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Engagement within a mobile phone-based smoking cessation intervention for adolescents and its association with participant characteristics and outcomes

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Abstract

Background: Although mobile phone-delivered smoking cessation programs are a promising way to promote smoking cessation among adolescents, little is known about how adolescents might actually use them.

Objectives: To determine adolescents’ trajectories of engagement with a mobile phone-delivered smoking cessation program over time, and the associations these trajectories have with baseline characteristics and treatment outcomes.

Methods: We performed secondary data analysis on a dataset from a study that compared a mobile phone-delivered integrated smoking cessation and alcohol intervention to a smoking cessation only intervention for adolescents recruited in vocational and upper secondary school classes (N= 1418). Throughout the three-month intervention, participants in both intervention groups received one text message prompt per week that either assessed smoking-related target behaviours or encouraged participation in a quiz or a message contest. Sequence analyses were performed to identify engagement trajectories. Analyses were conducted to identify predictors of engagement trajectory and associations between engagement trajectories and treatment outcomes.

Results: Three engagement trajectories emerged: (1) stable engagement (n= 646, 45.6%), (2) decreasing engagement (n=501, 35.3%), and (3) stable non-engagement (n=271, 19.1%). Adolescents who were younger, had no immigrant background, perceived more benefits of quitting smoking, and reported binge drinking preceding the baseline assessment were more likely to exhibit stable engagement. Due to different reach of more engaged and less engaged participants at follow-up, three statistical models (complete-cases, last-observation-carried-forward, and multiple imputation) for the associations of engagement trajectory and smoking outcome were tested. For 7-point smoking abstinence, no association revealed significant over all three models. However, decreasing engagement with the program was associated over all three models with greater reductions in daily tobacco use than non-engagement.

Conclusions: The majority of tobacco-smoking adolescents engaged extensively with a mobile phone-based smoking-cessation program. However, not only stable engagement, but also decreasing engagement with a program might be an indicator of behavioural change. Measures to avoid non-engagement appear especially necessary for older smokers with an immigrant background who do not drink excessively. In addition, future studies should not only examine the use of specific program components, but also users’ engagement trajectories to better understand the mechanisms behind behavioural change.

**Keywords**: tobacco, alcohol, adolescents, mobile phone, usage trajectories, outcome

1. Introduction

Tobacco smoking is one of the main contributors to the global burden of disease [1]. A survey of 15- and 16-year-old adolescents covering 36 European countries revealed that 21% considered themselves current smokers [2]. Since tobacco use often starts in adolescence, intervening before the development of a substance use disorder gains importance [3].

Mobile phone-based programs for smoking cessation are promising tools for delivering treatment to large numbers of adolescents [3]. Such programs have already been proven more effective than minimal or no intervention in adult smokers [4–8]. While only trends towards the effectiveness of such programs in adolescents have been documented to date [6], studies emphasize their acceptance by adolescent smokers with mixed intentions to quit smoking, and by adolescent smokers of different genders, educational levels, and immigrant backgrounds [9,10].

Mobile phone-based smoking cessation programs are delivered via apps [11] or text messaging [10,12], with the greatest difference being the level of engagement demanded by the two approaches. The first demands that users proactively engage with the program, while the latter requires users to actively disengage from the program [13]. For text messaging-based programs, there is some evidence that the predominant engagers are female [14] and older, and that they exhibit lower rates of daily cigarette consumption [15]; but none of these studies was conducted on adolescents.

User engagement with different smoking cessation programs has been linked to positive behavioural changes. With web-based interventions, for instance, higher numbers of visits and page views were associated with abstinence [16–18]. Recent studies on text messaging-based interventions point in the same direction. In a study by Balmford and Borland [19], the efficacy of a text messaging-based smoking-cessation program was associated with completion of the program. Participants who elected to stop the program were less likely to be abstinent at follow-up. In another study by Heminger et al. [14], rather than overall engagement, “post-quit” engagement and the use of specific program features, like pledges, were specifically predictive of six-month abstinence. Even more accurately, a study by Christofferson et al. [15] identified five different classes of user engagement, which in turn were associated with different levels of interventional success. These investigators extracted two classes of engagement (high engagement and increasing engagement) and three classes of disengagement (rapidly-decreasing engagement, delayed decreasing engagement, and low engagement), demonstrating that participants within the more engaged classes were significantly more likely to be abstinent at weeks 3, 4 and 5 than participants within less engaged classes.

However, there are also studies that question the association between high engagement and positive behaviour changes [11,19,20]. For instance, Balmford and Borland [19] found that users with the lowest text messaging-intensity had a greater chance of being abstinent at the one-month follow-up. The researchers concluded that users tend to be selective as to what they need, which is not to be confused with a lack of motivation. Furthermore, they questioned whether it would be of more help if greater engagement could be achieved among less responsive users. In another pilot study [11] that investigated the use of an app-based smoking cessation program, the total number of actively-viewed Quit Tips and Medication Tips was predictive of non-abstinence at 12-week follow-up.

