Action control in dyads: A randomized controlled trial to promote physical activity in everyday life

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Abstract: RATIONALE Engaging in regular physical activity requires substantial self-regulatory effort such as action control (e.g., continuously monitoring and evaluating an ongoing behavior with regard to one's standards). OBJECTIVE The present study examined the effectiveness of an ecological momentary action control intervention for promoting daily physical activity. Also, we tested whether a dyadic compared to an individual intervention displayed an additional benefit. METHODS 121 overweight and obese individuals and their partners were randomly allocated to an intervention (n = 60; information + action control text messages) or a control group (n = 61; information only). The intervention was delivered in a dyadic vs. individual version of action control. Allocation ratio was 1:1:2 for the dyadic, individual, and control groups, respectively. Daily physical activity was assessed with triaxial accelerometers during a 14-day intervention phase and a 14-day follow-up phase. RESULTS Participants in the intervention group showed a higher probability (36.5%) to achieve the recommended daily activity levels (30 min of moderate-to-vigorous physical activity per day performed in bouts of at least 10 min) during the intervention and follow-up phase compared to those in the control group (23.0%). The intervention and control group did not differ in terms of daily moderate-to-vigorous physical activity (40.7 vs. 38.6 min per day, p = 0.623). CONCLUSION Interventions facilitating action control via text messages seem to be an effective tool for increasing adherence to physical activity guidelines in everyday life. The comparable effects for the dyadic and individual intervention suggest that automated text messages may be just as effective as personalized messages from the romantic partner. Further investigation is needed to examine the usefulness of a dyadic conceptualizing of action control. (controlled-trials.com ISRCTN15705531).

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Action control in dyads:

A randomized controlled trial to promote physical activity in everyday life

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Abstract

Rationale: Engaging in regular physical activity requires substantial self-regulatory effort such as action control (e.g., continuously monitoring and evaluating an ongoing behavior with regard to one's standards). *Objective:* The present study examined the effectiveness of an ecological momentary action control intervention for promoting daily physical activity. Also, we tested whether a dyadic compared to an individual intervention displayed an additional benefit. *Methods:* 121 overweight and obese individuals and their partners were randomly allocated to an intervention ($n = 60$; information + action control text messages) or a control group ($n = 61$; information only). The intervention was delivered in a dyadic vs. individual version of action control. Allocation ratio was 1:1:2 for the dyadic, individual and control groups, respectively. Daily physical activity was assessed with triaxial accelerometers during a 14-day intervention phase and a 14-day follow-up phase. *Results:* Participants in the intervention group showed a higher probability (36.5%) to achieve the recommended daily activity levels (≥ 30 minutes of moderate-to-vigorous physical activity per day performed in bouts of at least 10 minutes) during the intervention and follow-up phase compared to those in the control group (23.0%). The intervention and control group did not differ in terms of daily moderate-to-vigorous physical activity (40.74 vs. 38.58 minutes per day, $p = 0.623$). *Conclusion:* Interventions facilitating action control via text messages seem to be an effective tool for increasing adherence to physical activity guidelines in everyday life. The comparable effects for the dyadic and individual intervention suggest that automated text messages may be just as effective as personalized messages from the romantic partner. Further investigation is needed to examine the usefulness of a dyadic conceptualizing of action control. (controlled-trials.com ISRCTN15705531)

Keywords: randomized controlled trial, self-regulation, action control, dyadic, physical activity, accelerometer, obesity, text messages

Physical inactivity remains one of the most pressing public health issues of the 21st century, and is a key risk factor for the major non-communicable diseases such as cardiovascular diseases, diabetes and cancer (Mozaffarian et al., 2016). Worldwide, one in four adults is not sufficiently active, and 39% are overweight or obese (World Health Organization [WHO], 2016a, 2016b). Thus, regular physical activity is a relevant health behavior, and of special importance in the context of overweight and obesity. According to current guidelines, adults should engage in at least 150 minutes in moderate-intensity physical activity or at least 75 minutes of vigorous-intensity physical activity throughout the week (or an equivalent combination of the two). All activity should be performed in bouts of at least 10 minutes duration (e.g., CDC, 2016; WHO, 2016b). While people are generally aware of the relevance of health behaviors, they often fail to consistently perform these behaviors (De Ridder & De Wit, 2006). Engaging in health behaviors on a regular basis requires substantial self-regulatory effort from the individual. The Health Action Process Approach (HAPA; Schwarzer, 2008) proposes that self-regulatory strategies such as planning and action control facilitate effective goal attainment. At the same time, research suggests that social relationships play a major role for health behavior change (e.g., Berkman, Glass, Brissette, & Seeman, 2000). So far, however, the two lines of research were mainly examined independently of each other. This study is the first to investigate the effectiveness of a theory-based action control intervention in promoting physical activity in everyday life that also addresses the dyadic context of romantic couples.

