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Compensation and Transfer Effects of Eating Behavior Change in Daily Life: Evidence from a Randomized Controlled Trial

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Abstract

Pursuing specific eating goals may lead to the adoption of other healthy behaviors (transfer) or compensation with unhealthy behaviors. Previous research has mostly investigated such processes using non-experimental studies focusing on interindividual differences. To investigate transfer or compensation of eating behavior in daily life, we analyzed data from a 2 (eating goal: more fruit and vegetables [FV] vs. fewer unhealthy snacks) x 2 (intervention vs. control group) factorial randomized trial. Adopting a within-person perspective, we studied potential transfer and compensation 1) between different eating behaviors and physical activity (PA), and 2) in response to an eating behavior change intervention. Participants (N=203) received either goals to increase FV intake or decrease unhealthy snack intake and completed a daily e-diary. Eating more unhealthy snacks predicted 0.16 less FV portions ($\beta = -0.07$; $p < 0.001$) and 18% less unhealthy snack intake the next day ($p < 0.001$). Eating more FV predicted 0.42 less FV portions the next day ($\beta = -0.07$; $p < 0.001$). Participants with the FV eating goal intervention decreased unhealthy snacks ($p = 0.012$) and PA ($p = 0.019$) by 8% compared to controls, respectively. Similar but non-significant patterns were observed for participants with the decreasing unhealthy snack goal intervention ($p > 0.05$). Results indicated both compensation and transfer processes in daily life. Relationships mostly occur within the same behavior and rather support compensatory effects. In turn, a behavior change intervention to promote FV intake potentially enhances non-assigned eating behaviors, indicating transfer, but may lower PA.

Keywords: multiple health behavior change, transfer effects, compensation, eating behavior, physical activity

Introduction[2]

A healthy diet is as an essential part of a healthy lifestyle. Fruit and vegetable (FV) consumption is related to weight loss, lower overweight, and lower obesity (Ledoux et al., 2011; Pengpid & Peltzer, 2016; Yu et al., 2018) as well as reduced risk for cardiovascular disease, ischemic heart disease, and overall mortality (Crowe et al., 2011; Wang et al., 2014). Conversely, extensive fat and sugar intake have been associated with an increased risk for overweight, obesity, and cancer (World Cancer Research Fund & American Institute for Cancer Research, 2018). Thus, for a healthy lifestyle, it is recommended to have a high amount of FVs in one's diet and to avoid high levels of saturated fat and sugar intake (Montagnese et al., 2015). However, adult's intake of fat and sugar is on average too high (Azaïs-Braesco et al., 2017; Kehoe et al., 2019), and FV consumption is on average too low (Mertens et al., 2019). Hence, several studies developed interventions targeting one of those health behaviors, e.g. sending text messages to increase FV consumption (Brookie et al., 2017) or social support groups to decrease unhealthy snacking (Inauen et al., 2017).

Although changing one health behavior is beneficial, health benefits regarding chronic disease prevention are larger when more health behaviors are implemented, such as combining FV consumption, decreasing sugar intake, and increasing physical activity (PA) (Hu et al., 2001; Yusuf et al., 2004). However, nutrition intervention studies typically only investigate a targeted behavior and do not assess effects on related eating behaviors (e.g. Brookie et al., 2017; König & Renner, 2019). People can respond to changing one health behavior with either displaying or neglecting other healthy behaviors. Behavioral compensation typically means that a person engages in a healthy behavior in order to compensate for the effects of an unhealthy behavior they engaged in or plan to endorse in the near future (Amrein et al., 2017; Knäuper et al., 2004). In contrast, behavioral transfer means that engagement in one health

[2] Abbreviations: FV = fruit and vegetables; PA = physical activity

behavior, called “gateway behavior”, e.g. eating more FV (Nigg et al., 2009), leads to more engagement in another healthy behavior (e.g. being more physically active) or less engagement in another unhealthy behavior (e.g. eating less unhealthy snacks) (Dolan & Galizzi, 2015; Fleig et al., 2015; Geller et al., 2017; Lippke et al., 2012).

Empirically, several cross-sectional studies support transfer effects between energy-related behaviors, suggesting that people with a healthier diet are also more physically active (Blakely et al., 2004; Cavadini et al., 2000; Keller et al., 2008). Or, vice versa, those who are less physically active also have a less healthy diet (Lawder et al., 2010; Poortinga, 2007). Comparatively fewer studies have investigated behavioral relationships within the same health behavior domain, such as food intake. For example, a study with almost 4,000 US adults compared dietary behaviors on two days, with one day having a snack episode in it and the other one without a snack episode. Results showed that on the snack day, participants ate more fruits but skipped main meals (Kant & Graubard, 2019).