Three methodological issues make the contribution of a user’s level of engagement to long-term abstinence somewhat uncertain: (1) Only one study has reported long-term outcome associations with engagement [14]. (2) Setting a quit-date and having a quit attempt is an integral component of most smoking-cessation programs [17,19,11,15,14]. Such interventions are typically divided into pre-quit and post-quit phases. There is a lack of studies investigating engagement with a mobile phone-based intervention that was matched to stages of change and did not require subjects to set a quit date. This is of special interest, since most adult and adolescent smokers do not report any serious intention to quit within the next month [10,21]. (3) On the other hand, smokers who enroll in such cessation programs already tend to report an intention to quit smoking [14,15,19], which can lead to a self-selection of more engaged, and thus more successful subjects. To our knowledge, no studies have investigated engagement with a mobile phone-based cessation program in proactively-recruited smokers at different stages of change.

Thus, the current study aimed to examine trajectories of program engagement associated with long-term outcomes within a randomized controlled trial assessing a fully-automated, mobile phone-based program for young smokers that was based on the Health Action Process Approach (HAPA) stages of change model [22]. Factors that predict engagement and completion of the three-month program were analysed to sort out for whom such programs still need to be improved. In addition, this study investigated adolescents’ engagement with different features of a mobile phone-based intervention, since identifying more and less influential components of such interventions has recently been raised as a means to help refine other health behaviour change programs [23].

1. Methods

*2.1 Participants and Procedures*

Data for this study were extracted from a two-arm, parallel-group, cluster-randomised controlled trial that used school class as the randomisation unit, as detailed elsewhere [24,9]. Students in vocational or upper secondary schools in Switzerland were invited to participate in a technology-based program called *MobileCoach Tobacco* if they (1) either smoked on a daily or occasional basis (at least 4 cigarettes in the preceding month and at least one cigarette during the preceding week), and (2) owned a mobile phone*.* Participating students were reimbursed 10 Swiss francs for participating in the baseline and follow-up assessments, and with 0.5 Swiss francs for each of the 11 text message assessments that they answered within the *MobileCoach Tobacco* program.

In the original trial, the efficacy of an integrated smoking cessation and alcohol intervention (MCT+) was tested against a smoking cessation only intervention (MCT) for smoking cessation in adolescents. A total of 1’471 students from 360 Swiss vocational school classes participated in this study. They were randomly assigned to either the combined program (MCT+, n= 730) or to the smoking cessation only program (MCT, n= 741). The original study found no significant difference between the programs in terms of reducing the number of cigarettes used per day (MCT+ vs. MCT: - 2.7 vs. -2.8), nor in increasing the 7-day point prevalence of smoking abstinence at follow-up (MCT+ vs. MCT: 14.9% vs. 14.0%).

The intervention was designed with, and triggered by, the open-source behavioural intervention platform MobileCoach version 1.1 [25]. The original study protocol was approved by the ethics committee of the Faculty of Philosophy at the University of Zurich, Switzerland (date of approval: 24 June, 2014). The study was registered at Current Controlled Trials ISRCTN (ISRCTN02427446, assigned 8 September 2014) and executed in full compliance with the Declaration of Helsinki.

*2.2 Description of MobileCoach Tobacco*

The MCT+ program combined (1) tailored web-based feedback on individual drinking behaviours delivered directly after completion of the baseline assessment; (2) tailored mobile phone text messages to promote drinking within low-risk limits over a three-month period; (3) tailored mobile phone text messages to support smoking cessation for three months; and (4) the option of receiving twice daily strategies for smoking cessation centred around a self-defined quit-date. Only components (3) and (4) of the integrated intervention were delivered to participants in the MCT group. The theoretical backgrounds of these intervention components are described elsewhere [9].

The web-based feedback, intended only for participants in the combined program, was provided immediately after completion of the baseline assessment. It included individually-tailored information (1) about calorie intake based on personal drinking data, and (2) age and gender-specific norms on the number of drinks consumed per week, as well as on the individual’s frequency of binge drinking.

The alcohol-related text messages provided information on (1) strategies for drinking within low-risk limits, and (2) the association between smoking and alcohol consumption. These text messages were sent only to those subjects within the *MCT+* condition who reported binge drinking previous to their baseline assessment, where binge-drinking is equivalent to the consumption of five or more drinks on a single occasion for men, and four or more drinks for women. These text messages were sent on Saturdays at 7 pm on even weeks, while on odd weeks they were sent at each particular individual’s typical drinking day and time.

The tobacco-related text messages provided information relevant to each subject’s individual HAPA stage of change [22]. Based on the HAPA stage [22], subjects can be divided into ‘pre-intenders’ (individuals with no intention to quit smoking) and ‘intenders’ or ‘actors’ (individuals who seriously intend to quit smoking or have already quit). For pre-intenders, the text messages addressed the benefits of quitting, risks of smoking, and methods for improving self-efficacy. For intenders, the text messages initiated planning processes; while for actors they emphasized self-regulatory skills.

