J Behav Med (2015) 38:306–317
DOI 10.1007/s10865-014-9598-x

Volitional processes and daily smoking: examining inter- and intraindividual associations around a quit attempt

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Received: May 14, 2014 / Accepted: September 17, 2014 / Published online: October 8, 2014

Abstract The Health Action Process Approach (HAPA) assumes that volitional processes are important for effective behavioral change. However, intraindividual associations have not yet been tested in the context of smoking cessation. This study examined the inter- and intraindividual associations between volitional HAPA variables and daily smoking before and after a quit attempt. Overall, 100 smokers completed daily surveys on mobile phones from 10 days before until 21 days after a self-set quit date, including self-efficacy, action planning, action control, and numbers of cigarettes smoked. Negative associations between volitional variables and daily numbers of cigarettes smoked emerged at the inter- and intraindividual level. Except for interindividual action planning, associations were stronger after the quit date than before the quit date. Self-efficacy, planning and action control were identified as critical inter- and intraindividual processes in smoking cessation, particularly after a self-set quit attempt when actual behavior change is performed.

Keywords Smoking cessation · Volitional processes · Health behavior change · Health Action Process Approach · Inter- and intraindividual

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Introduction

Smoking is a serious public health threat worldwide. It accounts for at least 30 % of all cancer deaths and is a major cause of many other health problems such as heart disease, stroke, aneurysms and chronic bronchitis (American Cancer Society, 2014). In 2012, one fourth (25.9 %) of the Swiss adult population aged 15 years or more smoked regularly and more than half (56.9 %) of the smokers reported the desire to quit smoking (Gmel et al., 2013). Quitting smoking is associated with immediate and long-term health benefits for smokers of all ages (World Health Organization [WHO], 2013). Thus, it is of high importance to examine which factors contribute to successful smoking cessation.

The Health Action Process Approach (HAPA; Schwarzer, 2008) provides a theoretical framework for identifying important processes for behavior change and proposes that self-regulatory skills and strategies are needed to translate intentions into action (e.g., Schwarzer et al., 2011). To gain a better understanding of such self-regulatory processes in the context of smoking cessation, this study's main aim was to examine associations of volitional HAPA variables and daily smoking before and after the quit date at both the inter- and intraindividual level.

Volitional processes of health behavior change

The HAPA (Schwarzer, 2008) suggests a distinction between (a) preintentional motivational processes, that lead to the formation of a behavioral intention, and (b) postintentional volitional processes, that lead to the actual health behavior (see Fig. 1). Within the motivational phase, risk perception, outcome expectancies, and self-efficacy are

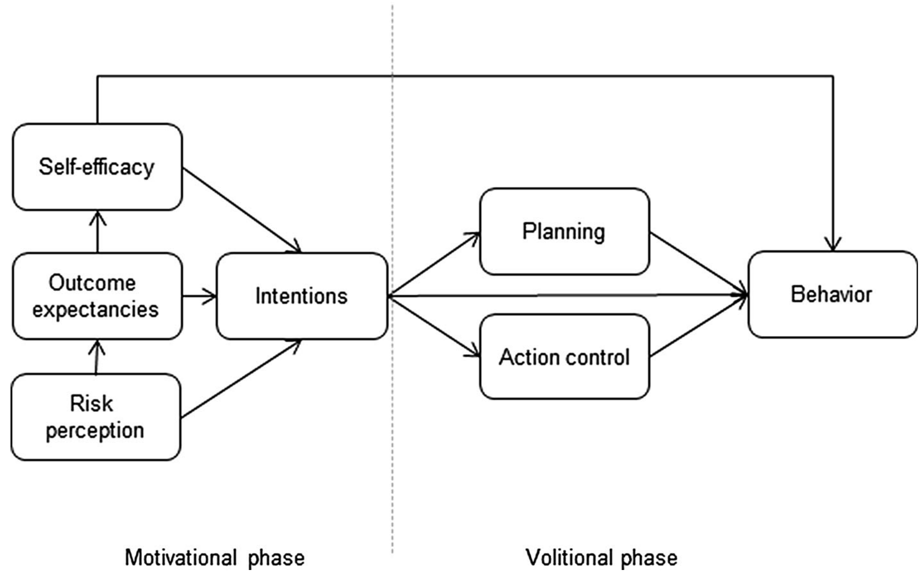

Fig. 1 The Health Action Process Approach (HAPA; Schwarzer, 2008)