Some intervention studies investigated compensation and transfer effects between energy-related behaviors, but only few studies investigated effects of a nutrition intervention of non-intervened nutrition behaviors and non-intervened physical activity, for example a FV consumption intervention’s effect on fat intake or physical activity. A systematic review summarizing the effects of dietary interventions on non-exercise PA, which refers to activities of daily living, did not find support for behavioral compensation in six out of seven studies (Silva et al., 2018). However, those studies investigated explicitly activities of daily life and not overall PA. One recent laboratory study investigated the effects of unhealthy snacking on participant’s activity choice (Petersen et al., 2019). Participants were either provided with a healthy or an unhealthy snack. They then had to choose either to engage in an exercise activity (treadmill run) or a sedentary activity (gaming on the iPad). Participants who were provided with a healthy snack chose more often to engage in a sedentary activity afterwards (44%) than participants that were provided an unhealthy snack (24%; $\varphi = 0.35$, $p = 0.035$) (Petersen et al., 2019), which supports behavioral compensation. Within the nutrition domain, one study showed that an intervention to increase hazelnut snacks decreased saturated fat intake from 11.9% to 11.2% ($p < 0.01$) and carbohydrate intake from 47.3% to 43.3% ($p < 0.01$) in the respective group compared to two other snack groups (chocolate and potatoes crisps) and no snack group (Pearson et al., 2017), hence supporting behavioral transfer. Results of intervention studies that investigated the effects of a PA intervention on food intake were heterogeneous. Findings were showing no compensation of PA with unhealthy snacks (d = 0.12, $p > 0.05$) (Inauen et al., 2018), compensation of prescribed exercise with higher energy intake (123.6 more kilocalories per day) compared to the control group (-2.3 kilocalories less per day; $p < 0.05$) (Martin et al., 2019), and transfer effects of a PA intervention to lower fat intake from baseline (31.24% dietary fat intake) to follow-up twelve months later (30.36%, $p < 0.01$) (Dutton et al., 2008). Regarding FV consumption, one study did not show changes in FV intake due to a PA intervention ($p > 0.05$) (Dutton et al., 2008) while another one found increased FV consumption after a six-week exercise intervention (partial $\eta 2=0.02$, $p < 0.01$) (Fleig et al., 2011).

To date, studies investigating cross-behavioral relationships have mostly used basic observational study designs such as cross-sectional studies or intervention studies with only a few assessments and long follow-up periods. This type of research in dietary behaviors has some limitations. First, recall-bias is a common problem when reporting dietary behaviors retrospectively (Seitzinger et al., 2019; Van Zyl et al., 2016). Second, previous studies assessed dietary behaviors, such as snacking, only at a single or very few time points. The data obtained at a single occasion is assumed to represent the person as a whole and to be time-invariant and stable (Hoffman, 2015) and is hence used to examine interindividual (between-person) differences, e.g., comparing the typical snack intake over a week between study participants. However, the problem is that many dietary behaviors, such as snacking, are not stable within a person.

Intensive longitudinal methods (Bolger & Laurenceau, 2013) can potentially overcome these limitations. They allow studying individuals' health behaviors in their everyday lives through multiple assessment in or close to real-life, thus maximizing ecological validity and reducing recall bias (Bolger & Laurenceau, 2013). Even more, the collected data enables researchers to model both within- and between-person processes (Bolger & Laurenceau, 2013), hence capturing individuals' variability within and across health behaviors. The within-person perspective allows to investigate intraindividual variation over time, thus considering that dietary behaviors can vary over time within a person. For example, on a particular day, a person may eat one snack, on the subsequent day they eat five snacks, on day three two snacks and so on. It is crucial to distinguish within- and between-person effects as relationships at the within-person level often do not necessarily mirror those at the between-person level (Hoffman, 2015). Also, the distinction of within- and between-person effects allows to model both.

In addition, intensive-longitudinal methods allow the distinction of fixed and random effects. Fixed effects refer to the model of the means, describing for the typical person how an outcome (e.g. snacking) varies as a function of a predictor (e.g., PA). However, the effect of a predictor on an outcome may be heterogeneous, i.e. different for each person (Bolger et al., 2019). Intensive-longitudinal data allow modelling between-person differences in the processes of interest using random effects, in this way modeling and predicting patterns of variance (Hoffman, 2015).

Although intensive longitudinal data are a very promising approach to investigate within-person cross-behavioral relationships, only two studies so far applied this design. One study monitored healthy adults for seven consecutive days, finding no association between variabilities of PA and caloric intake on a day-to-day basis (Hooker et al., 2020). Another study monitored a sample of young African-American college students across seven consecutive days in their energy-related behaviors, showing that PA was transferred to healthy dietary intake (FV consumption, water intake) and simultaneously compensated with unhealthy dietary intake (sugar-sweetened beverage and fried fast food consumption) within a two-hour time frame (Maher et al., 2020). As both of these studies were observational, no conclusions on causality of the effects can be drawn.

In summary, several studies investigated relationships between different dietary behaviors and PA, with heterogeneous results. In addition, when going beyond correlational analysis, PA was mostly referred to as the gateway behavior (Fleig et al., 2011; Maher et al., 2020), but studies investigating the relationship vice versa, i.e. dietary intake predicting PA, are scarce. Also, studies mostly investigated relationships between different health behavior domains, such as dietary intake and PA (Blakely et al., 2004; Cavadini et al., 2000; Keller et al., 2008), but studies applying a within-person perspective to investigate relationships within the food domain are lacking. Further, although two intervention studies investigated relationships between healthy eating and PA (Petersen et al., 2019; Silva et al., 2018), none have done so for different energy-related behaviors, and none have used randomized designs to arrive at robust conclusions on causality of effects.

Hence, this study aims to expand previous research, using an intensive longitudinal approach in a 2 (eating goal: more FV vs. fewer unhealthy snacks) x 2 (intervention vs. control group) factorial randomized trial with daily assessments of FV, unhealthy snacks, and PA across 10 days (Inauen et al., 2017, see also *Figure 1*). The hypotheses are presented in the following:

H1: Increases in FV consumption are related to same-day decreases in unhealthy snack consumption and vice versa. Increases in FV consumption and decreases in unhealthy snack consumption are related to same-day increases in PA.

H2: Increases in FV consumption are related to next-day decreases in unhealthy snack consumption and increases in PA. Decreases in unhealthy snack consumption are related to next-day increases in FV consumption and increases in PA.

