.82).

Procedure

After providing informed consent to participate, participants were given a sealed study pack containing a numbered packet of dental floss (Colgate Total Premium, 10 m), a participant information sheet, and a guide to correct flossing procedures. The provided dental floss was to serve as a means of confirming participants' self-reported flossing and eliminated a lack of dental floss from potentially confounding the results. Participants were asked not to use their own dental floss, but rather to only use that with which they were provided for 7 days. They were also asked not to share the dental floss with other members of their household.

Participants followed a web address enclosed in the study pack to take part in the study. After digitally providing consent to partake in the study and answering a baseline question about frequency of flossing in the past 7 days, participants were randomly delivered one intervention from each factor (described in Fig. 1) according to the full factorial design. The order in which participants received the interventions was randomized to eliminate ordering effects. Immediately after the interventions, participants completed a questionnaire measuring perceived control and intrinsic and extrinsic motivation.

One week after the intervention, participants received an email asking them to return the floss packets to a predetermined drop-off point and to complete an online

follow-up questionnaire assessing flossing frequency over the past 7 days. The returned floss packets were opened and residual dental floss was measured and subtracted from 1,000 cm in order to validate participants' self-reported flossing measures. After completion of the follow-up questionnaire, participants received a debriefing email explaining the aims of the study.

Analyses

Data were analyzed using SPSS 22. Possible intervention effects were tested using intention-to-treat analyses of covariance (ANCOVAs) with all randomized participants remaining in the analyses. Missing data at follow-up were imputed separately for each intervention condition using the expectation maximization method [31]. Main and interaction effects of the four intervention combinations on flossing behavior at 1-week follow-up were tested within a 2×2 full factorial ANCOVA with age, gender, and baseline flossing entered as covariates. Effect sizes are given using eta squared (small=0.01; medium=0.06; large=0.14). Mediation analyses were performed on completed study data using the PROCESS macro for SPSS which estimates mediation effects directly [32]. For all coefficient estimations (ANCOVAs and mediation analyses), a nonparametric bootstrapping procedure with 5,000 resamples was employed [33], which does not impose the assumption of normality of the sampling distribution.

Results

In total, 300 university undergraduate and graduate students were invited to participate in the study. Of these, 115 individuals declined and 185 entered the study (mean age=21.8 years (SD=6.1); range, 17–50 years; 75.1 % female). In total, N=125 completed the follow-up measurement. Figure 2 shows the flow of participants through the study. Tables 1 and 2 show the means, standard deviations, and intercorrelations of each variable—both cumulatively and separated by allocated group. All variables were significantly correlated with each other, except for extrinsic motivation and flossing at follow-up (p>0.05). Residual floss packages were returned by 54 participants and showed a significant correlation of r=0.62 with the self-reported measure of flossing.

Preliminary Analyses

Power Analysis

Based on a meta-analysis which found small-to-medium effects for the relationships between intrinsic motivation, behavior (r=0.29), and perceived control (r=0.37), we assumed that a medium-sized effect would be meaningful within this research. Therefore, using parameters of f=0.25, α=0.05, and power (1-β)=0.80 in a four-group design with main effects and interactions, the estimated sample size necessary was N=128. Expecting a response rate between 40 and 50 % from sending invitations to follow-up, we decided to invite 300 students to take part in the study (see Fig. 2). As 125 of 185 individuals remained at follow-up in the present study (response rates 62 % [185/300] for baseline and 42 % [125/300] for follow-up; response rate of 68 % [125/185]), the actual power is sufficient to detect effects of f=0.25 or larger.

Randomization Check

ANOVA of flossing behavior showed no differences between the four groups at baseline (p>0.05), indicating randomization was successful. Follow-up response rates did not differ significantly between the four intervention groups; $\chi^2(1,184)=1.71$; p=0.63. Thus, attrition was not a function of allocation.

Attrition Analysis

Further analyses (independent samples t test) comparing participants who discontinued study participation before the follow-up flossing measure and those who completed the study showed that intrinsic motivation was significantly higher in those who completed both measurements (p<0.05). This finding is in line with both the social cognitive theories and self-determination theory assumptions that intention to perform a behavior and intrinsic motivation are important determinants of an individual's level of perseverance with the behavior. Additionally, there was a significant gender difference with female students more likely than males to complete the post-intervention follow-up measure. There were no significant differences in age, perceived control, or extrinsic motivation between the individuals who completed the study and those who dropped out (all, p>0.05).