assumed to be joint predictors of intentions to perform a certain health behavior. With the formation of an intention, the motivational phase is completed and the person enters the volitional phase. Within the volitional phase, it is assumed that more proximal predictors become important, such as action planning and action control. Self-efficacy, which refers to beliefs in one's capability to perform a desired action, is assumed to be crucial for both phases, motivation and volition (Sniehotta et al., 2005). Action planning or implementation intentions (cf. Gollwitzer, 1999) address the prospective self-regulatory strategy of forming concrete plans about when, where, and how to perform the intended behavior and have demonstrated usefulness in facilitating health behavior change (e.g., Kreausukon et al., 2012). Action control is a concurrent self-regulatory strategy to ongoing behavior and comprises three subfacets: awareness of standards, self-monitoring and self-regulatory effort (Scholz et al., 2008). Awareness of standards refers to being aware of one's self-set intentions in terms of behavior change. Self-monitoring involves observing one's behavior and evaluating whether it corresponds with one's intentions. Self-regulatory effort stands for the compensatory action invested to reduce discrepancies between one's behavior and self-set intentions. The concept of action control in behavioral self-regulation draws from the negative feedback loop proposed by Carver and Scheier (1998), aiming at reducing discrepancies between input and standard (e.g., trying to refrain from smoking). Self-monitoring, that by providing input information on actual behavior allows for the comparison with one's standards, has proved to be an effective technique in behavior change (Michie et al., 2009). Overall, the HAPA has demonstrated applicability across a variety of different samples and health behaviors (Schwarzer, 2008). In terms of smoking, studies provide evidence that the HAPA variables predict smoking reduction among young adults (Schwarzer & Luszczynska, 2008) and that changes in HAPA variables predict changes in smoking behavior across four weeks (Scholz, Nagy, et al., 2009). However, there are still important gaps in research on health behavior change that need to be addressed.

First, when it comes to identifying individuals at different stages along the health behavior change process, the HAPA proposes a subdivision of the volitional phase in order to distinguish between a *postintentional preactional* phase, in which a decision has been made but the behavior has not yet been performed (i.e., intenders), and a *postintentional actional* phase, in which the target behavior has been initiated (i.e., actors) (Schwarzer, 2008). Although stage-specific factors are assumed to be essential for passing through the different phases (e.g., Lippke et al., 2005), the HAPA does not explicitly state how the proposed volitional processes come into play within the preactional and actional phase. Some studies suggest that the underlying volitional processes might be quite similar in the preactional and actional phase, by facilitating progression or regression in stage transition (Parschau et al., 2011; Wiedemann et al., 2008). Other studies in contrast provide evidence that actors report higher levels of volitional processes than individuals in the preactional phase (e.g., Chiu et al., 2012; Lippke et al., 2005). These latter findings suggest that the volitional processes could be of increased importance in the actional phase. However, studies are needed that examine the change in importance of volitional variables on a daily level around a clear-cut change from the preactional to the actional phase, such as in the context of smoking cessation (e.g., before and after the quit date). Thus, investigating the effectiveness of the volitional processes on daily smoking in a prospective design around a quit attempt will provide an important advancement in understanding the processes involved in behavior change.

Second, only few studies so far have tested the associations of self-regulatory HAPA processes and health behavior at the intraindividual level. As Nezlek (2001) points out those do not necessarily correspond with associations at the interindividual level. Scholz et al. (2008) found evidence that associations between motivational and volitional factors and running activity across 11 occasions were in line with theoretical predictions of the HAPA at both the inter- and intraindividual level. Furthermore, Scholz, Keller, et al. (2009) tested the model's assumptions in a sample of first-year students across nine measurement points. The results mainly confirmed associations specified by the HAPA at the intraindividual level in that motivational factors were positively associated with intentions for physical exercise and volitional factors were positively associated with physical exercise. Also in terms of other established health behavior theories, testing the models' assumptions at the intraindividual level is rather scarce. Some studies provide evidence for intraindividual effects of social-cognitive predictors of the theory of planned behavior (TPB), for example by examining weekly intentions on total steps counted (Conroy et al., 2011) or day-to-day changes in behavioral intentions, attitudes and self-efficacy for daily condom use (Kiene et al., 2008). In the context of smoking cessation, Shiffman et al. (2000) examined the day-to-day variation in self-efficacy and found it to predict smoking relapses after quitting. Examining associations within individuals at a daily level is of high importance, because smoking cessation is a dynamic day-to-day process and fluctuations are more common than most traditional models of change imply (cf. Peters & Hughes, 2009). However, no study so far has systematically investigated self-regulatory volitional processes at a day-to-day level within an established framework of health behavior change in the context of smoking cessation. Thus, in the present study we sought to account for these gaps.

Aims of the present study

The aims of the present study were twofold. First, we tested whether the volitional variables self-efficacy, action planning, and action control predicted daily smoking in individuals intending to quit before and after a quit attempt at the interindividual and intraindividual level. We hypothesized that—in line with assumptions of the HAPA—each of the three volitional processes was negatively associated with daily smoking on both levels. Second, based on previous research on stage transitions we assumed that all volitional processes would be involved in the preactional (e.g., before the quit date) and actional (e.g., after the quit date) phase of smoking cessation. However, in line with first findings on actors showing higher means in some of the volitional factors (cf. Chiu et al., 2012; Lippke et al., 2005), we assumed that daily volitional processes would become even more important after the quit date, when individuals finally have to take action and refrain from smoking. Thus, we hypothesized that the associations between the volitional processes and daily smoking would be more pronounced after the quit date than before.