During the three-month *MobileCoach Tobacco* program, participants in both intervention groups received one text message prompt per week that either assessed smoking-related target behaviours or encouraged the subject’s participation in a quiz or message contest. These prompts were easily answered by typing a single letter, number, or sentence using the mobile phone’s reply function. Every four weeks, smoking-related target behaviours, including the person’s HAPA stage of change, were assessed through the question: ‘Have you recently smoked cigarettes?’, with the following response options (1) ‘Yes, and I do not intend to quit’ (pre-intender), (2) ‘Yes, but I am considering quitting’ (pre-intender), (3) ‘Yes, but I seriously intend to quit’ (intender), or (4) ‘No, I have already quit smoking’ (actor). Furthermore, among pre-intenders, the number of cigarettes smoked per day or week (depending on smoking status: daily/occasionally) was assessed every four weeks. For intenders and actors, the use of strategies to cope with craving, which were individually chosen within the baseline assessment, was assessed: e.g., ‘Did you apply the following strategy recently? When I am at a party, I distract myself from smoking by dancing. Yes (Y) No (N)’.

Quizzes were included thrice during the *MCT,* with the questions targeting: (1) smoking norms (percentage of smokers within the same age- and gender-specific reference group); (2) the health consequences of smoking cessation (days until positive health consequences after smoking cessation); and (3) expenditures on cigarettes (money spent on cigarettes per year).

A contest that required participants to create a text message to motivate other participants to quit smoking (for non-intenders) or to provide concrete ways to help others quit smoking (for intenders and actors) was conducted twice during the intervention period. The best text message from each of the two categories, rated weekly by a tobacco cessation expert, was sent anonymously to participants in the respective categories after 48 hours.

Finally, additional text messages were offered to subjects who reported having the intention to quit smoking. Intenders and actors were informed biweekly about the option of receiving additional information around a chosen quit-date. After entering a scheduled quit date, the program provided up to two daily text messages on quit-day preparation and relapse prevention (weeks –1 to +1: two daily text messages; weeks +2 and +3: one daily text message).

*2.3 Measures*

Participants took part in an online health survey during a regular class session, by which data on potential predictors of engagement and outcome variables were collected. The socio-demographic characteristics that were assessed were gender, age, educational attainment, and immigrant background. The following common Swiss levels of educational attainment were assessed: (1) none, (2) secondary school, (3) extended secondary school, and (4) technical or high school. We assessed the country of birth of both parents of the students to identify any potential immigrant background. Based on this information, participants were assigned to one of the following categories: (1) neither parent born outside Switzerland, (2) one parent born outside Switzerland, or (3) both parents born outside Switzerland. For further analysis, we grouped subjects with either a one- or two-sided immigrant background into a single category for comparison against non-immigrants.

The health-related variables that were assessed were perceived stress, physical activity, body weight, typical number of drinks consumed per week, and whether any binge drinking had occurred in the month prior to the baseline assessment. Perceived stress was measured using the following single item: “In the last month, how severely have you felt stressed?” Participants were asked to indicate their response on a 6-point Likert scale that ranged from “not at all” to “very”. Self-reported moderate-to-vigorous physical activity (VPA) was measured by a question derived from the Health Behaviour in School Aged Children (HBSC) study [26]: “Outside school, how many hours a week do you exercise or participate in sports that make you sweat or out of breath?” The typical number of drinks consumed weekly was assessed via a seven-day drinking calendar similar to the Daily Drinking Questionnaire [27], for which participants were asked to think about a typical week in the preceding month and record the number of standard drinks they typically consumed each day during that week. Examples of standard drinks containing 12–14 g of ethanol were provided for beer, wine, spirits, alcopops, and cocktails, along with conversion values (e.g., three 0.5 L cans of beer = 6 standard drinks). Binge drinking was assessed by asking participants to report the number of standard drinks they consumed on their heaviest drinking occasion over the preceding 30 days.

Tobacco smoking status was assessed using the question, “Are you currently smoking cigarettes?” with the following response options: (1) Yes - I smoke cigarettes daily; (2) Yes - I smoke cigarettes occasionally, but not daily; and (3) No. In occasional smokers, we assessed the number of days they typically smoked per month, the total number of cigarettes smoked within the previous seven days, and the number of cigarettes smoked on a typical smoking day. In daily smokers, we only assessed the mean number of cigarettes smoked per day. For occasional smokers, the average number of cigarettes smoked per day was computed by multiplying the typical number of smoking days per month with the number of cigarettes smoked on a typical smoking day, and dividing this product by 30.

Additionally, we assessed the following smoking-related variables: HAPA stage of change, and the number of previous quit attempts. Each subject’s HAPA stage of change was assessed using the following question: “Have you recently smoked cigarettes?” with the following response options (1) “Yes, and I do not intend to quit” (Pre-contemplation), (2) “Yes, but I am considering quitting” (Contemplation), and (3) “Yes, but I seriously intend to quit” (Preparation). Subjects were asked about their previous attempts to quit smoking with the question — “Have you ever made a serious attempt to quit smoking?” — for which they were provided the response options “No”, “Yes – once”, and “Yes – more than once”.

Engagement with the program was assessed in terms of the number of program participants who unsubscribed from the program (program attrition), the number of responses to the weekly text message prompts, the percentage of retrieved versus sent media objects within the program, and the number of smokers who entered a quit-date and activated the additional quit-day preparation program.

Smoking behaviour at six-month follow-up was assessed as the (1) 7-day point prevalence of smoking abstinence; and (2) the mean number of cigarettes smoked per day. To assess the 7-day point prevalence of smoking abstinence, subjects were asked to indicate whether they had taken a puff of a cigarette within the seven days previous to follow-up. The mean number of cigarettes smoked per day was assessed and computed in the same way as at the baseline assessment.