Ordering Effects

To nullify ordering effects, half of the participants were randomly allocated to receive the perceived control intervention first, while the other half began with the motivational intervention. No significant ordering effects appeared for any of the variables under study ($t(126)=1.03$, p=0.31).

Intervention Completion

Overall, eight individuals filled in the baseline questionnaire but did not undergo and complete interventions from both factors. Four participants did not complete an intervention from either factor, two completed only the perceived control intervention, and two completed only the motivation

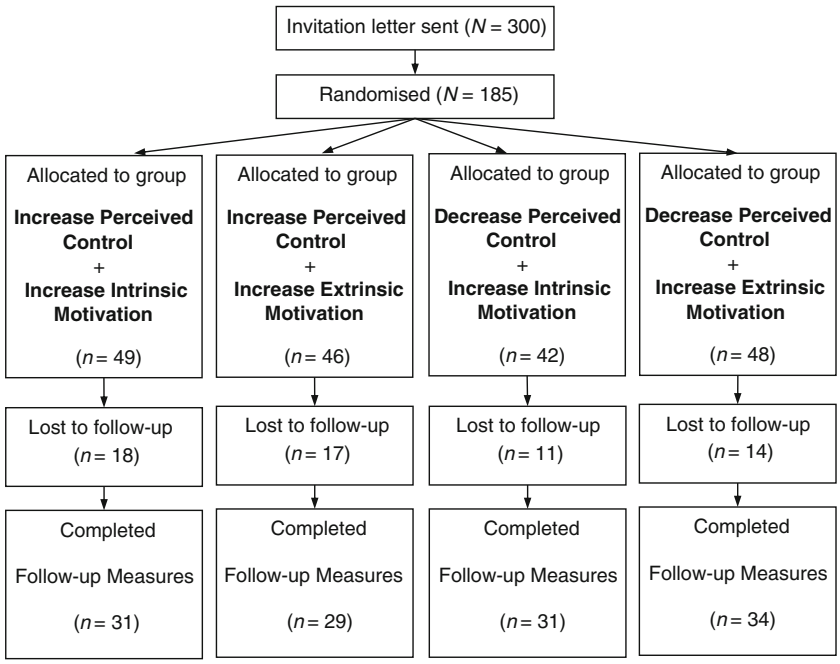

Fig. 2 Flow chart of the allocation of participants within the full factorial design

intervention. No significant relationships were found between participants that did not complete the interventions and baseline flossing.

Effects on Flossing Behavior

A full factorial ANCOVA for post-intervention flossing and controlled for baseline flossing, age, and sex showed a small main effect of the perceived control intervention on flossing behavior ($F(1,184)=3.92$, $p=0.04$; $\eta^2=0.02$). This equates to one more instance of flossing per week by participants who received the intervention to increase perceived control (estimated marginal mean=5.60; SE=0.33) than those who received the intervention to decrease perceived control (estimated marginal mean=4.66; SE=0.34). While participants who received the intervention to increase intrinsic motivation (estimated marginal mean=5.48; SE=0.34) reported flossing 0.7 times per week more than those who received the intervention to increase extrinsic motivation (estimated marginal mean=4.78; SE=0.33), the main effect of the motivation intervention was not significant ($F(1,184)=2.17$, $p=0.14$).

There was an interaction effect of the control and motivation interventions ($F(1, 184)=11.80$, $p=0.001$, $\eta^2=0.06$) on flossing behavior. A focused contrast revealed that the increasing control/increasing intrinsic motivation group reported significantly more flossing at follow-up than all other groups (bootstrapped mean difference=2.43; $t(183)=4.04$, $p<0.001$) with a medium-to-large effect size (Cohen's $d=0.67$) (see Fig. 3). The covariates past behavior ($F(1,184)=53.78$, $p<0.001$; $\eta^2=0.23$) and age ($F(1,184)=49.14$, $p=0.03$; $\eta^2=$

Table 1 Group means and standard deviations for demographic and study variables including tests for differences between groups