Method

Procedure and participants

This study was part of a larger project on 'Dyadic and individual regulation to end chronic tobacco use' (DIRECT), funded by the Swiss National Science Foundation (100014_124516). For more details on the study see Ochsner et al. (2014).[1] It comprised a prospective longitudinal design with daily diary assessments during 32 consecutive days. Participants were recruited via a market research institute as well as flyers and postings. Eligibility criteria were that participants smoked at least one cigarette per day (defined as a criterion for daily smoking by the WHO, 1998) and intended to quit smoking, were in a committed heterosexual relationship with a non-smoking partner for at least 1 year and cohabiting for at least 6 months. Both partners had to be at least 18 years of age and speak fluent German. Pregnancy and the ongoing attendance to a professional smoking cessation program served as exclusion criteria. Non-smoking partners also participated in the project, but were not focused on in the present study. Participating couples were invited to the lab for baseline assessment and smokers were instructed to choose a quit date for smoking cessation. They were instructed to complete electronic diaries on smartphones provided for this occasion every evening within 1 h of going to bed from 10 days before until 21 days after the self-set quit date. All participants received a reminder email 1 day prior to the first diary entry. In addition, participants who missed entries for more than three consecutive days received a reminder per telephone. After the diary assessment, participants returned to the lab for a follow-up assessment (on average 29 days after the quit date) and performed a carbon monoxide test of expired air to bio-

[1] This study was part of a larger longitudinal study. Based on these data, the research team has pursued other unique theoretical questions in publications with a different theoretical focus and different data subsets (Lüscher et al., in press; Lüscher et al., 2014; Ochsner et al., in press; Ochsner et al., 2014).

chemically verify smoking status. Each participating couple then received CHF100. All participants were treated in accordance with APA's ethical guidelines.

In total, data from 106 smokers were collected. Six smokers were excluded from the present analyses as they dropped out of the study before their self-set quit date and were thus not part of the study's population of quitters. The final sample consisted of $N = 100$ smokers (72 % male) who completed a total of 2,926 diary entries (91.4 %). Participants were between 19 and 72 years old ($M = 40.48$, $SD = 9.82$), 27 % had higher education (general qualification for university entrance, "Matura"), 66.7 % were married and 58 % had children.

Measures

All HAPA variables were assessed daily using single items adapted from scales by Scholz et al. (2009). Response format was 1 (not at all true) to 6 (completely true). All items presented here were translated from German. Table 1 gives an overview on means, standard deviations, range, and intraclass correlations (ICC) of main variables in the present study.

Self-efficacy was measured by the item "I am confident that I can refrain from smoking tomorrow even if it is difficult."

Action planning was assessed by the item "I have made a detailed plan for tomorrow as to how I achieve not to smoke."

Action control was assessed by the item "Today I constantly monitored whether I acted the way I intended to in terms of my smoking" which addresses the subcomponent of self-monitoring, one of the three subfacets of action control.

Daily numbers of cigarettes smoked was assessed by the items "Did you smoke today (including only one puff)?" with the response format of no (0) and yes (1), and if yes, "How many cigarettes did you smoke today?". Participants who reported having not smoked today were given a zero. Non-integers (one participant reported 0.25 cigarettes and two reported 0.5) were conservatively rounded to the next higher integer as the applied Poisson model considers non-negative integers only.

Nicotine dependence was assessed at baseline by the six items of the Fagerström-test of nicotine dependence (Heatherton et al., 1991) such as "Do you smoke even if you are so ill that you are in bed most of the day?". The total score represents the sum of item scores, with higher scores indicating higher levels of nicotine dependence. Nicotine dependence was used as a covariate in the present study.

Smoking abstinence was measured with a biochemical verification of point prevalence at the follow-up. For this purpose a carbon monoxide test (CO) of expired air was applied by using a Smokerlyzer (Bedfont Instruments, Harrietsham, UK). As West et al. (2005) point out, a CO test is the preferred method of detecting recent smoking and provides at least a minimum assurance concerning abstinence. The authors suggest a cut-off point of 9 parts per million (p.p.m.) as usual for CO validation. Therefore, in the present study participants were categorized as *non-smoking* (≤9 p.p.m) versus *smoking* (>9 p.p.m).