*2.4 Statistical analyses*

As a first step, we analysed whether persons who actively unsubscribed from the intervention differed from those who remained in the intervention, applying Pearson chi-square analysis to examine differences in categorical variables, and unpaired Student’s t tests for continuous variables. Given that the combined intervention was more extensive, we also examined whether program attrition differed as a function of study condition. Participants who had either unsubscribed or did not receive the text messages, as seen from program log files, were excluded from further analysis. Then, we explored the use of different program features for the total sample and by treatment arm.

Subsequently, we examined engagement trajectories by analysing answers to weekly prompts, which were identical for both study groups. To this end, we performed sequence analysis using the TraMineR library (version 1.8-8) in R [28]. For each participant, answers to prompts (as described above) were ordered into a sequence of states (i.e., engagement trajectories). Similarities between participants’ state sequences were computed using the optimal matching (OM) distance algorithm. OM is defined as the minimal effort, in terms of insertions, deletions and substitutions, of transforming one sequence into another. Homogeneous engagement trajectory groups (clusters) were then constructed from the distance matrix, using agglomerative nesting hierarchical clustering and Ward’s linkage method. The number of clusters chosen was based on the highest relative loss of inertia (see function HCPC in FactoMineR package [29]) and upon the quality of the clusters according to the average silhouette width [ASW, 30]. The ASW ranges from -1 to +1 and can be interpreted as the degree of coherence among assignments to clusters: a high degree of coherence (close to 1) indicates large between-group distances and strong within-group homogeneity.

Upon detecting different engagement trajectories, we examined for baseline differences between the clusters. Subsequently, we conducted multinomial logistic regression analysis to identify predictors of clusters characterized by lower engagement trajectories, compared to those with higher engagement trajectories. Initially, separate univariate multinomial logistic regression analyses were performed (subsequently referred to as univariate analyses) to evaluate potential predictors of engagement trajectories. After these univariate analyses, multivariate prediction models were developed. As suggested by Hosmer, Lemeshow, and Sturdivant [31], variable selection consisted of the following steps: (1) Significant predictors (*p* < .05) identified during univariate analyses were entered into the preliminary multivariate model. (2) Variables that were non-significant at *p* > .05 were removed, one at a time, starting with those with the highest p-values (backward selection). (3) To account for suppressor effects, the resulting model was verified by adding the aforementioned excluded variables, separately, to the regression model. Only variables that were significant at *p* < .05 were retained in the final multinomial regression model (forward selection).

Finally, we compared smoking outcomes between participants grouped by their engagement trajectory. Since participants were nested in school classes, we conducted a generalized linear mixed model (GLMM) for the 7-day point prevalence of abstinence. For changes in consumed cigarettes per day, we conducted a linear mixed model (LMM). Engagement trajectory was included as an independent variable (fixed effect), and school class as a single random effect (random intercept). These analyses were conducted using the lme4 library (version 3.2.1) in R [32] on three statistical models due to the disparate reach of more engaged than less engaged participants at follow-up: (1) a complete-case dataset (CCA), (2) a last-observation-carried-forward (LOCF) dataset, and (3) an intention-to-treat dataset (ITT). Details of outcome analysis and missing data imputation procedures are provided in Haug et al [9]. R version 3.3.3 was used to perform all sequence analyses and outcome analyses, while SPSS version 22 was used for all other analyses. All statistical tests were two-tailed, with *p* < .05 set as the criterion for statistical significance.

1. Results

*3.1 Participants*

Of the original 1471 study participants, 1418 (96.4%) completed the program. Those who failed to complete their intervention had either signed off (n= 31, 2.1%) or discontinued the intervention due to technical problems (n= 22, 1.5%). No significant baseline differences were observed between those who did and did not complete the intervention. Program attrition also did not differ between the two treatment arms, with 13 of the 741 (1.8%) participants in the *MCT* choosing to unsubscribe compared to 18 of the 730 (2.5%) assigned to the *MCT+* (*χ*2 = 0.90, *P=* .34). Of the 1418 participants analysed for this study, 863 (60.9%) were female. The reported mean age was 18.6 (*SD* = 3.1). More than half (n= 740, 52.2%) reported either a one-sided or two-sided immigrant background, and almost all (n= 1180, 83.2%) had reached at least the lowest educational degree (i.e., secondary school) (Tab. 1). Two-thirds of the sample (1083/1418, 76.4%) took part on the follow-up assessment; 538 of the 730 (72.6%) participants assigned to the *MCT*, and 545 of the 730 (74.7%) assigned to the MCT+.