Variable	Total sample $n=185$	Increase control Increase internal mot. $n=49$	Increase control Increase external mot. $n=46$	Decrease control Increase internal mot. $n=42$	Decrease control Increase external mot. $n=48$	p
Gender (% female)	75.5	70.8b	73.9a,b	90.5a	68.8b	0.08
Age	21.8 (6.08)	21.9 (5.04)	22.5 (7.56)	21.2 (5.51)	21.7 (6.17)	0.78
Baseline flossing	2.17 (3.36)	2.61 (3.55)	1.06 (2.26)	2.71 (3.45)	2.33 (3.81)	0.07
Perceived control	5.37 (1.26)	5.72 (1.22)a	4.96 (1.28)b	5.43 (1.28)a,b	5.35 (1.18)a,b	0.03
Intrinsic motivation	5.20 (1.41)	5.52 (1.40)	4.88 (1.50)	5.09 (1.45)	5.28 (1.28)	0.15
Extrinsic motivation	3.78 (1.18)	3.81 (1.21)a,b	3.60 (1.21)a,b	4.22 (1.03)a	3.55 (1.16)b	0.03
Follow-up flossing	5.17 (3.76)	6.96 (3.57)a	4.76 (3.21)b	4.62 (3.50)b	5.18 (4.05)a,b	<0.001

Note: Values refer to imputed data. p values of one-way ANOVA with intervention groups as four-level factor and for gender chi-square test. For each variable, group values without the same lowercase letters significantly differ from one another ($p<0.05$)

Table 2 Correlations between basic demographic and study variables

	Variables	1	2	3	4	5	6
1	Gender [a]	–					
2	Age	0.01	–				
3	Baseline flossing	−0.01	0.20**	–			
4	Perceived control	−0.23**	−0.02	0.32***	–		
5	Intrinsic motivation	−0.16*	−0.03	0.34***	0.51***	–	
6	Extrinsic motivation	−0.15*	−0.09	0.07	0.16*	0.33**	–
7	Follow-up flossing[b]	−0.05	−0.03	0.39***	0.45**	0.41**	0.01

*$p<0.05$; **$p<0.01$; ***$p<0.001$

[a] Gender is coded 1=female and 2=male students

[b] Questionnaire-assessed flossing behavior was correlated with objectively assessed flossing from returned dental floss packets ($r=0.62$**; $n=54$)

0.03) significantly predicted behavior at follow-up. The covariate gender was not significant ($F(1,184)=11.30$, $p=0.29$).

Effects on Theoretical Constructs

The motivation intervention factor had a significant main effect on extrinsic motivation in an unexpected direction ($F(1,184)=5.10$, $p=0.03$, partial $\eta^2=0.03$; for full ANCOVA results see Table 3). Participants who received the intervention to increase intrinsic motivation scored higher on extrinsic motivation than participants who received the intervention to increase extrinsic motivation. Regarding interaction terms, the interaction of perceived control and motivation intervention factors had a significant effect on perceived control ($F(1,184)=5.40$, $p=0.03$; partial $\eta^2=0.03$). The group that received interventions to increase perceived control and extrinsic motivation had the lowest perceived control score ($M=4.96$; SD=1.28). Furthermore, the perceived control and motivation intervention interaction term significantly predicted intrinsic motivation ($F(1,184)=5.56$, $p=0.02$; partial $\eta^2=0.03$) (see Table 3).

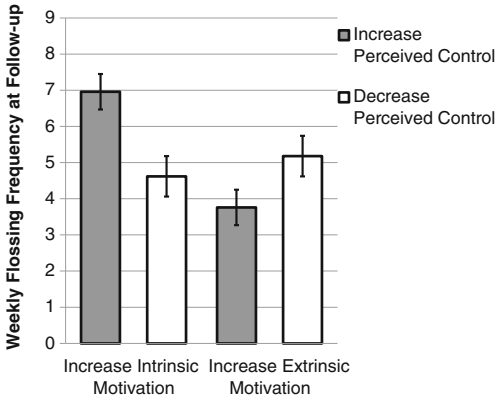

Fig. 3 Mean values of follow-up flossing behavior by intervention group. Note: *Error bars* are for SE. The interaction effect of the control and motivation intervention ($F(1,184)=11.81$; $p=0.001$; $\eta^2=0.063$) on flossing behavior was significant, indicating that participants in the increasing perceived control+increasing intrinsic motivation group flossed 2.3 more times per week than participants from the other three groups