H3: Persons in the goal condition eating more FV will show significant decreases in unhealthy snack consumption and increases in PA. Persons in the goal condition eating fewer unhealthy snacks will show significant increases in FV consumption and increases in PA.

For H2, in addition to the cross-behavioral relationships between the two eating behaviors and PA, we explored relationships within the same behavior (FV consumption, unhealthy snacking, PA).

Methods

We analyzed data from a 2 (eating goal: more FV vs. fewer unhealthy snacks) x 2 (intervention vs. control group) factorial randomized trial (Inauen et al., 2017). Participants were randomly allocated to four conditions in a 1:1:1:1 allocation ratio: 1) intervention group (social support) – eating fewer unhealthy snacks, 2) control condition – eating fewer unhealthy snacks, 3) intervention group (social support) – eating more FV, and 4) control condition – eating more FV. The relevant intensive-longitudinal outcome data for the present study were collected once a day three days prior to the intervention (Days 1-3), and during the intervention (Days 4-10). Ethical approval was obtained from the Internal Review Board of the University of Zurich.

The hypotheses of the present study were registered prior to data analysis on the Open Science Framework available at: https://osf.io/243du/. The main effects of the intervention on assigned eating goals showed that the social support intervention was able to promote healthy eating for the targeted eating behaviors compared to controls (Inauen et al., 2017). The focus of the present study are the cross-behavioral effects during the intervention period (observational effects), and intervention effects for non-assigned eating behaviors.

Participants and procedures

A detailed description of the trial and the procedures has already been reported (Inauen et al., 2017). Participants were recruited of the staff and student population of the University of Zurich via social networks, emails and flyers. We targeted participants with an intention-behavior gap regarding healthy eating, using the heading “Do you intend to eat healthily but find that difficult sometimes?”. Participants were excluded from participation if they were younger than 18 years, had a Body-Mass-Index (BMI) below 18, currently participated in a weight loss program or were on a diet, did not own a smartphone, or were not fluent in German. Sample size was determined a priori to detect a small to medium intervention effect (d = 0.35) on the assigned healthy eating goal using G*Power (Faul et al., 2007). Based on an independent samples t-test, 80% power, and the assumption of two-tailed Type 1 error probability, we determined a total sample size of 204 participants. As our pilot study suggested 15% dropout, we aimed to recruit 236 participants to obtain a final sample of 204 participants.

A research assistant randomized the participants into the conditions by entering their names in the order that they signed up for the study into a list of block-randomized cells (block size eight), created by random number generation. We applied a single-blind design with interventionist being blinded until participants visited the lab to provide written consent and the participants being blinded to allocation until the end of the second follow-up. Participants' height and weight were measured through research staff before they were given the questionnaire for the baseline survey. Following that, all participants received basic information on healthy eating about their assigned eating goal. Participants randomized to the intervention group then received instructions for the social support intervention. For the following 13 days (including three post-intervention days not relevant here), all participants were asked to keep an e-diary that prompted them to report their eating and PA behavior once a day in the evening. After the end of the study, participants were entered into a lottery for a prize with a value of $1,000 US or to receive course credit (students only).

Measurement

Eating behavior. Eating behavior was assessed via self-report through e-diaries. Each evening, participants were asked “How many servings of fruit and vegetables did you eat today?” and “How many unhealthy snacks did you eat today?”. An unhealthy snack was defined as any food of the non-core categories (e.g. candies or cake) consumed between main meals (Kelly et al., 2007). The outcome was assessed in number of FV portions and number of unhealthy snacks. As reports were based on a single question each day, reliability could only be estimated as the consistency of responses over 10 days. This resulted in a Cronbach’s alpha of 0.92 for FV consumption and 0.84 for unhealthy snack consumption, indicating a systematic response (Inauen et al., 2017). Validity of momentary assessment for dietary intake on a day level has been confirmed (Bruening et al., 2016).

Physical activity. Physical activity (PA) was also assessed via self-report through electronic e-diaries. Each evening, participants were asked “How many minutes were you physically active today?” We estimated the consistency of the responses across the 10 days for the PA variable, resulting in a Cronbach’s alpha of 0.87, indicating a systematic response.

Covariates. At study registration, several sociodemographic and health characteristics of participants were assessed, including age, sex, vegetarian/vegan diet, diabetes as well as height and weight (taken by trained research staff) to calculate the body mass index (BMI). Furthermore, active participation in the WhatsApp chat groups was coded (0 = no message sent; 1 = at least one message sent). In addition, social desirability (Paulhus, 1991; Winkler et al., 2006; alpha = 0.61), restrained eating (Grunert, 1989; Van Strien et al., 1986; alpha = 0.88), and stress (Kuhl & Fuhrmann, 1998; alpha = 0.87) were assessed.

Intervention

All participants received *information on healthy eating* by trained students of the psychology Master program at individual lab appointments. The information material included behavior change techniques (BCTs) 1.1 “Goal setting” and BCT 5.1 “Information about health consequences” (Michie et al., 2013). For a detailed description of the intervention materials, see the supplement of Inauen et al. (2017). The information material (presented as a fact sheet) was tailored to the assigned eating goal (decreasing unhealthy snack consumption / increasing FV). The fact sheet included a definition and health effects of the assigned eating goal as well as current recommendations for the eating behavior. The participants’ assigned eating goals were verbally reinforced with one sentence that was also printed on the factsheet (“Therefore, it is very important that you eat more fruit and vegetables / avoid unhealthy snacks”).