*3.2 Use of different program features*

Table 2 summarizes different program use characteristics across the total sample and by intervention group. Participants answered a mean of 6.6 (*SD* = 3.5) out of 11 text message prompts. Each participant received between three and five text messages containing media objects (videos, pictures) which had to be downloaded. On average, participants downloaded 20.5% (*SD* = 31.5) of the received media content. Participants in the *MCT+* downloaded media content significantly more often than their *MCT* counterparts (23.6% vs. 17.9%, *P* < .001). Roughly half of the subjects answered all or almost all of their text message prompts. The fewest answers were recorded for the contest prompt at week 8 (24.9%) and for the HAPA stage query at week 10 (42.9%).

|  |
| --- |
| Table 2. Use of program components by the overall study sample and by study group. Values represent n (%) unless stated otherwise. |
|   | All | MCT | MCT+ | *P* value |
|   | (N= 1418) | (n= 712) | (n= 706) |   |
| Questions answered, *M (SD)* ab | 6.6 (3.5) | 6.5 (3.6) | 6.8 (3.5) | .22 |
| Percent media objects viewed / of media objects sent, *M (SD)* ab | 20.8% (31.5) | 17.9% (32.6) | 23.6% (30.0) | <.001 |
| Answer to Quizzes cd |  |  |  |  |
| Quiz Costs (week 1) | 975 (68.8%) | 481 (67.6%) | 494 (70.0%) | .33 |
| Quiz Health (week 5) | 898 (63.3%) | 438 (61.5%) | 460 (65.2%) | .16 |
| Quiz Norms (week 9) | 863 (60.9%) | 429 (60.3%) | 434 (61.5%) | .64 |
| Answer to HAPA stage of change cd |  |  |  |  |
| Stage 1 (week 2) | 1206 (85.0%) | 598 (83.9%) | 608 (86.1%) | .26 |
| Stage 2 (week 6) | 975 (68.8%) | 485 (68.7%) | 490 (68.8%) | .96 |
| Stage 3 (week 10) | 609 (42.9%) | 295 (41.4%) | 314 (44.5%) | .25 |
| Answer to smoking-related questions (%) cd |  |  |  |  |
| CPD/CPW or Coping strategy (week 3) | 992 (70.0%) | 490 (68.8%) | 502 (71.1%) | .35 |
| CPD/CPW or Coping strategy (week 7) | 876 (61.8%) | 444 (62.4%) | 432 (61.2%) | .65 |
| CPD/CPW or Coping strategy (week 11) | 749 (52.8%) | 361 (50.7%) | 388 (55.0%) | .11 |
| Answer to Contest (%) cd |  |  |  |  |
| Motivational or Quit Contest (week 4) | 626 (44.1%) | 303 (42.6%) | 323 (45.8%) | .23 |
| Motivational or Quit Contest (week 8) | 353 (24.9%) | 175 (24.6%) | 178 (25.2%) | .78 |
| Setting of a quit-date (%) cd | 156/ 475 (32.8%) | 79/239 (33.1%) | 77/236 (32.6%) | .92 |
| a *t* test,b (df=1416), c *χ2* test, d (*df*= 1). CPD/CPW= cigarettes smoked per day/ cigarettes smoked per week |

*3.3 Engagement analysis*

Our inspection of answer behaviour over the three-month intervention revealed different types of engagement trajectory. Some participants exhibited a stable answer pattern (either usually answered or almost never answered text messages). Other participants displayed irregular trajectories. The highest relative loss of inertia measure suggested a three-cluster solution: cluster 1 = stable engagement (SE), cluster 2 = decreasing engagement (DE), and cluster 3 = stable non-engagement (SNE). Based on the average silhouette width (ASW), the quality of the three clusters ranged from poor (cluster 2 = -0.02) to good (cluster 1 = 0.55) and excellent (cluster 3 = 0.70). The low ASW for cluster 2 was because the engagement trajectories included within the cluster differed to a great extent. Some subjects answered text messages only in the beginning, while others answered depending on the topic. There were also some participants who only started to answer text messages at the end of the program (Fig. 1). Since the common element within all these trajectories included in cluster 2 is their instability, the three-cluster solution was considered adequate for the purposes of this study.

Figures 1 and 2 describe the three clusters in different ways. The first figure displays the response or non-response of individuals to each of the eleven prompts within the different clusters. Figure 2 highlights the prototype engagement trajectory within each of the three clusters. The typical participant within cluster 1 (SE) answered to almost all text messages, except for the second request to send their own message to motivate other participants to quit smoking or remain cigarette free. The typical participant within cluster 3 (SNE) did not respond to any of the prompts. Meanwhile, the typical participant within cluster 2 (DE) did not reply to the two message contests, and exhibited a steadily-decreasing response rate. This last pattern is associated with the repetition of questions, like queries relating to the person’s HAPA stage of change and cigarettes per day/per week (CPD/CPW).

Figure 1: Individual engagement trajectories within each of the three clusters. Rows represent participants, columns represent the 11 prompts which could be answered by the participants. Black boxes represent non-replies, grey boxes replies.

Figure 2: The prototype engagement trajectory within each cluster. Columns represent the 11 prompts which could be answered by the participants. Black boxes represent non-replies, grey boxes replies.







*3.4 Predictors of engagement trajectory*

Table 1 summarizes the baseline characteristics of participants by engagement trajectory. There were significant differences between the three clusters with regard to age (*P* = .006), immigrant background (*P* <.001), educational attainment (*P* = .04), binge drinking (*P* <.001), HAPA stage of change (*P* <.05), and self-perceived benefits of quitting (*P*<.001).