Action Control in Health Behavior Change

Action control is based on the principle of negative feedback control of Carver and Scheier (1998), and refers to continuously monitoring and evaluating an ongoing behavior with regard to one's standards. It comprises three sub-facets (Sniehotta, Nagy, Scholz, & Schwarzer, 2006): a) *awareness of standards* that refers to being constantly aware of one's set intentions in terms of behavior change, b) *self-monitoring* that involves keeping track of one's actual behavior in order to allow for comparisons with standards, and c) *self-regulatory effort* needed to reduce potential discrepancies between actual behavior and standards, by attempting to adhere to goal-directed means (e.g., previously formed action or coping plans, preparatory behaviors), but not the target behavior (e.g., physical activity) itself. Overall, experimental studies support the effectiveness of action control for behavior change (e.g., Schüz, Sniehotta, & Schwarzer, 2007; Zhou, Sun, Knoll, Hamilton, & Schwarzer, 2015). By using self-monitoring tools and diaries, these studies have particularly addressed the sub-facet of self-monitoring that has been established as an important behavior change technique (BCT) (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). So far, the sub-facets of awareness of standards or self-regulatory effort have not been taken into account explicitly. However, as the theory of action control proposes that the three components work jointly in a feedback loop, experimental designs should test the concept of action control comprehensively by targeting all three sub-facets. Text message reminders via mobile phones could be an experimental approach in fostering all three sub-facets of action control. They can serve as simple reminders of goals (i.e., awareness of standards), prompt assessment of current behavior (i.e., self-monitoring) and engagement in ways to facilitate goal achievement (i.e., self-regulatory effort). Text messaging is a familiar, quick and cost-effective way to reach individuals in their everyday lives and natural settings, referred to as ecological momentary interventions (Heron & Smyth, 2010). A recent meta-analysis provides evidence that text message interventions are efficacious in improving behavioral outcomes in health promotion, especially in the context of physical activity (Head, Noar, Iannarino, & Grant Harrington, 2013). However, more theory-based interventions applying text messages are needed in order to test and develop behavior change theory (Fjeldsoe, Marshall, & Miller, 2009).

Moreover, previous literature on action control shows limited insight into how behavior change unfolds in everyday life during and after action control interventions. Studies have often used longitudinal research designs, testing behavior effects at a macro-time level with follow-ups two to six weeks after intervention (e.g., Fleig, Lippke, Pomp, & Schwarzer, 2011; Schüz et al., 2007). While it is essential to establish intervention effects at a macro-time level, there is a need to better understand behavior change from day to day during the intervention and right after the intervention.

Dyadic Regulation in Health Behavior Change

Even though performing health behaviors often occurs in a social context, the role of social relationships for people's self-regulation has been rather neglected (e.g., Fitzsimons & Finkel, 2010). Involving close others in behavior change efforts has been shown to benefit health behavior change. In the context of chronic disease, couple-based interventions have proved more effective than traditional patient-oriented approaches (Martire, Schulz, Helgeson, Small, & Saghafi, 2010). Similarly, recent evidence supports the effectiveness of dyadic collaboration in mother-daughter dyads (Sorkin et al., 2014) and partner-based interventions (Prestwich et al., 2014) in the context of dietary intake. Another recent, large population-based study found that partners' positive health behavior changes are highly linked (Jackson, Steptoe, & Wardle, 2015). This suggests the importance of targeting couples in behavior change interventions. The involvement of a partner may increase motivation, positive social exchanges and foster individual regulation such as self-efficacy or action control, and thus result in better outcomes (e.g., Prestwich et al., 2012; Sorkin et al., 2014).

With regard to established self-regulation strategies in health behavior change, first studies have focused on the usefulness of extending individual planning to the level of the dyad. Burkert, Scholz, Gralla, Roigas, and Knoll (2011) tested dyadic planning (i.e., creating plans together with a partner on when, where and how a target individual will implement a new behavior) in the context of pelvic-floor exercise in prostatectomy patients. While no specific effects of a dyadic planning intervention were found, patients instructed to plan dyadically still benefitted from the intervention: Self-reported dyadic planning was associated with more pelvic-floor exercises due to indirect effects via action control and social control. Similarly, collaborative implementation intentions (i.e., jointly planning and enacting the behavior with a partner) have been found effective in different health contexts (Prestwich et al., 2012; Prestwich et al., 2014). To the best of our knowledge, action control has not yet been studied on a dyadic level. We define *dyadic action control* as the involvement of a partner in the process of continuously monitoring an individual's self-set intentions, actual behavior and, if necessary, increased attempts to apply discrepancy-reducing means. This could include that the partner actively reminds the person of behavioral goals, checks for current progress, and encourages goal achievement. In part, this may overlap with strategies of social control, referring to attempts to influence and regulate the behavior of a close other (Lewis & Rook, 1999). Both concepts share that a network member is actively engaged in regulating the target person's behavior (e.g., by using reminders). However, social control may also involve attempts to constrain behavior or induce a change even if an individual is unwilling to make a change. Dyadic action control on the other hand is rather viewed as a co-regulation strategy that comes into play only after an individual has set an intention with regard to behavior change (i.e., post-intentional), and is specific to the volitional process of action control.

The Present Study

This study examined the effectiveness of a theory-based action control intervention using text messaging to promote daily physical activity in two phases: During the 14-day intervention period (intervention phase) and during the 14 days following the intervention (follow-up phase). Moreover, we tested whether a dyadic action control intervention has superior effects on daily physical activity compared to an individual action control intervention. In doing so, the study addressed important gaps in the literature on self-regulation. First, prior studies did not comprehensively address the different sub-facets of action control, and have not investigated behavior change at a daily level during and after action control interventions. Second, the social context of regulating health behaviors has mainly been neglected. We hypothesized that 1) participants in the intervention group will show higher levels of daily physical activity during the intervention and follow-up phase compared to a control group (receiving a standard information intervention only), and that 2) participants in the dyadic action control group show even higher levels of daily physical activity compared to participants in the individual action control group during the intervention and follow-up phase. Another initial hypothesis of the project concerned the moderating function of gender and self-regulation variables (for details please see trial registration http://www.controlled-trials.com/ISRCTN15705531). However, as no moderating effects were found, the moderating function is not focused on in the present study. For interested readers, results can be obtained from the first author.