The *social support intervention* was based on BCT 3.1 “Social support (unspecified)” (Michie et al., 2013). Following the healthy eating information, participants that were allocated to the social support condition were informed that they would be invited to a WhatsApp chat group by the group administrator on Day 4 of the diary for seven days. WhatsApp is a popular smartphone app (Montag et al., 2015). The application provides a chat room where people can exchange multimedia content through the smartphone’s internet connection and other internet-connected devices. Confidentiality of participants’ identity and exchanged content was ensured. Participants were assigned to WhatsApp chat groups after randomization (N = 32; range: 2-5 participants; median = 3 participants/group) plus one trained female supporter (a member of the study team). Supporters provided one standardized support message on each of the seven intervention days. In addition, all supporters were instructed to reply with a supportive message to any message posted based on list of standardized supportive responses.

Data analysis

To make the best use of our data, we analyzed them using generalized estimating equations (GEE) that consider dependency of the observations within-persons over time (Hardin &

Hilbe, 2013; Liang & Zeger, 1986) rather than conducting aggregated analyses as initially foreseen in the study registration. Two of our outcomes (number of unhealthy snacks and PA minutes) were positively skewed, wherefore we specified a negative binomial distribution and a log link function for those two outcomes (Gardner et al., 1995). For FV consumption, we specified a linear distribution. For all analyses, the significance level was set at $p < 0.05$. Prior to the data analysis, values of FV consumption, unhealthy snacking, and PA were restricted to 3 SD around the mean to account for the effects of outliers (Howell, 1998). In addition, the Mahalanobis distance was calculated to identify multivariate outliers using linear regression (Tabachnick & Fidell, 2013). Multivariate outliers were defined as $p < 0.001$ for the $\chi 2$-value of the case (Tabachnick & Fidell, 2013). All models were calculated with univariate outliers restricted to 3 SD and multivariate outliers excluded.

To distinguish within-person and between-person effects, we performed centering (Inauen et al., 2016). For the between-person effects, representing stable differences in eating behaviors and PA, we calculated the average number of FV portions and unhealthy snacks as well as PA minutes for each person across Days 1 to 10 (between-person mean). These were grand-mean centered by subtracting the mean of all participants from each person's mean. For the within-person changes in eating behaviors and PA, we centered the number of FV portions, unhealthy snacks, and PA minutes on the person's mean within the study period by subtracting the person's individual mean from the daily value. We further calculated the intraclass correlation coefficient that shows the part of the overall variance that is due to between-person effects by estimating one null model for each health behavior (Singer et al., 2003).

Following procedures explained in Inauen et al. (2017), each model adjusted for the pre-intervention time, which was centered on the last day before the intervention (Day 3) started using -2, -1, and 0, and the intervention time (centered on the last day of the intervention). We time-lagged FV consumption, unhealthy snacking, and PA by one day to investigate prospective associations between one day and the next day within and between the three behaviors. The working correlation structure of the GEEs was set to first-order auto regressive correlation (AR 1). For outcomes with negative binominal distribution, the effect sizes are reported in rate ratios (RRs). The RRs indicate the percentage decrease (values < 1) or increase (values > 1) in numbers of unhealthy snacks or PA minutes for each unit increase in the predictor (Atkins et al., 2013). For outcomes with normal distribution, we calculated the standardized beta coefficient suggested by Hox et al. (2017).

The natural logarithm of number of unhealthy snacks was considered as a linear function of FV consumption and PA on the same day (H1) and of FV consumption, unhealthy snacks, and PA the day before (H1). The natural logarithm of PA minutes was considered as a linear function of FV consumption and unhealthy snacks the same day (H1) and the day before together with PA the day before (H2). The number of FV servings were specified as a linear function of unhealthy snacks and PA the same day (H1) and of unhealthy snacks, FV consumption, and PA the day before (H2). As the data was obtained from an intervention study, we adjusted for group (control vs. intervention) and eating goal (increasing FV vs. decreasing unhealthy snacking) in all models. Also, we tested interactions between our predictors of interest (FV consumption, unhealthy snacking, PA) and group as well as between our predictors of interest and eating goal (FV consumption / unhealthy snacking).

To test H3, the dataset was divided into 1) the FV eating goal intervention and control group and 2) the snacking eating goal intervention and control group. For the FV consumption intervention, the number of unhealthy snacks and PA minutes were considered as a linear function of time and an interaction between group (control / intervention group) and time. For the unhealthy snacking intervention, the number of FV portions and PA minutes were considered as a linear function of time and an interaction between group (control / intervention group) and time.

All analyses were conducted with IBM SPSS Statistics 26.0. To test the robustness of our results, we first ran bivariate correlations between the covariates and our outcomes variables

(FV consumption, unhealthy snacking, and PA). We then re-ran the models with the covariates that were significant in the correlation analysis.

Results

Preliminary analysis

Participants were recruited in October 2014, the intervention took place from November to December 2014. Overall, 232 participants were randomized into one of the four conditions (see *Figure 1*). 203 participants (87.5%) filled in at least one diary entry and were thus included in the analyses. Participants who did not fill out a single e-diary entry were not significantly different from those included in the analysis regarding sex, age, and student/work status. Baseline characteristics are presented in *Table 1*. Participants were mostly females (75.5%), on average 27.5 (SD = 8.6) years old, enrolled as students (58.7%; 41.3% staff member and other adults), and had a mean BMI of 23.5 (SD = 4.0). Participants answered on average 8.0 (79.5%) prompts for FV intake (SD = 3.15), 8.08 (80.1%) for unhealthy snacks (SD = 3.03), and 8.09 (80.3%) prompts for PA (SD = 3.03). At baseline, participants in the intervention group did not differ significantly from those in the control group regarding FV consumption, unhealthy snacking, and PA. The intraclass correlation coefficient was 0.50 for FV consumption, 0.40 for unhealthy snacking, and 0.52 for PA.

