Optimizing digital smoking cessation interventions

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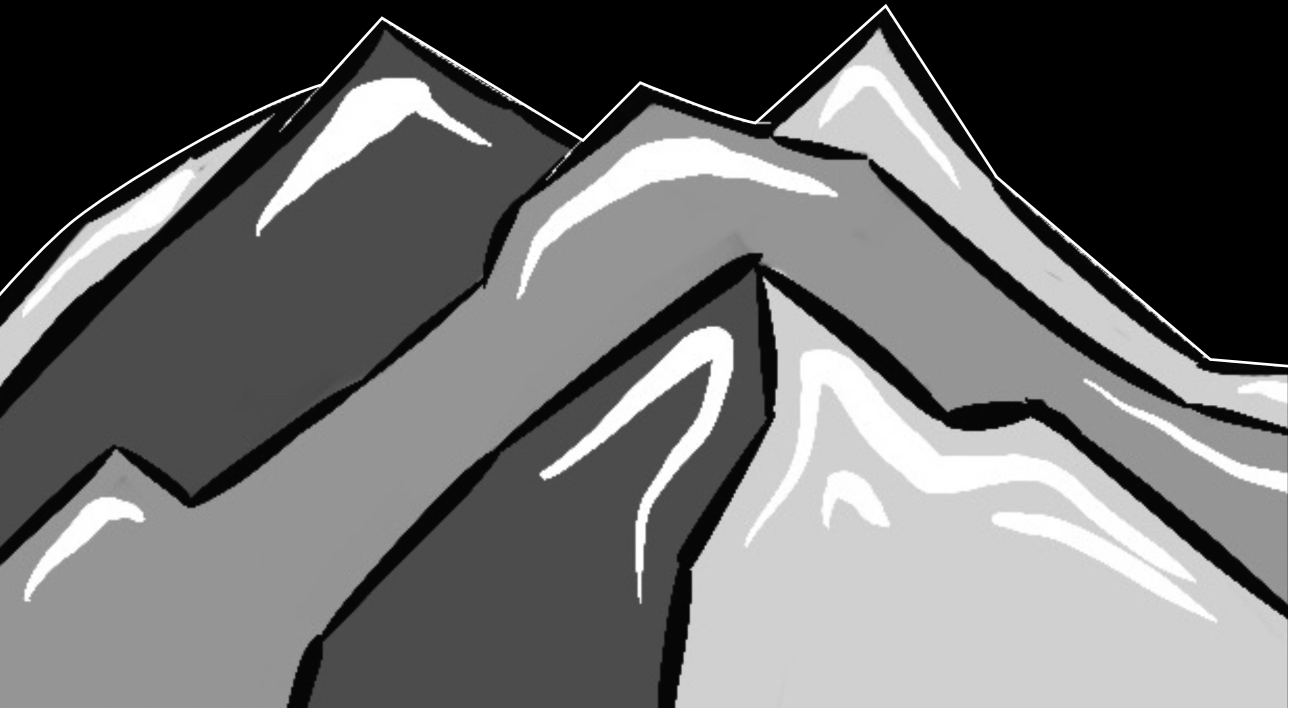


CHAPTER 1

General Introduction

General Introduction

This thesis describes research studies in the field of smoking cessation and relapse prevention. These studies focus on digital smoking cessation interventions at the individual (i.e., micro) level. Specifically, it was explored how digital smoking cessation interventions can be improved by (1) increasing user engagement through animated videos, (2) providing information about electronic cigarettes (e-cigarettes), and (3) addressing relevant aspects of the participant's (social) environment (i.e., contextual factors). Because most of the studies conducted coincided with the COVID-19 pandemic and its associated measures (e.g., lockdown), this thesis also examined the impact of the pandemic on beliefs toward smoking and quitting. This chapter provides information on the background and objectives of the studies conducted as part of this thesis.

SMOKING BEHAVIOR

In 2021, 15.2% of the adult population in the Netherlands reported to smoke daily and 5.4% to smoke non-daily (Trimbos-instituut, 2022). Of the daily smokers[1], 17.8% smoked 20 or more cigarettes per day (i.e., heavy smokers). More men smoke compared to women (24.7% vs. 16.6%) and people with higher levels of education smoke less than people with intermediate or lower levels of education (15.3% vs. 24.2% vs. 23.9%) (Trimbos-instituut, 2022).

In 2020, 1.1% of adults regularly used an e-cigarette in the Netherlands (Trimbos-instituut, 2022). These were almost exclusively tobacco smokers. Only 0.1% of adults who neither smoke nor have a smoking history used an e-cigarette (Trimbos-instituut, 2022). A growing concern is the popularity of e-cigarette use among youth because it is associated with the use of other tobacco products, including cigarettes, and nicotine exposure during adolescence can damage the developing brain and cause addiction (Martinelli et al., 2021; U.S. Department of Health and Human Services, 2016).