Method

This study was part of a single-blind randomized controlled trial ‘a Dyadic Action Control Trial in overweight and obese Couples’ (DYACTIC; for a detailed description see study protocol (Scholz & Berli, 2014). It was funded by the Swiss National Science Foundation (PP00P1_133632/1) and registered as a randomized controlled trial (ISRCTN15705531). The project comprised an intervention group, receiving an action control intervention delivered either as an individual or a dyadic intervention, and a control group that received standard information only. Additionally, there was a variation within the control group with regard to the report of physical activity behavior in the daily diary (i.e., half of the control group only completed questions on social-cognitive variables, but not on self-reported physical activity behavior using daily diaries to control for a potential self-monitoring effect) (see Scholz & Berli, 2014). However, as this difference was of no significant relevance for the analyses, it will not be further focused on in the present study.

Participants and Procedures

Participants were heterosexual couples living in a committed relationship for at least 12 months and cohabiting for at least six months. Both partners had to be overweight or obese (body mass index [BMI] ≥ 25 kg/m^2), physically inactive (< 30 minutes per day of moderate-to-vigorous physical activity [MVPA]), but intending to engage in the recommended amount of physical activity. The criterion of accumulating at least 30 minutes of MVPA every day (performed in bouts of at least 10 minutes) was based on the physical activity recommendations for adults of the Swiss Federal Office of Sports at the time of the study (BASPO, 2009). Eligibility criteria were assessed in phone interviews at initial contact (yes/no items). We specifically focused on a post-intentional sample, as action control is theoretically assumed to be beneficial in individuals who have already set themselves an intention in terms of behavior change (Schüz et al., 2007). Moreover, participants had to be between 18 and 75 years of age, fluent in German, and be able to receive and read text messages throughout the day. Twenty-four hour shift workers were excluded to ensure that their partners had the same circadian rhythm. Further exclusion criteria were pregnancy and current enrollment in a professional weight loss program, as these factors might influence physical activity patterns. Participants were recruited via advertisements, flyers, and a market research institution from March 2012 until October 2013 in Bern, Switzerland.

Upon completion of an initial short online questionnaire, assessing socio-demographics and any health risks, couples were invited to the lab for the baseline assessment. According to a computer-generated allocation sequence that was concealed in a set of sealed, numbered envelopes, study staff members randomly assigned couples to the study groups, and individuals within each couple to target person or partner. Restricted randomization with block size of eight was used in a ratio of 1:1:2 for the dyadic, individual, and control group interventions, respectively. Thus, within a block of eight participating couples, two couples were assigned to both the dyadic and individual interventions, and four couples were assigned to the control group, with alternating gender for the target person.

Throughout the study, participants were not informed of the intervention content for the different study groups or what group they were assigned to. At baseline, participants provided written informed consent, completed a questionnaire, and were instructed on the 28-day diary period starting the following day. This diary period involved electronic end-of-day diaries on a study smartphone and the use of accelerometers for all participants. The first 14 days comprised an intervention phase with text messages across 10 weekdays (see below), followed by 14 days of assessment only. After this period, they were again invited to the lab to return the devices and complete the follow-up assessments. Each participating couple then received CHF100 ($107) as financial incentive. This study was approved by the institutional review board of the Faculty of Human Sciences of the University of Bern, 21 February 2012 (Reference number: 2011-12-36206).

Intervention

After completing baseline questionnaires, participants of all groups received an information leaflet on health-enhancing physical activity for adults. The recommendation involved the accumulation of at least 30 minutes of MVPA every day, performed in bouts of at least 10 minutes, based on guidelines by the Swiss Federal Office of Sports for adults at the time of the study (BASPO, 2009; please note that in 2013 these guidelines were updated to meet the global standards of the WHO and CDC specifying a minimum weekly amount). In terms of the BCT taxonomy (Michie et al., 2013), this refers to the BCT “information about health consequences”.

Intervention group: Dyadic and individual action control. Based on the information leaflet, target persons of the intervention group were then instructed to set behavioral intentions (BCT "goal setting"; Michie et al., 2013), in order to achieve the recommended level of health-enhancing physical activity. Participants were asked to think of specific behavioral activities that would enable them to meet the goal of accumulating at least 30 minutes of MVPA per day, and write them down on a worksheet (e.g., “go to work by bike"). Trained supervisors ensured the correct completion of this task, but did not interfere otherwise with the process. Across the following 14-day intervention phase , participants received a short text message once every weekday, resulting in a total of 10 text messages. The text messages were aimed at increasing the target person's action control by enhancing the awareness of the behavioral intentions (3 messages; e.g., "This message is a small reminder of your intentions to be physically active for 30 minutes each day"), by prompting self-monitoring of current physical activity behavior (4 messages; e.g., "Which of your intentions in terms of physical activity have you already carried out today?"), and by encouraging to apply self-regulatory effort if needed (3 messages; e.g., "If you haven't achieved your goal of 30 minutes physical activity today, there will certainly still be a good opportunity for it."). They were formed in variants, but were not tailored to the individuals. The text messages were sent in a specific order and at specific times of the day that was equivalent for all participants. For a detailed description of the text messages see Scholz and Berli (2014). In terms of BCTs (Michie et al., 2013), the text message intervention targeted 'self-monitoring of behavior' and 'discrepancy between current behavior and goal standard'.

The intervention was varied as follows:

Individual action control group. In this group, target persons set behavioral intentions on their own, and received the daily action control text message across 10 weekdays from the study staff.

Dyadic action control group. In this group, target persons *and* their partners collaboratively set behavioral intentions to increase the target person's physical activity to the recommended minimum, and the partners were instructed to send the same action control text messages to the target persons as in the individual action control group, but in a personalized form (i.e., greetings, form of dialect). They were not allowed to change the content of the message. Partners received a text message from the study staff each weekday reminding them to send the appropriate text message (saved as draft on their study smartphone) to the target person within the next hour. Target persons were not informed about what instructions were given to their partner, and were instructed not to discuss them with their partner.