Please place Figure 1 and Table 1 around here

Relationship between FV consumption, unhealthy snacking, and PA within the same and the next day

Several relationships between the three health behaviors emerged across eating goals and group conditions (see *Table 2 and Table 3*). For FV consumption as outcome, if participants ate more snacks than usual on one day, they ate 0.16 fewer FV portions the next day (β = -0.07, SE = 0.04, $p < 0.001$). Also, if participants consumed more FVs the previous day, they ate 0.42 fewer FV portions the next day (β = -0.27, SE = 0.03, $p < 0.001$). No significant relationships were found between FV consumption and the other two health behaviors on the same day and with PA the previous day.

For unhealthy snacking as outcome, if participants ate more unhealthy snacks than usual, they ate 18% fewer unhealthy snacks the next day (B = -0.20, SE = 0.03, $p < 0.001$). No other significant relationships were found. No significant relationships neither with health behaviors the same day nor the previous was observed for PA behavior as outcome. However, we ran the main model without PA the previous day as a predictor as the model did not converge. To ensure that the within-person effects were the same when PA the previous day was entered as a predictor, we re-ran the model without estimating autoregressive effects which made the model converge. The results remained substantively unchanged.

For all models presented in Table 2 and Table 3, interactions were tested between the predictors of interest (same- and previous day FV portions, unhealthy snacks, and PA) and intervention (control group / intervention group) as well as between the predictors of interests and eating goal (increasing FV consumption / decreasing unhealthy snacking). Two interactions attained significance (see *Appendix*). In the intervention group, being more active was related to 0.01 fewer FV portions the same day (β = -0.11, SE < 0.01, $p = 0.022$), and more FV intake was related to 7% less PA the same day (B = -0.07, SE = 0.03, $p = 0.026$) compared to the control group.

When adjusting for covariates, the results remained substantively unchanged.

Please place Table 2 and Table 3 around here

Intervention effects on the non-targeted health behaviors

Results for the eating goal group assigned to reduce unhealthy snacking are presented in *Table 4 and Table 5*. For FV consumption, three days prior to the intervention, there was no difference in FV intake between the intervention and the control group (B < 0.01, SE = 0.25, p = 0.998). On the last intervention day, the typical person in the intervention group consumed 0.80 (β = 0.18, SE = 0.45) more FV portions than a person in the control condition. However, this was not statistically significant (p = 0.074). The day-to-day trend did not differ between the intervention and control condition (B = 0.11, β = 0.16, SE = 0.07, p = 0.116; see also *Figure 2*).

For PA, three days prior to the intervention, the intervention group increased PA 22% more each day than the control condition (B = 0.20, SE = 0.10, p = 0.047). However, on the last intervention day, the intervention group conducted 37% less PA than the control group, although this was not statistically significant (B = -0.40, SE = 0.24, p = 0.089). Regarding the day to day change, the intervention group's PA decreased by 7% each day compared to controls (B = -0.08, SE = 0.03, p = 0.023).

Please place Tables 4 and 5 and Figure 2 around here

For the eating goal group assigned to increase FV intake, results are presented in *Table 6.* Three days prior to the intervention, there was no difference in the number of unhealthy snacks consumed between the intervention and the control group (B = 0.06, SE = 0.12, p = 0.603). At the last intervention day, the average person in the intervention group consumed 43% fewer unhealthy snacks than a person in the control group (B = -0.57, SE = 0.21, p = 0.007). Also, the day-to-day decrease was 8% larger for participants in the intervention group compared to the control group (B = -0.08, SE = 0.03, p = 0.012; see also *Figure 3*).

For PA, the pattern was similar to the intervention with the eating goal to decrease unhealthy snacking. Three days prior to the intervention, the intervention group increased PA 32% more each day than the control condition (B = 0.28, SE = 0.14, p = 0.047). However, regarding the day to day change during the intervention, the intervention group decreased their PA 8% more than the control group (B = -0.09, SE = 0.04, p = 0.019). At the last intervention day, intervention and control group did not differ significantly in their PA minutes (B = -0.18, SE = 0.25, p = 0.482).

Please place Table 6 and Figure 3 around here

When including covariates in the analysis, participants that received the intervention to decrease unhealthy snacking did not significantly decrease their PA from day to day anymore (B = -0.07, SE = 0.04, p = 0.069). Also, for participants receiving the intervention to increase FV intake, the effect on unhealthy snacking on Day 10 was no different anymore between intervention and control group (B = -0.30, SE = 0.35, p = 0.393), however, the gradual change from day to day remained stable. For both eating goal intervention groups, changes in PA prior to the intervention were not significantly different anymore from the control group. All other results remained stable.

Discussion

To the best of our knowledge, this is the first study to investigate effects between and within FV consumption, unhealthy snacking, and PA using a randomized controlled trial with intensive-longitudinal outcome data. Regarding the relationship between FV consumption and unhealthy snacking, our results suggest that those behaviors are independent of each other within the same day. This contrasts with a previous study which showed that FV consumption and unhealthy dietary intake were related within a 2-hour time frame (Maher et al., 2020). The differences could be due to the different time frames (two hours vs. entire day). The relationship between FV consumption and PA was moderated by the intervention group, showing a compensation effect in the intervention group. Higher FV consumption was related to less PA on the same day. However, this was not found for the control group. This contrasts with previous observational, intensive longitudinal studies that showed no relationship between caloric intake and PA-variability within the same day (Hooker et al., 2020), or found transfer effects within a 2-hour time frame (Maher et al., 2020). Possibly, the healthy eating intervention caused a compensation effect regarding PA within the same day, which may explain why intervention participants decreased PA over the course of the intervention (see H3).