Mediation Analyses

Overall, results indicated support for the three mediation hypotheses. Looking into the main effect of the perceived control intervention (1=increasing perceived control, 2=decreasing perceived control) on flossing, there was a weak but significant mediation effect via perceived control ($B=-0.35$, 90%LLCI| ULCI= −0.87|−0.02) in that the increasing control intervention groups had higher levels of perceived control and these, in turn, were associated with higher levels of flossing.

In a multiple mediator model, the mediation effect of the motivation intervention (main effect; 1=intrinsic, 2=extrinsic) on flossing behavior through extrinsic motivation was significant ($B=0.28$, 90%LLCI|ULCI=0.02|0.76), but the mediation effect through intrinsic motivation was not ($B=0.03$, 90%LLCI|ULCI=−0.63|0.22).

In a final mediation model with all three theoretical constructs as parallel mediators between the interaction effect (increasing control and intrinsic motivation group=1 vs. all others=0) and flossing, perceived control ($B=0.57$, 90%LLCI|ULCI=0.22|1.19), and intrinsic motivation ($B=0.43$, 90%LLCI|ULCI=0.09|0.96) were the only significant mediators. These results are shown in Fig. 4.

Discussion

This study conducted the first full factorial experimental test of brief interventions targeting changes in perceived control and intrinsic and extrinsic motivation—the major determinants of behavior in social cognition models and self-determination theory, respectively—to increase dental flossing behavior.

Table 3 Effects on theoretical constructs

Outcomes	Intrinsic motivation				Extrinsic motivation				Perceived control			
Predictors	Sum of squares	*F*	Sig.	Partial eta squared	Sum of squares	F	Sig.	Partial eta squared	Sum of squares	*F*	Sig.	Partial eta squared
Type III sum of squares[a]												
Age	0.27	0.14	0.71	0.001	1.35	1.01	0.32	0.01	0.05	0.04	0.848	0.00
Gender[b]	11.73	6.10	0.01	0.03	3.28	2.47	0.12	0.01	15.44	10.44	0.001	0.06
Perceived control factor[c]	0.17	0.09	0.77	0.00	1.16	0.87	0.35	0.01	0.002	0.001	0.97	0.00
Motivation factor[c]	1.22	0.63	0.43	0.004	7.07	5.31	0.02	0.03	5.82	3.93	0.049	0.02
Interaction term[d]	10.69	5.56	0.02	0.03	1.91	1.43	0.23	0.01	7.99	5.40	0.03	0.03
R^2 (adjusted R^2)	*0.06*	(*0.04*)			*0.07*	(*0.04*)			*0.10*	(*0.08*)		
Type II sum of squares[a]												
Age	0.27	0.14	0.71	0.001	1.35	1.01	0.32	0.01	0.05	0.04	0.85	0.00
Gender[b]	11.73	6.10	0.01	0.03	3.28	2.47	0.12	0.01	15.44	10.44	0.001	0.06
Perceived control factor[c]	0.09	0.05	0.83	0.00	1.06	0.79	0.37	0.004	0.004	0.003	0.96	0.00
Motivation factor[c]	1.52	0.79	0.38	0.004	6.80	5.10	0.03	0.03	6.37	4.31	0.04	0.02
Interaction term[d]	10.69	5.56	0.02	0.03	1.91	1.43	0.23	0.01	7.99	5.40	0.02	0.03
R^2 (adjusted R^2)	*0.06*	(*0.04*)			*0.07*	(*0.04*)			*0.10*	(*0.08*)		

Note: N=184. Analysis of covariance results based on bootstrapped (5,000 resamples) imputed data. Significant interpretable values in bold, and R^2 values in italics.