Control group. Target persons of the control group were not instructed to set any behavioral intentions. They received a text message once every weekday during the same period and time of the day as target persons of the intervention groups, reminding them to fill in the end-of-day diary.

Study Measures

Physical activity. Daily physical activity was assessed with a triaxial accelerometer monitoring device (GT3X+, ActiGraph, Pensacola, FL) for 28 consecutive days following the baseline session. The GT3X+ is a light (19 g), compact (4.6 × 3.3 × 1.5 cm) accelerometer that measures acceleration on three axes, providing a composite measure (i.e., "vector magnitude"). It has been widely used in research and is a reliable and valid instrument for measuring levels of physical activity (Sasaki, John, & Freedson, 2011). Participants were instructed to wear the monitor at the hip on the side of the dominant hand from the moment they got up in the morning until they went to bed at night, and to remove it only for showering or water-based activities lasting more than 30 minutes. Data were assessed at a frequency of 30 Hz and reintegrated into 60 s-epochs for data processing. No filter option was applied (e.g., low-frequency extension). ActiLife 6 Software (ActiGraph, Pensacola, FL) was used for data processing and analyses. Non-wear time was filtered using an automated algorithm based on ≥ 90 min of consecutive zeros in vector magnitude counts per minute (cpm), allowing for interruptions of up to two minutes (Choi, Liu, Matthews, & Buchowski, 2011). Data were screened separately for each participant in order to identify spurious data or monitor malfunctioning (e.g., counts >20,000 cpm). Due to battery problems, 16 participants lost part of their activity data resulting in 3.8% of missing data (M = 7.4 days, SD = 3.9, Range = 2-19). For the present study, only days with at least 10 hours of wear time (Colley, Connor

Gorber, & Tremblay, 2010) were considered as valid and included in analyses, leaving 2,854 available days (85.7%).

For each participant, total minutes in MVPA per day were calculated based on the threshold of ≥2,690 cpm in vector magnitude (Sasaki et al., 2011), resulting in *overall daily MVPA in minutes*. As the distribution of the variable was strongly skewed, it was log transformed for the main analyses. Second, based on recommendations for health-enhancing physical activity in Switzerland at the time of the study, total minutes in MVPA performed in bouts of at least 10 minutes per day were calculated. To count as a bout, 10 consecutive minutes of observations had to exceed the moderate intensity cut-point (allowing a maximum of two observations to fall below the cut-point during that period). A dummy-coded variable *adherence to recommended daily MVPA in bouts* was created, with values ≥ 30 coded as 1 = achieving the recommended level of at least 30 minutes of MVPA per day performed in 10 minute bouts (or XX min per week), values <30 coded as 0 = not achieving the recommended MVPA levels.

Intervention fidelity

To evaluate whether the intervention was implemented as planned, participants were instructed not to delete any messages from the study smartphones. Once the devices were returned to the lab, the text messages were extracted and reviewed precisely for any inconsistencies. In the control group, two messages (0.003%) were erroneously sent to the study smartphone of the other partner. In the individual action control group, all messages were sent and received as planned. In the dyadic action control group, all target persons received a minimum of six action control text messages from their partners; of these individuals, 51.7% received all 10 messages in the intended manner (i.e., correct content on the correct day), and seven individuals (24.1%) received less than half of the messages in the intended manner, and were considered as low fidelity participants.

Data Analysis

Based on a power of 0.80, an alpha level of < .05, and a medium effect size derived from previous action control interventions (e.g., Schüz et al., 2007), a total sample size of N = 128 participants (64 in each group) were needed to test for mean differences between the intervention and control group (Cohen, 1992).

We used multilevel modeling in SPSS 22 to account for the nested structure of repeated measures within individuals. For the continuous outcome, (log-transformed) *overall daily MVPA in minutes*, we ran linear mixed models. For the dichotomous outcome, *adherence to recommended daily MVPA in bouts*, we ran logistic regressions using generalized linear mixed models. To model effects over time, we created a *time* variable, in 7-day units centered on first day, that represented all diary days (Day 1 = 0, Day 2 = 0.14, .., Day 7 = 1, etc.). Moreover, a dummy-coded variable *follow-up phase* was computed (coded as 0 = days during the intervention; 1= days after the intervention). To test for differential effects during the intervention and follow-up phase, interaction terms of the follow-up phase and group variables were generated and included in the model. Interaction terms with time in order were also generated to test whether the physical activity outcomes varied differently over time between groups. No significant effects emerged in our initial analyses, therefore, interaction terms with time were not included in the final models.

In order to test for the overall intervention effect, models comparing the intervention and control group were run. In a second step, the dyadic action control group was compared to the individual action control group to test for the hypothesized superior intervention effect. In all analyses, we routinely included daily accelerometer wear time as a covariate. Furthermore, we ran sensitivity analyses including baseline intention, sex, age and weekday (vs. weekend) as covariates. We re-ran analyses after excluding participants of the dyadic action control group with low intervention fidelity, which revealed the same pattern of results. Thus, we report the more parsimonious models.