Only for FV consumption and unhealthy snacking next-day associations were observed, but not for PA (H2). On average, a person that ate more unhealthy snacks than usual on one day consumed fewer FV and fewer unhealthy snacks the next day. Those associations were independent of the intervention and the eating goal. Hence, we see two different mechanisms regarding an increased number of unhealthy snacks. On the one hand, the average person may seek to compensate the same behavior the next day (eating fewer unhealthy snacks). On the other hand, the unhealthy snack consumption is carried forward to eating fewer FV servings the next day (disinhibition) (Lenne et al., 2017). A possible explanation for this finding could be that the person experiences regret. Regret is a negative emotion based on cognitive processing that occurs when a person realizes that the current situation would have been better if the decision had been made differently (Zeelenberg, 1999). Decision-justification theory suggests that regret consists of two core components: On the one hand, regret results from the cognitive processing that the outcome would have been better with a different decision, on the other hand, the individual experiences guilt feelings for making a bad choice (Connolly & Zeelenberg, 2002). Applied to unhealthy snacking, this could mean that participants evaluate the number of consumed snacks when they enter it into the e-diary in the evening. This may make participants aware that they ate more unhealthy snacks than typical for them on that day. As participants with an intention-behavior gap regarding healthy nutrition were targeted for study recruitment, one could assume that they may have felt guilty when realizing that they ate more snacks than usual. Due to these feelings of regret, participants may try to reduce their overall food intake the next day, including unhealthy snacks and FV. As participants were asked in the evening to report their food intake, this did not leave time to compensate within the same day, which might explain why the behaviors are unrelated within the same day. Another reason could be that when participants ate more unhealthy snacks on one day, they were less hungry the next day and hence ate less.

Our results also indicate that higher FV consumption on one day was related to less FV consumption the next day, hence, compensation occurred within the same behavior. However, as compensation usually describes that one health behavior is compensated with another health behavior (Amrein et al., 2017; Knäuper et al., 2004), variation within the same behavior across time is not considered as classic compensation but rather refers to a pattern where it is important to understand the underlying mechanisms. For example, in the PA domain, the relationship between PA behavior at different time points is theorized as the activity-stat hypothesis, assuming that PA is controlled by an individual's intrinsic activity center that regulates the total amount of PA to a set point and, based on that, controls future activity (Eisenmann & Wickel, 2009; Rowland, 1998). The hypothesis is supported by the majority of studies for adults (Gomersall et al., 2013). If a similar mechanism exists for diet behaviors and which time frames would be relevant for dietary pattern within the same eating behavior remains to be investigated in the future.

For H3, we investigated if the eating goal intervention was effective in changing the non-targeted eating behavior and PA. Regarding the non-targeted eating behavior, the social support intervention group with the FV eating goal decreased the number of unhealthy snacks from day to day. A similar, although statistically not significant direction was observed in the social support intervention with the goal to decrease unhealthy snacking, showing a trend towards more FV consumption. No studies investigating a similar research question with a similar design were found. The decrease in the number of unhealthy snacks might be explained with the enhancement of the targeted behavior: As reported in Inauen et al. (2017), the social support intervention group with the FV eating goal increased FV consumption. To achieve that goal, they might have replaced some unhealthy snacks with FV, and consequently decreased the number of unhealthy snacks. However, although the intervention was effective in decreasing the number of unhealthy snacks in the unhealthy snack eating goal intervention group (Inauen et al., 2017), this was not statistically significant associated with an increase in FV portions. A reason for this could be that although participants might have decided against an unhealthy snack, this does not automatically mean that they chose to replace it with FV. For example, in two focus group studies, participants reported that the health aspect of snacking had a low relevance, while the treat or reward aspect of the snack experience was much stronger (Dohle et al., 2015; McIntyre & Baid, 2009). Thus, participants might not consume a food item that counts as unhealthy snack, but still something that is denser in energy than FV items, e.g. a yoghurt.

For the intervention effect on PA, PA decreased on a day-to-day basis during the course of the intervention for both eating goals, indicating compensation effects. However, for the unhealthy snacking eating goal, this was not significant anymore when the covariates were included, indicating that the effect was unstable for this group. The findings are supported by a laboratory study that showed that people who consumed a healthy snack consisting of dried fruit were less likely to engage in PA afterwards compared to participants that consumed an unhealthy snack (Petersen et al., 2019), which also indicates compensation. Interestingly, this study also showed that the relationship between snacking and subsequent activity was mediated by perceived healthiness of the snack, although both the healthy and the unhealthy snack had the same caloric amount (Petersen et al., 2019). The perceived healthiness of changing the eating behavior (increasing FV consumption / decreasing unhealthy snacking) could be one reason why participants compensated with less PA. Another reason could be that self-regulation processes that were needed to pursue the eating goal led to a neglect of PA behavior goals (Mann et al., 2013).