*Table 1*: Demographic and health behaviour characteristics of the study sample by engagement trajectory. Values represent n (%) unless stated otherwise.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | All | Stable engagement | Decreasing engagement | Stable non-engagement |  *P* value |
| (N= 1418) | (n= 646) | (n= 501) | (n= 271) |  |
| Intervention group ac |  |  |  |  |  |
| MCT | 712 (50.2%) | 319 (49.4%) | 248 (49.5%) | 145 (53.5%) | .48 |
| MCT+ | 706 (49.8%) | 327 (50.6%) | 253 (50.5%) | 126 (46.5%) |  |
| Female sex ac | 863 (60.9%) | 398 (61.6%) | 293 (58.5%) | 172 (63.5%) | .35 |
| Immigrant background ac | 740 (52.2%) | 293 (45.4%) | 268 (53.5%) | 179 (66.1%) | <.001 |
| Age in years*, M (SD)* bc | 18.6 (3.1) | 18.4 (2.8) | 18.8 (3.4) | 18.9 (2.9) | .006 |
| Educational level ae |  |  |  |  |  |
| Secondary school | 1180 (83.2%) | 555 (85.9%) | 401 (80.0%) | 224 (82.7%) | .04 |
| Vocational school | 189 (13.3%) | 67 (10.4%) | 86 (17.2%) | 36 (13.3%) |  |
| Technical/ high school or University | 30 (2.1%) | 13 (2.0%) | 10 (2.0%) | 7 (2.6%) |  |
| Unknown | 19 (1.3%) | 11 (1.7%) | 4 (0.8%) | 4 (1.5%) |  |
| Hours of moderate to vigorous extracurricular physical activity per week, *M* *(SD)* bc | 3.5 (3.6) | 3.4 (3.4) | 3.7 (3.8) | 3.2 (3.6) | .08 |
| Number of alcoholic drinks consumed per week, *M* *(SD)* bc | 9.9 (12.1) | 10.2 (12.1) | 10.3 (11.8) | 8.4 (12.5) | .09 |
| Binge drinking (%) ac |  |  |  |  |  |
| No | 465 (32.8%) | 191 (29.6%) | 158 (31.6%) | 116 (42.8%) | <.001 |
| Yes | 952 (67.2%) | 455 (70.4%) | 342 (68.4%) | 155 (57.2%) |  |
| Tabacco smoking status (%) b |  |  |  |  |  |
| Daily smoker | 1075 (75.8%) | 476 (73.7%) | 390 (77.8%) | 209 (77.1%) | .22 |
| Occasional smoker | 343 (24.2%) | 170 (26.3%) | 111 (22.2%) | 62 (22.9%) |  |
| Number of cigarettes smoked per day (CPD), *M* *(SD)* bc | 10.1 (7.3) | 9.9 (7.3) | 10.5 (7.4) | 10.0 (7.1) | .32 |
| Stage of change (%) ad |  |  |  |  |  |
| No intention to quit | 396 (28.0%) | 200 (31.0%) | 124 (24.8%) | 72 (26.8%) | .03 |
| Considering quitting | 825 (58.3%) | 372 (57.6%) | 291 (58.2%) | 162 (60.2%) |  |
| Serious intention to quit | 194 (13.7%) | 74 (11.5%) | 85 (17.0%) | 35 (13.0%) |  |
| Benefits of quitting smoking, *M* *(SD)* bc | 1.38 (0.3) | 1.41 (0.3) | 1.36 (0.3) | 1.37 (0.3) | <.001 |
| Previous quit attempts (%) ad |  |  |  |  |  |
| None | 507 (35.9%) | 247 (38.2%) | 173 (34.6%) | 87 (32.5%) | .10 |
| One | 608 (43.0%) | 276 (42.7%) | 205 (41.0%) | 127 (47.4%) |  |
| Two or more | 299 (21.1%) | 123 (19.0%) | 122 (24.4%) | 54 (20.1%) |  |

a *χ2* test, b *F value*, c (df=2), d (df= 4), e (df=6)

Table 3 shows which of the afore-mentioned variables were predictive of engagement trajectory within the multivariate model. Being older (OR= 1.05, *P* = .04) and having an immigrant background (OR= 0.76, *P* = .02) predicted a decreasing engagement with the program compared to a stable engagement. Furthermore, participants who perceived more benefits of quitting were more likely to display stable than decreasing engagement with the program (OR= 0.52 *P* = .007). Compared to stable engagement, non-engagement was predicted by immigrant background (OR= 0.47, *P* <.001) and binge-drinking behaviour (OR= 1.54, *P* = .005). Being a stable non-engager was more likely than being a stable engager, when participants reported an immigrant background and no binge drinking within the month previous to baseline.

|  |
| --- |
| Table 3: Predictors of engagement trajectory  |
|   | *β* (SE) | *P* value | OR | CI [95%] |
| Stable engagement (*ref.*) vs. Decreasing engagement |  |  |  |  |
| Intercept | -0.05 (0.57) | .93 |  |  |
| age | 0.05 (0.02) | .04 | 1.05 | [1.003;1.09] |
| immigration background (*ref.* yes) | -0.28 (0.12) | .02 | 0.76 | [0.59;0.96] |
| binge drinking (*ref.* yes) | 0.01 (0.13) | .98 | 1.00 | [0.78;1.30] |
| benefits of quitting smoking | -0.66 (0.24) | .007 | 0.52 | [0.32;0.84] |
| Stable engagement (*ref.*) vs. Stable non-engagement |  |  |  |  |
| Intercept | -1.07 (0.68) | .12 |  |  |
| age | 0.05 (0.03) | 0.05 | 1.05 | [0.99;1.10] |
| immigration background (*ref.* yes) | -0.76 (0.15) | <.001 | 0.47 | [0.35;0.63] |
| binge drinking (*ref.* yes) | 0.43 (0.15) | .005 | 1.54 | [1.14;2.08] |
| benefits of quitting smoking | -0.37 (0.29) | .21 | 0.70 | [0.39;1.24] |
| *Note:* *R2* = .04 (Cox & Snell), .05 (Nagelkerke). Model *χ2* (8) = 59.84, *p* < .001. SE = Standard error, OR = Odds Ratio, CI = Confidence interval. |