Data analysis

The primary focus of the present study was to examine whether volitional processes from the HAPA predicted daily smoking before and after a quit attempt at the inter- as well as at the intraindividual level. As the study involved intensive longitudinal data, statistical models that account for the nested structure of repeated measures within individuals were needed. To examine the amount of variability on both levels, intraclass correlations (ICC) were calculated for each variable in the study (see Table 1). Moreover, the dependent variable, numbers of cigarettes smoked, was a count variable that was highly skewed with a large number of zeroes ($n = 1{,}035$ zeroes, 35.4 % of total data points). To accurately model the data, we applied a generalized linear mixed model for count outcomes (GLMM) using Poisson distribution with logarithmic link function. GLMM's are an appropriate tool for analyzing non-normal data that involve non-independent observations (Bolker et al., 2009). The

Table 1 Means, standard deviations, and intraclass correlations (ICC) for main variables

	N	*n*	Missing (%)	*M*	*SD*	Range	ICC
Numbers of cigarettes smoked	100	2,924	8.6	7.89	9.06	0–60	0.51
Self-efficacy	100	2,926	8.6	3.96	1.75	1–6	0.27
Action planning	100	2,926	8.6	3.22	1.72	1–6	0.39
Action control	100	2,926	8.6	3.52	1.69	1–6	0.43

n = number of available diary entries. Two entries did not contain information on the amount of smoked cigarettes per day resulting in two more missing days for numbers of cigarettes smoked

Table 2 Correlations between volitional HAPA variables, numbers of cigarettes smoked and covariates at the inter- and intraindividual level

	1	2	3	4	5	6	7
1. Self-efficacy	–	0.68***	0.36***	−0.63***	–	–	–
2. Action planning	0.48***	–	0.37***	−0.48***	–	–	–
3. Action control	0.51***	0.70***	–	−0.42***	–	–	–
4. Numbers of cigarettes smoked	−0.71***	−0.29***	−0.41***	–	–	–	–
5. Sex (0 = female, 1 = male)	0.07	−0.04	0.05	0.04	–	–	–
6. Age	−0.09	0.14	0.15	0.25*	0.04	–	–
7. Higher education (0 = no, 1 = yes)	0.22*	−0.11	−0.02	−0.21*	−0.02	−0.14	–
8. Nicotine dependence	−0.35**	−0.04	−0.16	0.58***	0.07	0.19	−0.30**

Below diagonal are correlations at the interindividual level ($N = 100$); above diagonal are correlations at the intraindividual level ($n = 2{,}834$–2,924 available days). Because the covariates age, education, nicotine dependence vary between persons only, correlations were computed at the interindividual level

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

Poisson distribution is a discrete distribution for non-negative integers and, as opposed to normal distributions, is a much better fit for count data such as numbers of cigarettes smoked. Poisson regression is similar to logistic regression, except that the linear predictor of the regression model is connected to the outcome via a natural logarithm link function. Therefore, the regression coefficients from a Poisson model are on a log scale and are typically exponentiated and interpreted as rate ratios (Atkins & Gallop, 2007). Generally, the distance above and below 1 in rate ratios is interpreted as the percentage increase or decrease in the outcome for a one-unit increase in the predictor (Atkins et al., 2013).

To examine the associations between the volitional processes and daily smoking at the inter- and intraindividual level, we decomposed all predictor variables into individual mean levels across the 32 days (e.g., interindividual variation) and the daily fluctuation around these mean levels (e.g., intraindividual variation). For this purpose, individual mean levels were centered around the sample ("grand") mean and daily scores were centered around the individual ("group") mean. Also, continuous covariates at Level 2 (i.e., age and nicotine dependence) were centered around the grand-mean. To model systematic effects over time, a *time* variable was created to represent the 32 diary days. Moreover, we computed a dummy-coded variable *quit date* with days prior to the quit date set to 0 and the quit date itself and days after the quit date set to 1. To test for differential effects before and after the quit date, for all predictor variables an interaction between predictor and *quit date* was generated and included into the model as a truly non-linear change function (Singer & Willett, 2003).

For each volitional process a generalized linear mixed Poisson model with the following predictors was tested: time, quit date, the interaction between time and quit date, the interindividual variation of the volitional predictor, the intraindividual variation of the volitional predictor, and their interactions with quit date. Based on significant bivariate associations with numbers of cigarettes smoked (see Table 2), age, education and nicotine dependence were included as covariates, but due to limited space results are not discussed in the text. Furthermore, as suggested by Barr et al. (2013), for each model a maximal random effects structure was specified including random slopes of all Level 1 predictors (allowing individuals to differ in associations between predictor and outcome). In case of nonconvergence, the random effects structure was progressively simplified until convergence was reached.[2]

For descriptive purposes, we investigated the inter-correlations among the volitional HAPA variables, daily numbers of cigarettes smoked and covariates at the inter- and intraindividual level. To calculate the interindividual correlation, Pearson correlations of the individual mean levels were conducted. The average intraindividual correlation for Level 1 variables was calculated by standardizing each person's daily scores to have a mean of zero and a within-person standard deviation of one, and regressing one standardized variable on another variable in a mixed model (cf. Green et al., 2006). As all variables were standardized within person, the slope of the resulting model represents the bivariate intraindividual correlation. All analyses were carried out using the general linear mixed model procedure in SPSS 21.

[2] Due to the competing statement of repeated measures, models including a random effect of the intercept did not converge why no random intercept was specified in the analyses.