Strengths and limitations

The present study has several strengths. This study investigated behavioral transfer and compensation across and within behaviors during the same day and between two days using an intensive longitudinal approach. This study is also unique in providing evidence from a behavior change intervention targeting a randomly assigned eating goal, showing that an intervention targeting one eating goal can change another eating behavior in the desired direction, whilst indicating the improvements in eating behavior might be compensated with less PA. By using an intensive longitudinal design for behavioral relationships within and between days, this study allowed to gain new insights regarding the temporal development of transfer and compensation effects.

Simultaneously, this study has some limitations that should be considered for future studies. All outcomes were self-reported, and therefore prone to bias. We minimized retrospective bias through daily diaries which have been shown to be appropriate for self-reported food intake (Bruening et al., 2016). In addition, behavioral transfer and compensation mechanisms might occur in shorter time frames (Maher et al., 2020) that we were not able to capture as we had only one assessment per day. Also, statistical power was calculated to investigate the main effect of the study (Inauen et al., 2017), hence statistical power may be limited. Finally, we recruited a motivated and interested sample of participants with a healthy baseline diet, hence, generalizability regarding behavioral transfer and compensation in other samples, e.g. in people who are not interested in a healthy diet, might be limited.

Conclusion

In conclusion, our results indicate that independent of an eating goal and an intervention, FV consumption and unhealthy snacks are unrelated within the same day. Behavioral relationships with the next day are mainly found within the same behavior: More than usual unhealthy snack intake predicted less snack intake the next day, however, more than usual FV intake also predicted less FV intake the next day. Thus, it seems that participants compensate beneficially within one dietary behavior and detrimentally in the other dietary behavior the next day simultaneously.

Our study also showed that a nutrition intervention that focuses on a specific eating goal has the potential to enhance another eating behavior, but participants might compensate with less PA. These results should be replicated, but are already important to be considered for nutrition intervention studies to counteract PA compensation and consider positive effects on other health behaviors. Future intervention studies should investigate behavioral transfer and compensation using an intensive longitudinal approach with a longer intervention duration, more assessments throughout the day, and device-based PA measurement. In addition, future research should investigate dietary patterns and its underlying mechanisms within the same behavior and behavioral transfer and compensation within the same behavioral domain to understand behavior change comprehensively.

Declarations of interest

None

Author contributions

JI, MA, PR, and US conceptualized, designed, and conducted the study. CN specified the research questions for the present paper in collaboration with JI. CN analyzed and interpreted the data, supervised by JI, and with additional input from US. CN drafted the article, and all co-authors critically reviewed the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work and ensure that questions related to the accuracy and integrity of any part of the work were appropriately investigated and resolved.

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Table 1. Sociodemographic characteristics at baseline.

	Intervention		Control	
	Snacking goal (N = 52)	**FV goal (N = 48)**	**Snacking goal (N = 54)**	**FV goal (N = 49)**
Mean age (SD)	28.1 (9.7)	25.9 (7.4)	26.2 (7.8)	29.7 (9.0)
Mean BMI (SD)	23.7 (4.1)	23.1 (2.6)	22.9 (3.2)	24.4 (5.5)
Females (%)	40 (74.1)	31 (66.0)	45 (83.3)	38 (77.6)
FV consumption (portions)	3.64 (2.03)	4.29 (1.79)	3.76 (2.13)	3.92 (1.63)
Unhealthy snacks (number)	1.49 (1.10)	1.38 (1.48)	1.27 (1.40)	1.32 (0.96)
PA (minutes)	50.69 (53.35)	66.67 (106.89)	52.73 (59.14)	44.58 (40.07)

Note: BMI = body mass index, FV = fruit and vegetables, PA = physical activity

Table 2. Parameter estimates for generalized estimating equations models predicting same-day and next-day fruit and vegetable consumptions in portions (N = 187)

Fixed effects	*B*	SE	β	*p*	95%-CI Lower	95%-CI Upper
Intercept	3.46	0.23		<0.001	3.02	3.91
Time pre-intervention	-0.07	0.15	-0.01	0.634	-0.37	0.23
Time intervention	<0.01	0.03	0.00	0.884	-0.06	0.06
Intervention	0.47	0.25	0.11	0.058	-0.02	0.95
Eating goal	0.57*	0.24	0.13	0.018	0.10	1.04
Snacking within-person same day	-0.06	0.05	-0.03	0.240	-0.17	0.04
PA within-person same day	<0.01	<0.01	0.02	0.592	0.00	0.00
Snacking within-person previous day	-0.16*	0.04	-0.07	<0.001	-0.25	-0.08
PA within-person previous day	0.00	0.00	0.02	0.617	0.00	0.00
FV within-person previous day	-0.42*	0.03	-0.27	0.001	-0.49	-0.36
Snacking between-person	-0.25	0.13	-0.10	0.062	-0.51	0.01
PA between-person	<0.01	<0.01	0.05	0.369	0.00	0.01
FV between-person	0.02	0.05	0.676	1.02	0.93	1.12

Variable coding and units. time pre-intervention and time intervention: days; FV = fruits and vegetables in portions; Snacking = number of snacks; PA = physical activity in minutes; Intervention: Control group = 0, intervention group = 1; Eating goal: Snacking = 0, FV = 1; β = standardized beta coefficient; $*p < 0.05$

Table 3. Parameter estimates for generalized estimating equations models predicting same-day and next-day unhealthy snacking and physical activity behavior (for each model: N = 187)