[a] Type III sum of squares was used to test for interaction effects. Type II sum of squares was used to test for main effects. If there is no significant interaction effect, then type II is more powerful and follows the principle of marginality. If interaction is present, then type II is inappropriate while type III can still be used, but results need to be interpreted with caution (in the presence of interactions, main effects are rarely interpretable)

[b] Gender is coded 1=female and 2=male students

[c] The increasing perceived control×increasing intrinsic motivation group is coded as 1, all other groups are coded as 0

[d] interaction term control intervention×motivation intervention

Main Effect of the Perceived Control Intervention

As hypothesized, the intervention to increase perceived control had a significant main effect on flossing behavior: individuals who received this intervention reported more frequent flossing 1 week after the intervention than individuals who received the intervention meant to decrease perceived control.

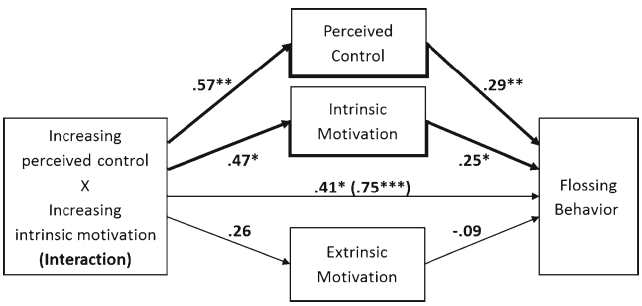

Fig. 4 Mediation model of the interaction effect of the intervention on follow-up flossing behavior via proposed theoretical constructs. Note: *p<0.05; **p<0.01. Standardized coefficients are displayed; all values are estimated using bootstrapping procedures, and the model is controlled for age, gender, and past behavior (not displayed); significant mediation paths are displayed in *bold*; the increasing perceived control×increasing intrinsic motivation group is coded as 1, all other groups are coded as 0

Mediation analyses subsequently revealed that the effects of the interventions on increases in flossing behavior were largely attributable to higher levels of perceived control. This experimental finding is in line with previous correlational and intervention research on oral self-care behaviors [22–25] and provides additional evidence on the importance of perceived control in explaining behavioral change.

Main Effect of the Motivation Intervention

Although individuals who had received the intervention to increase *intrinsic* motivation reported flossing more frequently posttreatment than those who received the intervention to increase *extrinsic* motivation, the magnitude of this main effect did not reach significance—perhaps because the study was not powered to detect small effects. The motivation intervention did however have a significant main effect on extrinsic motivation, albeit in an unexpected direction: The group that received the intervention to increase intrinsic motivation reported significantly higher levels of extrinsic motivation. This could be attributable to baseline differences between the groups but may also indicate that intrinsic forms of

motivation take time to develop [34] or that extrinsic motivation is more readily changeable within individuals than intrinsic motivation.

Interestingly, in examining mediation for this contrast, extrinsic motivation mediated the effect of the motivation manipulation on flossing behavior, whereas intrinsic motivation did not. This is again contrary to our hypotheses in that intrinsic motivation was expected to be predictive of flossing behavior at follow-up. While this finding may be an artifact of the unexpected direction of the intervention's effect on extrinsic motivation, the results are not entirely counterintuitive, as the group with the lowest flossing rate (decreasing control/increasing intrinsic motivation) also had the highest scores on extrinsic motivation. While this supports the idea that the type of motivation the participant feels for the behavior (controlling or self-determined) is critical in explaining behavioral change, more research is needed to fully explicate the conditions under which intrinsic motivation is superior to extrinsic motivation in changing health behaviors.

Interaction Effect of the Interventions

Individuals who had received the combination of interventions meant to increase perceived control, and intrinsic motivation reported significantly more flossing behavior and greater perceived control after the intervention than individuals in the other three intervention groups. These findings are in accordance with our hypotheses and add to evidence which has identified the importance of targeting both intrinsic motivation and perceived control to change behavior [34]. In investigating mediation of this interaction effect on flossing (increasing control × intrinsic motivation), in line with theoretical assumptions, perceived control and intrinsic motivation were significant mediators. The patterns evident within this cumulative mediation model are therefore markedly different from the previous mediation model which did not include perceived control and only showed extrinsic motivation as a mediator. This contrast gives credence to the idea that perceived control and intrinsic motivation interact, and perhaps strengthen one another, in predicting changes in behavior.