Health effects

Smoking is the number one cause of preventable premature disease and death worldwide (World Health Organization, 2021). Smoking is causally related to diseases of almost all organs of the body (U.S. Department of Health and Human Services, 2014). Smokers have a higher risk of developing multiple serious diseases, including heart disease, stroke, and diabetes (U.S. Department of Health and Human Services, 2014). The risk of developing multiple types of cancer is higher among smokers, including lung, stomach, esophagus, kidney, and bladder cancer (U.S. Department of Health and Human Services, 2014). In general, smokers suffer from poorer health than non-smokers. This increased morbidity and

1 In this thesis, the shorter term "smokers" is used instead of the more accurate term "individuals who smoke" to enhance readability.

mortality is caused by a complex mixture of chemicals produced by burning tobacco and its additives (U.S. Department of Health and Human Services, 2010, 2014). Tobacco smoke contains more than 7,000 chemicals, of which 250 are known to be harmful and 70 known to be carcinogens (U.S. Department of Health and Human Services, 2010, 2014).

Nicotine

Nicotine is the main addictive substance in tobacco (Benowitz, 2010). Smokers use nicotine to enhance their mood, either directly by inducing pleasure and reducing stress or indirectly by relieving withdrawal symptoms (Benowitz, 2010). Contrary to popular belief, nicotine plays only a minor role in the development of smoking-related diseases (Benowitz, 2010). Nicotine is a natural constituent of the tobacco plant. Tobacco can be smoked (e.g., cigarettes, cigars, pipe), chewed (e.g., chewing tobacco, snus), or sniffed (e.g., snuff). Nicotine replacement therapy, such as patches, chewing gum, lozenges, nose spray, and inhaler do not contain tobacco, but they do contain nicotine. E-Cigarettes do not contain tobacco and are marketed with and without nicotine. The use of e-cigarettes with nicotine can alleviate withdrawal symptoms on the one hand, but on the other hand it naturally maintains nicotine dependence. Because the use of e-cigarettes does not involve the combustion of tobacco, which produces significant toxins, e-cigarettes are often considered a less harmful and less toxic alternative to cigarette smoking (National Academies, 2018).

Conditioned behavior

In addition to nicotine dependence, classical conditioning plays a major role in the maintenance of addiction and in relapse behavior (Lazev et al., 1999; Winkler et al., 2011). With regular smoking, smokers associate certain moods or circumstances with the rewarding effects of nicotine (Benowitz, 2010). When smoking, the effects of nicotine occur very rapidly, so the associations between moods or circumstances and the rewarding effects of nicotine form quickly and become powerful with repeated exposure, which leads to addiction (Benowitz, 2010). This makes it particularly difficult for ex-smokers to stay quit, because even after deciding to quit, the everyday life of ex-smokers is full of smoking-related cues that can trigger relapse.

Quitting smoking

In 2021, 30.9% of the adult smokers made a serious attempt to quit smoking (quit for ≥24 hours) in the Netherlands (Trimbos-instituut, 2022). Because of nicotine dependence and conditioned behavior, most quit attempts fail. Only 3-5% of smokers achieve prolonged abstinence (i.e., abstinence for a sustained period after a defined quit date) for 6-12 months when they quit without support (Hughes et al., 2004). Most relapse among self-quitters occurs within the first 8 days after quitting (Hughes et al., 2004). After an supported quit attempt, about 17% of smokers achieve prolonged abstinence for more than 12 months (Robinson et al., 2019). The use of evidence-based support is associated with a higher likelihood of

quitting success (West et al., 2015; Zhu et al., 2000), yet many smokers do not make use of support (Borland et al., 2012; Filippidis et al., 2019).

Evidence-based smoking cessation support

Evidence-based support for smoking cessation can be divided into two main categories: behavioral support and pharmacotherapy. Behavioral support includes individual behavioral counseling (Lancaster & Stead, 2017), telephone counseling (Matkin et al., 2019), brief physician advice (Stead et al., 2013), group behavior therapy programs (Stead et al., 2017), and digital behavior change interventions (Taylor et al., 2017). Pharmacotherapy includes various forms of nicotine replacement therapy, such as patches and lozenges (Hartmann-Boyce et al., 2018), and prescription drugs, such as bupropion and varenicline (Cahill et al., 2013). A combination of behavioral support and pharmacotherapy is more effective in terms of quit success compared to either of those on their own (Hartmann-Boyce et al., 2019; Stead et al., 2016).