Fixed effects	*B*	SE	*p*	RR	95%-CI Lower	95%-CI Upper
Unhealthy snack consumption [number of snacks]						
Intercept	0.29	0.10	0.003	1.33	1.10	1.61
Time pre-intervention	0.07	0.08	0.375	1.07	0.92	1.24
Time intervention	-0.02	0.01	0.082	0.98	0.96	1.00
Intervention	-0.20	0.10	0.042	0.82	0.67	0.99
Eating goal	0.05	0.10	0.649	1.05	0.86	1.28
FV within-person same day	-0.03	0.02	0.117	0.97	0.94	1.01
PA within-person same day	<0.01	<0.01	0.354	1.00	1.00	1.00
FV within-person previous day	-0.01	0.02	0.710	0.99	0.96	1.03
PA within-person previous day	<0.01	<0.01	0.963	1.00	1.00	1.00
Snacking within-person previous day	-0.20	0.03	<0.001	0.82*	0.77	0.87
FV between-person	-0.06	0.04	0.082	0.94	0.88	1.01
PA between-person	<0.01	<0.01	0.442	1.00	1.00	1.00
Physical activity [minutes]						
Intercept	3.82	0.14	<0.001	45.72	34.84	60.00
Time pre-intervention	0.10	0.10	0.327	1.10	0.91	1.34
Time intervention	-0.02	0.02	0.116	0.98	0.95	1.01
Intervention	-0.04	0.13	0.772	0.96	0.74	1.25
Eating goal	-0.01	0.12	0.919	0.99	0.77	1.26
FV within-person same day	<0.01	0.02	0.878	1.00	0.97	1.04
Snacking within-person same-day	-0.01	0.03	0.632	0.99	0.93	1.04
FV within-person previous day	<0.01	0.02	0.875	1.00	0.97	1.04
Snacking within-person previous day	-0.02	0.02	0.368	0.98	0.94	1.02
Snacking between-person	0.08	0.08	0.281	1.09	0.93	1.27
FV between-person	0.02	0.05	0.676	1.02	0.93	1.12

*Variable coding and units. time pre-intervention and time intervention: days; FV = fruits and vegetables in portions; Snacking = number of snacks; PA = physical activity in minutes; Intervention: Control group = 0, intervention group = 1; Eating goal: Snacking = 0, FV = 1; RR = rate ratio; *p < 0.05*

Table 4. Parameter estimates for generalized estimating equations models predicting fruit and vegetable consumption in portions in the snacking goal group (N = 106)

Fixed effects	*B*	SE	β	*p*	95%-CI Lower	95%-CI Upper
Intercept (mean control group Day 10)	3.29	0.29		<0.001	2.72	3.85
Time preintervention (slope control condition)	0.15	0.18	-0.02	0.419	-0.21	0.50
Time intervention (slope control condition)	-0.07	0.05	0.15	0.168	-0.17	0.03
Intervention effect Day 10	0.80	0.45	0.18	0.074	-0.08	1.67
Intervention*time preintervention	<0.01	0.25	<0.01	0.998	-0.48	0.48
Intervention*time intervention	0.11	0.07	0.16	0.116	-0.03	0.24

*Variable coding and units. Intervention: Control group = 0, time pre-intervention and time intervention: days; β = standardized beta coefficient; *p < 0.05*

Table 5. Parameter estimates for generalized estimating equations models predicting physical activity behavior in minutes in the snacking goal group (N = 106)

					95%-CI	
Fixed effects	***B***	**SE**	***p***	**RR**	**Lower**	**Upper**
Intercept (mean control group Day 10)	4.02	0.19	<0.001	55.68	38.38	80.78
Time preintervention (slope control condition)	-0.11	0.09	0.193	0.89	0.76	1.06
Time intervention (slope control condition)	0.03	0.03	0.258	1.03	0.98	1.09
Intervention effect Day 10	-0.40	0.24	0.089	0.67	0.42	1.06
Intervention*time preintervention	0.20	0.10	0.047	1.22*	1.00	1.49
Intervention*time intervention	-0.08	0.03	0.023	0.93*	0.87	0.99

*Variable coding and units. time pre-intervention and time intervention: days; Intervention: Control group = 0, RR = rate ratio; *p < 0.05*

Table 6. Parameter estimates for generalized estimating equations models predicting unhealthy snacking and physical activity behavior in the FV goal group (for each model: N = 97)

					95%-CI for ***RR***	
Fixed effects	***B***	**SE**	**p**	***RR***	**Lower**	**Upper**
Unhealthy snacking [number]						
Intercept (Mean control group Day 10)	0.53	0.12	<0.001	1.70	1.36	2.14
Time preintervention (slope control condition)	0.04	0.09	0.649	1.04	0.87	1.24
Time intervention (slope control condition)	0.03	0.02	0.165	1.03	0.99	1.07
Intervention effect Day 10	-0.57	0.21	0.007	0.57*	0.37	0.86
Intervention*time preintervention	0.06	0.12	0.591	1.07	0.85	1.34
Intervention*time intervention	-0.08	0.03	0.012	0.92*	0.86	0.98
Physical activity [minutes]						
Intercept (Mean control group Day 10)	3.93	0.15	<0.001	50.74	37.73	68.24
Time preintervention (slope control condition)	-0.07	0.10	0.468	0.93	0.77	1.13
Time intervention (slope control condition)	0.02	0.03	0.391	1.02	0.97	1.07
Intervention effect Day 10	-0.18	0.25	0.482	0.84	0.51	1.38
Intervention*time preintervention	0.28	0.14	0.047	1.32*	1.00	1.75
Intervention*time intervention	-0.09	0.04	0.019	0.92*	0.86	0.99

*Variable coding. time pre-intervention and time intervention: days; FV = fruits and vegetables, Intervention: Control group = 0, intervention group = 1; RR = rate ratio; * p < 0.05*