Results

Sample

Of the 488 couples interviewed for eligibility, we successfully randomized 123 participants to the intervention (*n* = 61 in total: 31 in the dyadic group; 30 in the individual action control group) and control (*n* = 62 in total) groups, which was slightly lower than the desired sample from our power analysis (*N* = 128) (see sampling procedure in Figure 1). Of the randomized target persons, 121 participants (51.2% female) and their partners completed the baseline assessments (*M* = 46.13 years, *SD* = 13.62, Range = 22-72; BMI in kg/m^2: *M* = 31.00, *SD* = 5.58, Range = 25-62). Participants were in a committed relationship with an average duration of 18.79 years (*SD* = 14.33, Range = 1-52); 69.4% were married and 57.0% had kids. This study focuses on the target persons only. Table 1 displays the baseline sample characteristics for the target persons in the intervention and control groups. Intervention and control groups were similar at baseline (all $ps > .05$), except for physical activity intention. Participants in the intervention group reported higher intentions (*M* = 4.98, *SD* = 0.61) than participants in the control group (*M* = 4.70, *SD* = 0.72), $t(119) = -2.30$, $p < .05$. Even though the difference was small, we performed additional sensitivity analyses that included baseline intention as a covariate, and found no evidence to suggest that differences in physical activity intention explained study outcomes.

The following results are based upon intention-to-treat analysis, including all available data points. Accelerometer data were missing for two target persons (one couple dropped out of the study before the diary period; one couple's data could not be clearly assigned to partners due to exchange of device and were excluded), leaving a final sample of *N* = 119 target persons.

Descriptives

Across the 28-day diary period, participants of the control group achieved the recommended *daily MVPA in bouts* on average on 21.0% of the days (*SD* = 18.3, Range = 0 - 81), and participants of the intervention group on 32.7% of the days (*SD* = 22.6, Range = 0 -

78). Median level of *overall daily MVPA* was 40.0 and 45.0 minutes for participants of the control and intervention group, respectively. The intra-class correlation, defined as the amount of variance between second-level units in relation to total variance (Kreft & DeLeeuw, 1998) was 0.42. This indicates that almost half of the total variance in overall daily MVPA in minutes was due to stable inter-individual differences.

Overall Intervention Effect on Daily Activity: Intervention versus Control groups

To test Hypothesis 1, the effect of the action control intervention, we examined differences between the intervention and control groups in the two main outcomes of the current study (see Table 2). In terms of *adherence to recommended daily MVPA in bouts,* a significant effect emerged for the intervention group. Target persons of the intervention group showed a higher probability (36.5%; 95% *CI:* 28.4% to 45.5%) of achieving the recommended daily MVPA *in bouts* on the first intervention day than target persons of the control group (23.0%; 95% *CI:* 17.4% to 30.6%). Despite a general decrease in adherence over time, this effect remained until after the intervention ended: No changes occurred from the intervention to the follow-up phase for participants of both intervention and control group (i.e., non-significant effect for follow-up phase and follow-up phase × group interaction term). Figure 2 graphically depicts the model-predicted average effect over time for the intervention and control group.

There was no significant effect of the intervention group on *overall daily MVPA in minutes*, indicating that participants in the intervention group did not significantly differ from participants in the control group with regard to their total minutes in MVPA on the first intervention day (40.74 vs. 38.58 minutes back-transformed from log scale, respectively). Overall daily MVPA (in minutes) did not vary significantly across time. Moreover, no changes occurred in overall daily MVPA from the intervention to the follow-up phase in the intervention or control group (i.e., non-significant effect for follow-up phase phase and follow-up phase × group interaction term).

Intervention effects: Dyadic vs. individual action control

Hypothesis 2 further tested whether an action control intervention delivered dyadically is more effective in promoting daily physical activity than when delivered individually. Again, differences between the dyadic and individual group were examined for the two main outcomes of the current study (see Table 3). During the intervention or follow-up phases, participants in the dyadic and individual group did not differ in their *overall daily MVPA in minutes* or probability of *adherence to recommended daily MVPA in bouts* during the intervention or follow-up phases (37.0% [95% *CI:* 27.8% to 50.7%] vs. 39.9% [95% *CI:* 27.8% to 53.2%], respectively). Overall, these results indicate that contrary to our assumption, an action control intervention delivered in dyadic format did not have superior effects on daily physical activity outcomes when compared to the individual format.

Discussion

This study is the first to show support for the notion that a theory-based action control intervention is beneficial for promoting daily physical activity among inactive, overweight and obese individuals who intend to engage in regular physical activity. The study used an ecological momentary intervention design that combined accelerometer-based activity assessment with text messages delivered to people in their everyday lives. Participants in the intervention group had a higher probability of achieving the recommended amount of daily MVPA (i.e., 30 minutes performed in bouts of at least 10 minutes) during the intervention than participants in the control group. This effect was sustained in the follow-up phase. The intervention and control group did not differ in the total amount of daily MVPA (in minutes) during the 14 days of intervention or the 14 days following the intervention (i.e., follow-up phase).

The present findings suggest that the action control intervention effectively enhanced the achievement of the behavioral target of the intervention - activities performed in bouts of at least 10 minutes as an addition to routine activities in daily living (e.g., self-care, casual walking, taking out the trash). It appears that setting specific behavioral goals in terms of achieving the recommended activity levels, and subsequently receiving daily action control messages facilitates adherence to the recommended behavior. Indeed, the probability of achieving the recommended daily MVPA in the intervention group increased by 63% compared to the control group (*OR* = 1.92). This improvement lies above what has previously been found as a modest effect for changes in physical activity in a review of meta-analyses (OR between 1.2 and 1.3 for achieving a healthy activity target; Greaves et al., 2011). These results also emphasize the importance aligning of behavioral goals and behavioral outcome measures (Strath et al., 2013). As such, the intervention only affected achievement of the behavioral goal of adhering to the recommended activity guideline, but did not significantly change the overall level of moderate-to-vigorous daily physical activity compared to the control group. These differential findings should be viewed as complementary rather than conflicting. The findings underscore that individuals receiving the intervention focused on achieving the daily goal of 30 minutes performed in bouts of at least 10 minutes (e.g., going for a brisk walk, taking the bike to work) rather than on engaging in more physical activity overall including all moderate-intensity activity bursts below ten minutes (e.g., catching a bus, walking to the parking lot). Bouts of 10 minutes are an integral part of the global physical activity recommendations (e.g., Haskell et al., 2007).