Results

Preliminary analysis

Intra-class correlation (ICC) analyses of all variables revealed moderate ICCs varying from 0.27 to 0.51 (see Table 1). The ICC is a measure of the degree of dependence of data points and is defined as the amount of variance between second-level units, in this case individuals, in relation to total variance (Kreft & DeLeeuw, 1998). Therefore, as evidenced by an ICC of 0.51, half of the total variance in numbers of cigarettes smoked was due to stable interindividual differences.

Bivariate interindividual correlations among volitional HAPA variables ranged between 0.46 and 0.70 and was highest for action planning and action control (see Table 2). This indicates that participants with higher mean levels across the diary days in one of the volitional variables also reported higher mean levels in the other volitional variables. Average intraindividual correlations were moderate to high varying between 0.36 and 0.68. This indicates that on days on which participants reported higher-than-average levels in one of the volitional variables, they also reported higher-than-average levels in the other volitional variables. The highest correlation resulted for self-efficacy and action planning.

The CO test used to assess the point prevalence of smoking abstinence at the follow-up resulted in 67 non-smoking participants. Those 67 participants biochemically verified as non-smokers included all of the 34 participants that reported having smoked less than five cigarettes since their quit date, which serves as an indicator for the more rigorous measure of continuous abstinence (West et al., 2005).

Self-efficacy predicting daily smoking

The results of the model testing self-efficacy as a predictor for daily smoking are presented in Table 3. The intercept rate ratio (RR) of 12.64 provides the estimated numbers of cigarettes smoked on day 0 for the average person (i.e., when all covariates are equal to zero). A significant negative effect emerged for quit date, the RR of 0.14 indicating that numbers of cigarettes smoked decreased by 86 % from initial levels at day 0 to the day of the quit date. There was no significant effect for time nor for the interaction of time and quit date, indicating that numbers of cigarettes smoked were not associated with time before and after the quit date. At the interindividual level, a significant effect for self-efficacy and its interaction with quit date emerged. These results indicate that before and after the quit date higher individual mean levels of self-efficacy across the 32 days were associated with less cigarettes smoked. The RR's reveal that the reduction in numbers of cigarettes smoked with a one-unit increase in self-efficacy was greater after the quit date (64 %) than before the quit date (9 %). At the intraindividual level, only a significant interaction with quit date emerged: On days with higher self-efficacy than individual mean levels, less cigarettes were smoked after the quit date. The RR indicates a reduction of 11 % in numbers of cigarettes smoked after the quit date with a one-unit increase in self-efficacy. There was no significant intraindividual association between self-efficacy and numbers of cigarettes smoked before the quit date.

The random effects of the slopes of time, quit date and the interaction between time and quit date were significantly different from zero, indicating interindividual differences in associations between numbers of cigarettes smoked and quit date and time across diary days before and after the quit date. No significant random effects emerged for intraindividual self-efficacy before and after the quit date (i.e., associations between numbers of cigarettes smoked and daily fluctuations in self-efficacy did not differ between individuals). The Level 1 random effects at the bottom of the table give evidence for residual variance, representing the deviations of daily scores of numbers of cigarettes smoked from predicted values in the model, and for autocorrelation of residuals.

Action planning predicting daily smoking

The results of the model testing action planning as a predictor for daily smoking are displayed in Table 4. Again, a significant effect emerged for the intercept and for the quit date, but not for time across the 32 days or its interaction with quit date. At the interindividual level, action planning emerged as a significant negative predictor, indicating that higher individual mean levels of action planning across the 32 days were overall associated with less cigarettes smoked. The RR reveals that there was a reduction of 5 % in numbers of cigarettes smoked with a one-unit increase in action planning. No interaction effect with quit date emerged, revealing that associations between action planning and numbers of cigarettes smoked did not differ before and after the quit date. At the intraindividual level, only a significant interaction with quit date emerged, revealing that after the quit date on days with higher action planning than individual mean levels, less cigarettes were smoked. The RR indicates a reduction of 5 % in numbers of cigarettes smoked after the quit date with a one-unit increase in action planning. There was no significant intraindividual association between action planning and numbers of cigarettes smoked before the quit date.

The random effects of the slopes of time, quit date, the interaction between time and quit date and of intraindi-

Table 3 Generalized linear mixed Poisson model of numbers of cigarettes smoked regressed on self-efficacy

Fixed effects	*B*	*SE*	*RR*	95 % CI for RR	
				Lower	Upper
Intercept	2.54***	(0.04)	12.64	11.72	13.65
Time	−0.01	(0.01)	0.99	0.98	1.01
Quit date	−2.00***	(0.17)	0.14	0.10	0.19
Time × quit date	−0.01	(0.01)	1.00	0.98	1.01
Interindividual self-efficacy	−0.10***	(0.02)	0.91	0.86	0.95
Interindividual self-efficacy × quit date	−1.02***	(0.15)	0.36	0.27	0.48
Intraindividual self-efficacy	−0.00	(0.01)	1.00	0.98	1.02
Intraindividual self-efficacy × quit date	−0.12***	(0.03)	0.89	0.83	0.95
Age	0.02***	(0.00)	1.02	1.01	1.02
Higher education	0.27***	(0.06)	1.31	1.17	1.46
Nicotine dependence	0.17***	(0.01)	1.19	1.16	1.22