*3.5 Engagement trajectories and smoking behaviour*

Treatment outcome by type of engagement trajectory and comparisons of outcomes between engagement trajectories are summarized in Table 4. Reach at follow-up differed importantly between stable engagers (84.3%, 545/646), decreasing engagers (74.5%, 373/501), and non-engagers (59.0%, 160/271). Due to this, three statistical models were tested. Only the reduction in cigarettes per day among decreasing engagers differed significantly from stable non-engagers under the CCA, LOCF and ITT assumptions (CCA: *β*= 0.65, *P*= 0.02; LOCF: *β*= 0.43, *P*= 0.01; ITT: *β*= 0.54, *P*= .03). Decreasing engagers smoked significantly fewer cigarettes per day at the end of the intervention than non-engagers.

With respect to the seven-day point prevalence of abstinence at six-month follow-up, no comparison revealed a significant difference under all three assumptions. On ITT analysis, the odds of being abstinent at follow-up was higher among non-engagers than engagers (OR= 1.32, *P=*.02). But this finding must be interpreted with caution, since bias in the multiple imputation of missing data seems probable due to the different amount of available information at follow-up. Caution is also warranted, as under the missing-as-smoker assumption, the odds for being abstinent turn in the opposite direction.

Table 4: Comparison of treatment outcomes between different engagement trajectories. Descriptive data are based on complete cases.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Difference in cigarettes per day |  | 7-day point prevalence of smoking abstinence |
| Engagement trajectory |  | CCA | LOCF | ITT |  |  | CCA | MAS | ITT |
| *M (SD)* | *β (P* value) | *β (P* value) |  *β (P* value) |  | % (n) | OR *(P* value) | OR *(P* value) | OR *(P* value) |
| SE (Ref.)  | 2.36 (5.5) | 0.25 (.34) | -0.19 (.24) | 0.07 (.77) |  | 13.4% (73/545) | 1.18 (.16) | 0.96 (.76) | 1.32 (.02) |
| SNE  | 2.43 (5.6) |  |  |  |  | 18.1% (29/160) |  |  |  |
| SE (Ref.) | 2.36 (5.5) | 0.52 (.01) | 0.14 (0.32) | 0.40 (.04) |  | 13.4% (73/545) | 1.05 (.58) | 0.97 (.77) | 1.11 (.21) |
| DE | 3.44 (7.1) |  |  |  |  | 14.5% (54/373) |  |  |  |
| SNE (Ref.) | 2.43 (5.6) | 0.65 (.02) | 0.43 (0.01) | 0.54 (.03) |  | 18.1% (29/160) | 0.91 (.46) | 0.99 (.97) | 0.87 (.25) |
| DE | 3.44 (7.1) |  |  |  |  | 14.5% (54/373) |  |  |  |
| SE (Ref.) | 2.36 (5.5) | 0.25 (.046) | 0.00 (0.99) | 0.17 (.18) |  | 13.4% (73/545) | 1.06 (.31) | 0.98 (.74) | 1.09 (.08) |
| SNE & DE | 2.94 (6.4) |  |  |  |  | 15.6% (83/533) |  |  |  |

*Notes:* SE=Stable engagement, SNE=Stable non-engagement, DE=Decreasing engagement, CCA=Complete-case dataset, LOCF=Last-information-carried-forward, MAS=Missing-as-smoker, ITT= intention-to-treat dataset, Ref. = reference category.

Test value for continuous outcome= t-value; for dichotomous outcome= z value.

1. Discussion

Using a proactively-recruited sample of smoking adolescents with mixed intentions to quit smoking, the present study examined (1) the use of different components of a mobile phone-based smoking-cessation program; (2) different prototypes of engagement trajectory; (3) the association between engagement trajectories and adolescent characteristics; and (4) the association between engagement trajectories and treatment outcomes.

The main findings are: (1) The components of the mobile phone-based smoking-cessation program were used over the three-month intervention in a regular way, with quizzes being the component with the highest participation rate and repeated smoking-related assessments the least-used component. (2) Three distinct engagement trajectories emerged: two characterized by higher levels of engagement, stable and decreasing engagement, and one by a lower level of engagement: stable non-engagement. (3) Adolescents who were younger, had no immigrant background, perceived more benefits of quitting smoking, and reported binge drinking preceding their baseline assessment were more likely to exhibit a stable engagement trajectory throughout the intervention. (4) Subjects who displayed a decreasing engagement pattern generally reduced their daily tobacco use more than subjects whose level of engagement was low.