Another aim of this study was to investigate whether a dyadic conceptualization of action control is even more effective than an individual intervention. Involving a close other such as the romantic partner can have beneficial effects on behavior change (e.g., Jackson et al., 2015). However, contrary to our hypothesis, no superior effect of the dyadic group emerged compared to the individual group on daily physical activity outcomes during the intervention and follow-up phase. Several factors could have contributed to this finding. First, participants in the individual intervention group may have perceived the daily action control text messages just as supportive as participants in the dyadic group. Previous research suggests that automated text messages can be perceived as caring and supportive (Brandt, Dalum, & Thomsen, 2013). Therefore, participants of the individual intervention may have experienced the setting as equally dyadic, even though the text messages came from the study team instead of the partner. Second, the chosen setting for the individual and dyadic group might not have been distinctive enough. Besides choosing personal greetings and making modifications in terms of dialect wording, partners of the dyadic group were not allowed to change the content of the message, or to discuss the messages. Overall, this may have limited the personal component of dyadic interaction in favor of a standardized approach to systematically test for the experimental manipulation. Future studies might want to consider employing a more personal setting by using private smartphones (for a discussion see Scholz & Berli, 2014) and individualized message wording. Likewise, it would be interesting to test whether other forms of dyadic action control apart from text messaging (e.g., in person reminders) could be effectively used. Third, it needs to be kept in mind that one in four participants in the dyadic condition only received half of the messages in the intended manner. While a sensitivity analysis excluding those participants did not yield a different pattern of results, it cannot be ruled out that this may have masked potential differences between the two experimental groups.

Strength and Limitations

The present study has several strengths. First, it represents a first theory-based intervention targeting all three subcomponents of action control in an everyday life setting by using text messages in romantic couples. Second, the design of the present study also allowed examining the effects of the action control intervention on daily physical activity during and right after the intervention using an objective measure of accelerometry. Third, this is the first study to explore action control at the level of the dyad by recruiting romantic couples as participants. Even though no added value of a dyadic action control group emerged, this study may guide future studies examining an effective conceptualization of dyadic action control.

Some limitations need to be acknowledged as well. First, with our study design, it is not possible to systematically disentangle the effects of the different intervention components on behavior. It might be that the action control text messages primarily served to maintain the adherence to physical activity guidelines, or that the combination of both, the behavioral intentions and text messages, were responsible for boosting the adherence to physical activity levels. Text messages are often part of interventions applying multiple behavior change components. In order to systematically detect the effectiveness of the action control text messages, another intervention arm involving only goal setting but no text messages would be needed (Scholz & Berli, 2014). However, due to the strict inclusion criteria in the present study, this was not feasible with regard to achieving an adequate sample size to provide sufficient statistical power. Second, due to small sample sizes of the two intervention groups, this study was not adequately powered to detect an effect of the dyadic action control group over the individual action control group. Third, the content of the action control text messages were not tailored to the individual, that is, except for a personal greeting, participants received standard messages. Previous research has indicated that tailored health messages may be more effective for changing behavior (Fjeldsoe et al., 2009; Head et al., 2013). Future studies should consider employing reminders that are specifically linked to the behavioral intentions set by the individual. Fourth, recruitment via advertisements may have entailed a bias due to self-selection. Individuals volunteering to participate usually tend to have more favorable lifestyles and health outcomes (e.g., Lindsted, Fraser, Steinkohl, & Beeson, 1996).

Implications

This study adds to the evidence that action control text messages may be an effective and low-cost tool for delivering health promotion in the context of weight control. More research is needed to test the mechanisms hypothesized to explain the intervention effects, as behavioral intentions, self-reported action control, other self-regulatory strategies (e.g., planning, self-efficacy), or social exchange variables (e.g., social control, social support). This can particularly contribute to a better understanding how social exchange processes are elicited through self-regulation interventions. Based on our findings, we suspect that social processes were not only triggered in the dyadic group where the partner was actively involved in the action control process. It may also have been the case in the individual group where text messages were sent by the study staff, but partners also participated in the study pursuing the same activity goal as the target person. In line with this, the intervention may also have triggered dyadic regulation strategies (e.g., dyadic planning) in that participants discussed and planned their physical activities more jointly. Moreover, future research should concentrate in more detail on the effects of text message characteristics. For example, it would be interesting to examine whether the three sub-facets of action control differ in their effectiveness on daily physical activity outcomes. Also, as suggested by Fjeldsoe et al. (2009), the level of interaction with participants in text message interventions should be considered. This could be especially important for a dyadic intervention, by systematically examining the extent and nature to which partners respond to the messages received. At last, the present results encouragingly demonstrate that the intervention effect extends to the 14 days following intervention. Future studies should further test the longer-term maintenance of physical activity adherence following interventions. A longer time frame might also be useful for revealing differential effects of the dyadic and individual intervention, as an additional effect of the dyadic component may accumulate over time, or unfold nonlinearly depending on the situational context (e.g., in moments of low self-regulation capacity such as goal failure).

In sum, results of the present study emphasize that an ecological momentary intervention using action control text messages is particularly effective in enhancing daily adherence to physical activity guidelines in overweight and obese individuals. Future studies need to further investigate the usefulness of a dyadic conceptualization of action control for health behavior change.