Random effects (variances)	Estimate	*SE*	95 % CI	
			Lower	Upper
Level 2 (interindividual)				
Time	0.002***	(0.00)	0.001	0.004
Quit date	1.26***	(0.32)	0.76	2.07
Time × quit date	0.002*	(0.00)	0.001	0.004
Intraindividual self-efficacy	0.00	(0.00)	0.00	0.01
Intraindividual self-efficacy × quit date	0.03	(0.01)	0.01	0.07
Level 1 (intraindividual)				
Residual	1.61***	(0.08)	1.45	1.78
Autocorrelation	0.45***	(0.03)	0.39	0.51

$N = 100$ smokers with a maximum of 32 days, $n = 2{,}924$ available days. B = unstandardized regression coefficients, SE = standard errors, RR = rate ratios; 95 % CI = 95 % confidence interval. For quit date 0 = days prior to quit date, 1 = quit date and days after; for higher education 0 = no, 1 = yes

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

vidual action planning, but not of the interaction between intraindividual action planning and quit date, were significantly different from zero, indicating interindividual differences in associations between numbers of cigarettes smoked and predictors. Again, there were significant Level 1 random effects.

Action control predicting daily smoking

The results of the model testing action control as a predictor for daily smoking are presented in Table 5. At the interindividual level, action control as well as its interaction with quit date emerged as significant negative predictors. These results indicate that before and after the quit date higher individual mean levels of action control across the 32 days were associated with less cigarettes smoked. The respective RR's (0.93 and 0.62) show that there was a greater reduction in numbers of cigarettes smoked after the quit date with a one-unit increase in action control. At the intraindividual level, again a significant effect for action control and its interaction with quit date emerged. These results indicate that on days with higher action control than individual mean levels, less cigarettes were smoked before and after the quit date, and that reduction was greater after the quit date (11 %) than before the quit date (3 %).

The random effects of the slopes of time and quit date were significantly different from zero, indicating interindividual differences in associations between numbers of cigarettes smoked and time across the 32 days and quit date. Again, there were significant Level 1 random effects.

Discussion

The aim of the present study was to investigate the volitional HAPA processes as predictors of daily smoking before and after a quit attempt at the inter- and intraindividual level. Findings showed that at the interindividual

Table 4 Generalized linear mixed Poisson models of numbers of cigarettes smoked regressed on action planning

Fixed effects	*B*	*SE*	*RR*	95 % CI for RR	
				Lower	Upper
Intercept	2.56***	(0.04)	12.90	11.97	13.91
Time	−0.01	(0.01)	0.99	0.98	1.01
Quit date	−1.82***	(0.18)	0.16	0.11	0.23
Time × quit date	−0.01	(0.01)	0.99	0.97	1.01
Interindividual action planning	−0.06*	(0.02)	0.95	0.90	0.99
Interindividual action planning × quit date	−0.23	(0.16)	0.80	0.58	1.09
Intraindividual action planning	−0.00	(0.01)	1.00	0.97	1.02
Intraindividual action planning × quit date	−0.05*	(0.02)	0.95	0.91	1.00
Age	0.02***	(0.00)	1.02	1.01	1.02
Higher education	0.20***	(0.06)	1.23	1.10	1.37
Nicotine dependence	0.18***	(0.01)	1.20	1.17	1.23

Random Effects (variances)	Estimate	*SE*	95 % CI	
			Lower	Upper
Level 2 (interindividual)				
Time	0.002***	(0.00)	0.002	0.004
Quit date	1.91***	(0.46)	1.19	3.06
Time × quit date	0.003**	(0.00)	0.001	0.01
Intraindividual action planning	0.002*	(0.00)	0.001	0.01
Intraindividual action planning × quit date	0.01	(0.01)	0.00	0.03
Level 1 (intraindividual)				
Residual	1.62***	(0.08)	1.47	1.79
Autocorrelation	0.48***	(0.03)	0.42	0.53

$N = 100$ smokers with a maximum of 32 days, $n = 2{,}924$ available days. B = unstandardized regression coefficients, SE = standard errors, RR = rate ratios; 95 % CI = 95 % confidence interval. For quit date 0 = days prior to quit date, 1 = quit date and days after; for higher education 0 = no, 1 = yes

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

level, participants with higher individual mean levels of self-efficacy, action planning and action control across the 32 diary days reported less numbers of cigarettes smoked. Whereas for self-efficacy and action control negative associations with daily numbers of cigarettes smoked were stronger after the quit date than before the quit date, no difference in associations before and after the quit date was found for action planning. At the intraindividual level, all volitional variables emerged as significant negative predictors of daily smoking after the quit date. This indicates that on days on which participants reported higher self-efficacy, action planning, and action control than on average (i.e., their individual mean level across the 32 diary days), they also reported smoking less cigarettes. Action control also emerged as a significant negative predictor of daily smoking before the quit date, but again, the association after the quit date was much stronger than before the quit date.