From these results, it can be argued that the intervention increasing perceived control and promoting self-determined engagement with flossing (increasing control × intrinsic motivation) had beneficial effects on behavior and perceived control. In contrast, the increasing control × extrinsic motivation group scored lowest on nearly all variables. This suggests that participants who felt flossing was an externally controlled behavior were cognitively unresponsive to engaging in it, although this did not transform into a behavioral outcome as the decreasing perceived control/increasing intrinsic motivation group recorded the least frequent flossing.

Recent research has tried to integrate self-determination theory and social cognitive assumptions because these approaches seem to provide complementary explanations of the processes that underlie motivated behavior [12]. For instance, intrinsic motives might potentially work as distal predictors of perceived control. The theory suggests that motivation to engage in health-related behaviors for self-determined or controlling (extrinsically motivated) reasons predisposes individuals to form beliefs congruent with these motives—e.g., flossing in order to care for teeth as it is good for the individuals' own health (self-determined motive) vs. doing so to look good for others (external contingency; controlling). This is in line with the results of the present study which show that high control beliefs in conjunction with intrinsic motives result in additional flossing beyond the main effects of control or motivation in isolation.

Practical Implications

All intervention groups reported significantly higher rates of flossing after the intervention than they did at baseline. The average flossing rate for participants at baseline was just over two times per week, with the majority (55 %) reporting that they did not floss at all in the week prior to the intervention. At the end of the study, mean flossing rates varied across groups, from around four times per week in the decreasing perceived control/increasing intrinsic motivation group to more than seven times per week in the increasing perceived control/increasing intrinsic motivation group, with only the latter achieving the equivalent of the once-daily flossing rate recommended by the BDA. Within this group, more than 90 % of the participants reported more flossing post-intervention than at baseline. This is an important finding, as it shows that even brief interventions can (at least in the short term) effectively improve oral self-care behaviors—even to the rate thought necessary to produce maximum benefits in preventing cavities and gingivitis. Such interventions are therefore worthy of additional investigations to identify ways that they can be supplemented to improve oral self-care behavior over longer follow-up periods.

Strengths and Limitations

One strength of this study lay in its design, as it presents the first full factorial experimental test of variables from both the TPB and SDT. As such, it allowed manipulation of both perceived control and motivational focus (intrinsic/extrinsic), the combination of which resulted in significant changes in flossing behavior. Despite the strong design, the study does have a number of notable limitations. First, outside of the interaction effects, not all cognitive variables reported were affected by the perceived control or motivation interventions in the directions we had hypothesized. More effective and reliable manipulations of these constructs are needed in order to adequately test and refine theory. Second, while significant

behavioral changes were found over a 1-week period, the long-term effects of these manipulations is unclear and should therefore be further investigated in future research. Third, while the residual floss from returned floss packages was intended to be used as an objective measure of flossing behavior, the low return rate meant that it was not possible to use this even as a secondary outcome for this study. Future research in this area is needed to identify and develop reliable ways to objectively measure dental flossing that would be feasible over longer periods of time—perhaps using electronic sensors [35]. Finally, the student sample used in the study somewhat limits the generalizability of the findings, so replication across other populations is also merited.

Conclusions

This study demonstrates that a very brief intervention to increase perceived control, when embedded in a persuasive message promoting dental flossing behavior, can lead to significant increases in flossing behavior, a main effect which appears to operate through increases in perceived behavioral control. Furthermore, combining this intervention to increase perceived control with a brief intervention to increase intrinsic motivation appears to enhance these effects on flossing behavior, as the group of individuals who received both interventions nearly tripled their flossing frequency to the level recommended by the ADA. This full factorial experimental test of interventions to manipulate constructs crucial to both SDT and SCT is the first of its kind, and the first to experimentally demonstrate the importance of this interaction. These findings provide preliminary evidence for the utility of integrating of SCT- and SDT-based approaches to intervention development, as levels of perceived control and intrinsic motivation mediated this strong interaction effect. Future research should investigate whether these findings can be replicated across additional health behaviors, and whether the combination of SCT and SDT might also contribute to improved maintenance of behavioral changes.

Authors Statement of Conflict of Interest and Adherence to Ethical Standards Authors Liam Staunton, Paul Gellert, Keegan Knittle, and Falko F. Sniehotta all declare to have no conflict of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. The study was approved by the School of Psychology Ethical Board of Aberdeen University (PEC: 1810060780).

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