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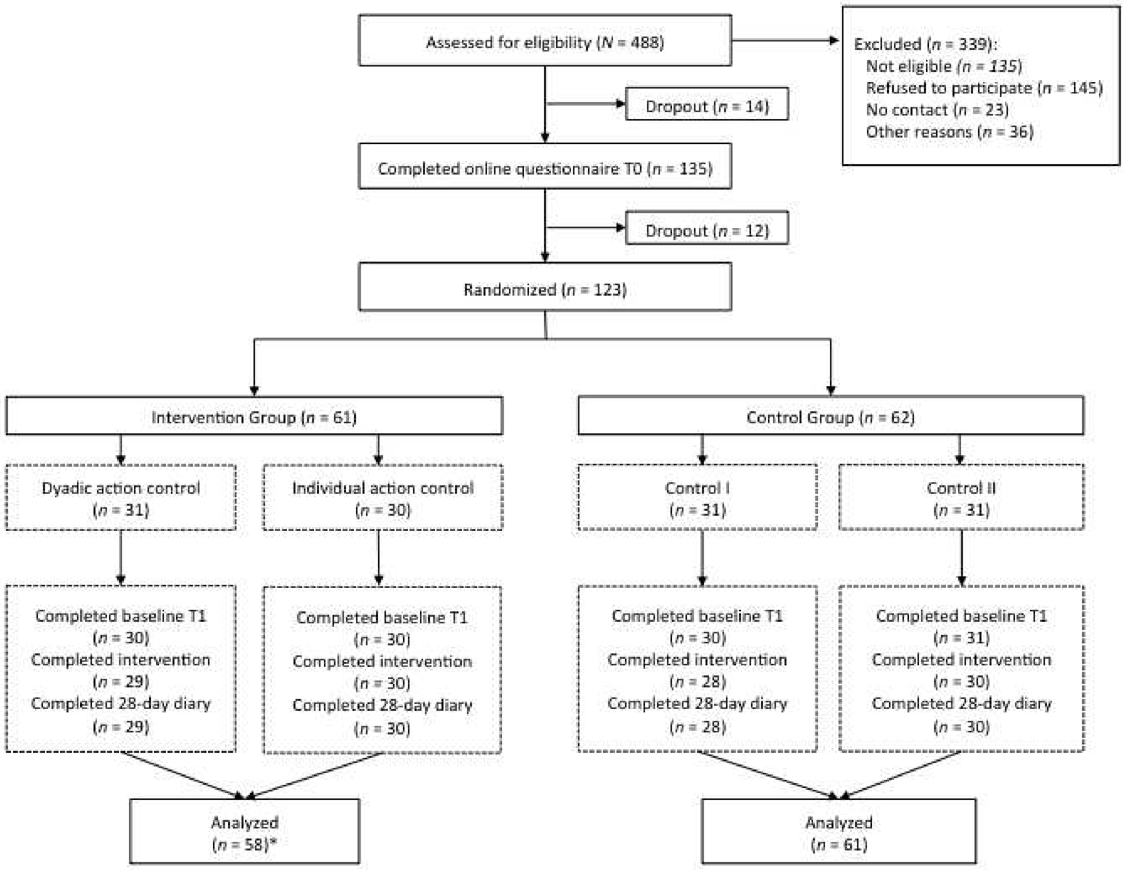

Figure 1. Flowchart of participating couples

Note. * In the dyadic action control group only 28 participants were included for intention-to-treat analyses as two target persons did not provide any accelerometer data from the 28-day diary phase, resulting in an analyzed sample of n = 58 for the intervention group.

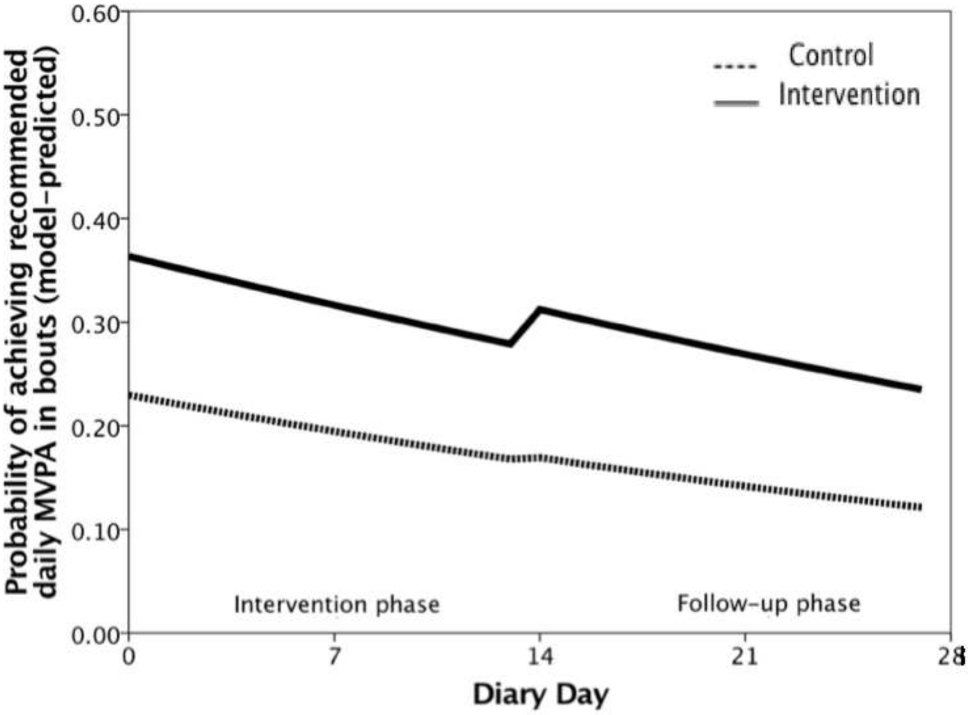

Figure 2. Graphic representation of the model-predicted average probability of achieving recommended daily moderate-to-vigorous physical activity (MVPA) in bouts across time for intervention and control groups.