Overall, the findings largely confirm the theoretical assumptions of the HAPA at both the inter- and intraindividual level and suggest that volitional self-regulatory processes might serve as beneficial factors in reducing the amount of daily smoking during a quit attempt. This is in line with previous research focusing on the interindividual level in the context of smoking (Scholz, Nagy, et al., 2009; Schwarzer & Luszczynska, 2008) and other health behaviors such as seat belt use, dental flossing, dietary behavior and physical exercise (Schwarzer et al., 2007). Furthermore, results corroborate first evidence from research on intraindividual associations in the context of physical activity (Scholz, Keller, et al., 2009; Scholz et al., 2008) and thus support the HAPA as a suitable model in predicting behavior change not only between but also within individuals.

Moreover, to our knowledge this study was one of the first to prospectively test for differential effects of the

Table 5 Generalized linear mixed Poisson models of numbers of cigarettes smoked regressed on action control

Fixed effects	*B*	*SE*	*RR*	95 % CI for RR	
				Lower	Upper
Intercept	2.55***	(0.04)	12.83	11.94	13.80
Time	−0.01	(0.01)	0.99	0.98	1.01
Quit date	−1.89***	(0.17)	0.15	0.11	0.21
Time × quit date	−0.00	(0.01)	1.00	0.98	1.01
Interindividual action control	−0.07***	(0.02)	0.93	0.89	0.97
Interindividual action control × quit date	−0.48**	(0.14)	0.62	0.47	0.82
Intraindividual action control	−0.03**	(0.01)	0.97	0.96	0.99
Intraindividual action control × quit date	−0.12***	(0.02)	0.89	0.86	0.91
Age	0.02***	(0.00)	1.02	1.01	1.02
Higher education	0.20***	(0.06)	1.22	1.09	1.37
Nicotine dependence	0.17***	(0.01)	1.19	1.16	1.22

Random Effects (variances)	Estimate	*SE*	95 % CI	
			Lower	Upper
Level 2 (interindividual)				
Time	0.001***	(0.00)	0.001	0.002
Quit date	1.82***	(0.36)	1.24	2.69
Time × quit date	–			
Intraindividual action control	–			
Intraindividual action control × quit date	–			
Level 1 (intraindividual)				
Residual	1.86***	(0.09)	1.70	2.05
Autocorrelation	0.57***	(0.02)	0.52	0.61

$N = 100$ smokers with a maximum of 32 days, $n = 2{,}924$ available days. B = unstandardized regression coefficients, SE = standard errors, RR = rate ratios; 95 % CI = 95 % confidence intervall. For quit date 0 = days prior to quit date, 1 = quit date and days after; for higher education 0 = no, 1 = yes. Due to nonconvergence, only random effects for time and quit date could be computed

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

volitional variables in the post-intentional preactional and actional phase and provides an important advancement in understanding the underlying processes in behavior change. We found support for our hypothesis that the two phases of smoking cessation, i.e., before and after a quit attempt, are quantitatively distinct: All analyses except for interindividual planning yielded a significant interaction effect with the quit date, revealing that negative associations between the volitional process variables and daily smoking were more pronounced after the quit date than before the quit date. These findings emphasize that the volitional variables of the HAPA are involved in the preactional and actional phase of behavior change, but seem to become particularly effective when action has to be taken. At the intraindividual level, self-efficacy and action planning even become relevant only after the initiation of the intended behavior change (i.e., when the actional phase is entered), pointing at a qualitative shift between pre- and post-quit periods. Thus, only after the quit date on days with higher than personal average reports of self-efficacy and action planning, likelihood of successful behavioral change becomes higher.

In this regard it is rather unexpected that for action planning at the interindividual level no significant interaction effect emerged, that is, associations with daily smoking did not differ before and after the quit date. This result may however indicate that higher levels of planning rather overall facilitate the amount of smoking during a smoking cessation episode than its effectiveness being triggered by the quit date (i.e., initiation of the behavior change).

Due to the relatively small sample size, we did not analyze a model combining all volitional predictors as too many predictors render a model less stable and less precise (Kreft & DeLeeuw, 1998). There is therefore no evidence on the unique contribution of each predictor in competition to each other and these results have to be interpreted cautiously.

Analyses did not reveal any significant effect for time, indicating that numbers of cigarettes smoked did not increase or decrease across days before and after the quit date once self-regulatory variables were taken into account. This might be explained by the fact that the volitional variables themselves varied over time and therefore accounted for potential time effects on numbers of cigarettes smoked.

It is important to note that the present study focused on the daily amount of cigarettes smoked in the context of a quit attempt while daily abstinence was not taken into account. However, one of our main aims was to test the effectiveness of volitional processes in the prospective design of a quit attempt, and as there is no variance in daily abstinence before the quit date, this would not have been possible with the dichotomous measure of self-reported daily abstinence.