This is the first study to examine engagement with a mobile phone-based smoking cessation intervention among adolescents. Interestingly, we found similar results among adolescents as for adults [17,19,15]. We also identified a cluster of people who fully committed to the program, as in the study by Balmford et al. [19]. Similarly, the current study replicates three of the five engagement clusters detected by Christofferson et al. [15]. While our cluster-solution was less fine-grained, the clusters were significantly different with respect to baseline characteristics, contrary to those reported by Christoffersons et al [15]. Distinct groups are essential if interventions have to be adapted to different types of engager.

Furthermore, this study was the first to examine factors that predict stable engagement with a mobile phone-based smoking cessation program among adolescents. Other than in previous studies on mobile phone-based programs for adult smokers [14,15], engagement was not related to gender. This could be explained by the gender-specific tailoring which was undertaken for *MobileCoach Tobacco* (e.g., the feedback on gender-specific drinking norms). Interestingly, in adolescents, being younger was associated with higher levels of engagement, versus being older among adults [15]. This result suggests a quadratic relationship between age and engagement. Younger and older people might become more engaged for a variety of reasons that include the program being more novel to them, having more free time, or being more likely to commit to tasks in general.

The current study revealed three further factors, besides age, to be predictive of engagement among adolescents: the individual’s immigrant background; their personal outcome expectancies with respect to quitting smoking (i.e., the benefits of quitting); and whether or not they previously engaged in binge drinking. An association between immigrant background and use of the program also was identified in a study by Businelle et al. [11] which investigated the feasibility and effectiveness of an app-based smoking-cessation intervention among socioeconomically-disadvantaged adults. Especially non-white participants used the two information-delivering features of the app, which were tips and information about medication for quitting. Future studies should investigate whether tailoring mobile phone-based interventions to a person’s immigrant background impacts the intervention’s effectiveness. Text messages for adolescents with an immigrant background could focus more heavily on information and fact-delivery.

Compared to previous research, the current findings underline the relevance of hazardous alcohol use in predicting engagement with a smoking cessation program. Recent studies on tobacco interventions [33–35] have already highlighted the underestimated role of combined alcohol and tobacco use among adolescents and its association with intervention effectiveness. Not only might mobile phone-based smoking cessation programs be more effective in adolescents who smoke and binge drink [9,33–35], they also could be more attractive to those adolescents. As such, measures are needed to make smoking cessation programs more attractive for adolescents who smoke but do not drink excessively.

Contrary to previous work on adult smokers [17,15,14], we were not able to certainly discern if more engaged subjects were more likely to be cigarette abstinent after the intervention. This was due to the different reach at follow-up of more engaged compared to less engaged participants. The only stable finding over all statistical assumptions was that a decreasing engagement trajectory was associated with a greater reduction in daily tobacco use than a non-stable engagement trajectory. This result suggests that not only stable engagement, but also decreasing engagement might be an indicator of behaviour change. As illustrated by other studies [14,19], disengaging from an intervention might not necessarily mean disengaging from behavioural change. Instead, it could indicate a shift from extrinsic to intrinsic motivation [36]. This conjecture is supported by the observation that subjects who remained highly engaged generally had less intention to quit smoking at the beginning of the intervention than those who exhibited decreasing engagement with the program.

One major challenge of future research, however, will be to sort out which kind of intervention is apt for non-engagers. One starting point will be to adapt smoking cessation programs for adolescents to address immigrant backgrounds and drinking behaviours to prevent stable non-engagement and, thereby, potentially enhance treatment effectiveness. Considering that most stable non-engagers were more highly motivated to quit smoking at baseline than most stable engagers, one question to answer will be if actions must be undertaken to increase active participation or not.

The findings of this study must be interpreted in view of its limitations. First, only answers to weekly prompts were included for engagement analysis. Other components of the program — such as downloading media content, setting a quit date, and extra-curricular texting behaviours — were not included in our analyses; and these components could all be analysed to determine their own predictive values [cf. 14,37]. However, our rationale for selecting answers to prompts that were identical for all participants was to render our inter-group comparisons more interpretable. Second, that answers to weekly prompts were rewarded with 0.50 Swiss francs to cover the expenses of the adolescents might have influenced the adolescents’ likelihood of responding. Third, as already emphasized by Heminger et al. [14], quantity and quality of answers to prompts could qualitatively differ (e.g., a smoker who replies to all smoking-related prompts and indicates greater daily use of cigarettes). Rather than just analysing registered events, future qualitative work should investigate whether the content of answers is associated with treatment outcomes. In addition, qualitative research should further investigate the different forms of motivation underlying engagement trajectories among smokers. As stated elsewhere [11], some highly-engaged participants might have seen the program as integral to maintaining abstinence, while other non-abstinent smokers may have remained highly engaged to prepare for future smoking cessation attempts or merely to receive the offered remuneration.

In summary, in our study, adolescents who smoked engaged to a large extent with a mobile phone-based smoking cessation program, irrespectively of their initial intention to quit smoking. Irregular engagement was in turn clearly associated with better long-term treatment outcomes. Further efforts should be undertaken to increase program engagement among older smokers with an immigrant background who do not drink excessively. In addition, future studies should not only examine the use of specific program components, but also users’ engagement trajectories to better understand the mechanisms behind behavioural change.

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