Table 1. *Baseline characteristics for target persons in intervention and control group (N = 121)*

Variables	Intervention Group (n = 60)	Control Group (n = 61)	χ^2
Female (%)	51.7	50.8	0.01
Married (%)	76.7	62.3	2.94
Higher education (%)	18.3	32.8	3.32
Employed (%)	65.0	65.6	.004
			t
Age (years)	48.33 (13.13)	43.97 (13.86)	-1.78
Body mass index (kg/m^2)	31.71 (6.47)	30.26 (4.48)	-1.43
Relationship duration (years)	19.56 (14.27)	18.03 (14.48)	-5.87
Baseline intentions	4.98 (0.61)	4.70 (0.72)	-2.30
Baseline action control	3.18 (1.23)	2.86 (1.10)	-1.49

Note. Summary statistics are presented as Mean (*SD*) unless stated otherwise. Group comparisons were non-significant, except for baseline intentions ($p < .05$).

Table 2. *Mixed models testing effects of intervention versus control group on daily physical activity outcomes*

	GLMM: Adherence to recommended MVPA bouts				Linear mixed model: Overall MVPA (minutes)			
					log-transformed			
			95% *CI* for *OR*			**95% *CI***		
Fixed effects	***B***	***OR***	**Lower**	**Upper**	***B***	**Lower**	**Upper**	***B*** [a]
Intercept [b]	-1.21**	0.30	0.21	0.44	3.68**	3.52	3.83	38.58
Wear-time (in hours)	-0.03	0.97	0.93	1.02	0.05**	0.04	0.07	2.21
Time (per 7 days)	-0.24**	0.79	0.68	0.92	-0.02	-0.07	0.02	-0.79
Intervention group [c]	0.65*	1.92	1.17	3.16	0.05	-0.16	0.27	2.16
Follow-up phase [d]	0.04	1.04	0.69	1.55	0.01	-0.10	0.12	0.26
Follow-up phase × Intervention group	0.15	1.17	0.79	1.71	-0.02	-0.13	0.09	-0.87
			95% *CI*			**95% *CI***		
Random effects (variances)	**Estimate**		**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**	
Level 2 (inter-individual)								
Intercept	1.43**		1.00	2.05	0.31**	0.23	0.41	
Time	0.05†		0.02	0.13	0.003	0.001	0.012	
Level 1 (intra-individual)								
Residual	0.84**		0.80	0.89	0.43**	0.41	0.45	
Autocorrelation	-0.002		-0.04	0.04	0.04†	-0.01	0.08	

Note. N = 119 persons with a maximum of 28 days, *n* = 2,854 available days. *B* = unstandardized regression coefficients. *CI* = Confidence interval. MVPA = Moderate-to-vigorous physical activity. *OR* = Odds ratio. [a] back-transformed to minutes per day for ease of interpretation. [b] Intercept = Level of the outcome for the control group at first intervention day. [c] Intervention groups: 0 = control group, 1 = dyadic and individual action control groups. [d] Follow-up phase: 0 = days during intervention, 1 = days following intervention. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$

Table 3. *Mixed models comparing effects of the dyadic versus individual action control intervention on daily physical activity outcomes*

	GLMM Adherence to recommended MVPA bouts				Linear mixed model: Overall MVPA (minutes)			
					log-transformed			
			95% *CI* for *OR*			95% *CI*		
Fixed effects	***B***	***OR***	**Lower**	**Upper**	***B***	**Lower**	**Upper**	***B*** [a]
Intercept [b]	-0.41	0.66	0.39	1.14	3.78**	3.54	4.01	42.62
Wear-time (in hours)	-0.03	0.98	0.91	1.04	0.05**	0.03	0.07	2.09
Time (per 7 days)	-0.35**	0.71	0.57	0.88	-0.04	-0.10	0.02	-1.54
Dyadic group [c]	-0.12	0.89	0.42	1.85	-0.07	-0.39	0.26	-2.85
Follow-up phase [d]	0.44	1.55	0.92	2.61	0.02	-0.12	0.17	1.07
Follow-up phase × Dyadic group	-0.09	0.91	0.54	1.54	-0.02	-0.16	0.12	-0.96
			95% *CI*			95% *CI*		
Random effects (variances)	**Estimate**		**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**	
Level 2 (inter-individual)								
Intercept	1.60**		0.97	2.63	0.35**	0.24	0.52	
Time [e]	–		–	–	–	–	–	
Level 1 (intra-individual)								
Residual	0.87**		0.81	0.94	0.41**	0.38	0.44	
Autocorrelation	0.02		-0.04	0.08	0.02	-0.04	0.07	

Note. N = 58 persons with a maximum of 28 days, *n* = 1,419 available days. *B* = Unstandardized regression coefficients. *CI* = Confidence interval. MVPA = Moderate-to-vigorous physical activity. *OR* = Odds ratio. [a] back-transformed to minutes per day for ease of interpretation. [b] Intercept = Level of the outcome for the individual action control group at first intervention day. [c] Dyadic group: 0 =

individual action control group, 1 = dyadic action control group. [d] Follow-up phase: 0 = days during intervention, 1 = days following intervention. [e] Due to non-convergence, no random effect for time could be computed. *p < .05, **p < .01