Furthermore, it should be noted that the present research focused exclusively on volitional factors and did not take the role of non-volitional, habitual processes in behavior change into account. This may however be important, as dual-process theories suggest that behavior is determined by two competing systems: a reflective system that involves deliberation of thoughts and cognitive effort, and an automatic system which operates outside of awareness and requires minimal cognitive resources and volitional control (e.g., Strack & Deutsch, 2004). In order to test for the relative contribution of automatic and reflective processes as well as their interaction in behavior change, future studies should include non-volitional measures such as habits.

Limitations

The present study has limitations that need to be addressed. First, all variables of interest were assessed by using single-items based on self-report. The end-of-day diary design employed in the present study however allowed to keep the recall interval quite small and to minimize problems with recall bias (Bolger et al., 2003). Moreover, single items were chosen to keep the daily questionnaire short and the participant burden low. Due to the employment of single-items, it was not possible to perform a reliability analysis. However, there is still evidence that the single-items served as valid and useful measures. The inter-correlations among the volitional variables for example showed moderate to high positive associations on the between- and within-person level as it is overall expected by the HAPA. Furthermore, for the assessment of daily smoking, a carbon monoxide (CO) test of expired air was employed to biochemically verify smoking status at the follow-up. As all participants who reported to not have smoked since their quit date were successfully biochemically verified as non-smoking, our measure of numbers of cigarette smoked seems to be a valid instrument. Finally, the associations between the volitional processes and daily smoking were all as expected by the theoretical assumptions. Still, an in depth validation of the single items outside the context of the multi-item scale would seem advisable.

Second, our analyses only tested same-day associations between volitional processes and daily smoking, and no conclusions can be drawn on the predictive direction. Based on our theoretical model, we assume that higher levels of volitional processes lead to a reduced amount of smoking, but we should also keep the inverse scenario in mind, that a reduced amount of smoking could lead to increased levels of volitional processes. For example, the experience of mastery that may arise from success in terms of smoking abstinence is assumed to be the strongest source of self-efficacy (Bandura, 1989). Moreover, by performing an intended behavior (e.g., not smoking), this may serve as a reminder of one's intentions and actions and thus enhance action control. The assumption that behavior change may also impact beliefs and cognitions is in line with theoretical approaches that stress the reciprocal interactions among cognition, behavior, and other factors (e.g., Bandura, 1989; Ellis, 1995). Thus, future studies should consider testing the reciprocal effects of volitional processes and daily smoking in the context of a quit attempt by applying cross-lagged analyses. Even though cross-lagged analyses cannot capture the causality either, it may help to establish the temporal order of an association. To approach the question of causality, ecological momentary interventions (EMI; Heron & Smyth, 2010), that is, interventions in the daily life of participants, are needed.

Implications

There are several important implications from the present research. First, the volitional HAPA processes could provide a promising target for theory-guided smoking cessation interventions, for example by boosting them through daily text messages before and especially after the quit date. Previous intervention studies employing text messages via mobile phones have shown improved smoking cessation rates in the short and long term (e.g., Free et al., 2011). Moreover, results suggest that volitional processes could be leveraged to assist smoking cessation in people's everyday lives. This may involve asking individuals to complete certain tasks such as tracking one's behavior in online tools or mobile apps (action control), making concrete plans for the day (action planning), or providing individuals with reinforcing feedback on progress (self-efficacy). Importantly, as results support the benefit of more-than-usual levels of volitional variables, such strategies should be tailored specifically to people's individual level of self-regulation competence.

Furthermore, as the volitional processes in daily life do not appear in isolation, future studies should examine more closely the individual contribution of each predictor in competition as well as the interplay of the volitional processes. It might also be worthwhile studying whether the intraindividual effects may vary as a function of the interindividual level, for example in that intraindividual variations are only effective when high levels of intentions, action control, action planning and self-efficacy exist (cf. Conroy et al., 2011). Moreover, further research in health contexts other than smoking cessation and physical activity is needed to test for intraindividual associations of existing health-behavior change theories.

In sum, this is the first study to examine the inter- and intraindividual associations between self-regulatory volitional processes and daily numbers of cigarettes smoked within the prospective design of smoking cessation, that is before and after a self-set quit date. Overall, the present findings emphasize the volitional HAPA processes as beneficial factors at the inter- and intraindividual level in the context of quitting smoking, gaining particular importance within individuals after the quit date when actual behavior change is performed.

Acknowledgments The first author is funded by the Swiss National Science Foundation (PP00P1_133632/1). This project was funded by the Swiss National Science Foundation (100014_124516).

Conflict of interest The authors Corina Berli, Sibylle Ochsner, Gertraud Stadler, Nina Knoll, Rainer Hornung and Urte Scholz declare that they have no conflict of interest.

Human and animal rights and Informed Consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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