Smoking cessation is both a physical and behavioral challenge, as nicotine is highly addictive and habits are difficult to change (Benowitz, 2010). Hence, to understand the studies presented in this thesis, it is helpful to be familiar with the theoretical framework that we used for intervention development and evaluation regarding this behavior, which is explained in the next section.

THE I-CHANGE MODEL AS A THEORETICAL FRAMEWORK

The I-Change model (The Integrated Model for Explaining Motivational and Behavioral Change) has been used as the theoretical framework throughout this thesis. The I-Change model is a comprehensive model that integrates various social-cognitive theories (Cheung et al., 2020; de Vries, 2017) (see Figure 1). The model is an integration of ideas from the Theory of Planned Behavior (Ajzen, 1991), Social Cognitive Theory (Bandura, 1998), the Transtheoretical Model (Prochaska & Velicer, 1997), the Health Belief Model (Champion & Skinner, 2008), and goal setting theory (Locke & Latham, 2002). The model defines three phases of motivational states: Awareness (pre-motivation), motivation, and action (post-motivation). Motivation is determined by three factors: attitude, social influences, and self-efficacy. Attitude describes the perceived pros and cons of a behavior. Social influences include social support (i.e., perceived support from relevant others), modeling (i.e., behavioral observation and perception of others' behavior), and social norms (i.e., normative pressures about what should or should not be done). Self-efficacy describes the perceived ability to perform a behavior, including in the presence of barriers. Furthermore, the model incorporates more distal factors, namely information factors (i.e., message characteristics, channels, and sources) and preceding factors including biological factors (e.g., age), psychological factors (e.g., personality traits), behavioral factors (e.g., skills), environmental factors (e.g., prices).

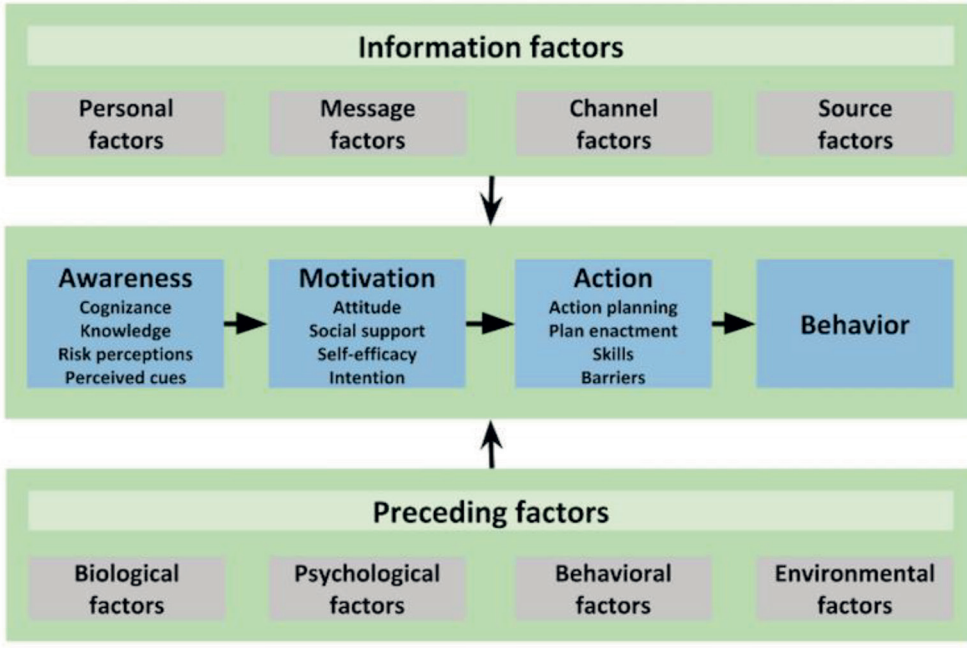


Figure 1. The I-Change model, reproduced from van het Schip et al. (2020).

The theoretical framework has been used extensively in intervention development for various health behaviors such as sunscreen use (de Vries et al., 2012), obesity prevention (Walthouwer et al., 2015), physical activity (Gomez Quinonez et al., 2016), and smoking cessation (Elfeddali et al., 2012; Smit et al., 2012; Stanczyk et al., 2011; Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016; te Poel et al., 2009).

A digital smoking cessation intervention (Stanczyk et al., 2011), which we will return to later in this thesis, is an illustrative example of how the I-Change model can be used in intervention development. In this intervention, participants received feedback on several determinants of the I-Change model, such as attitude, perceived social influence, perceived self-efficacy, and preparatory action plans. The information was contingent on participants' readiness to quit smoking and reflected the various factors of the I-Change model as a function of motivational state. For participants who intended to quit smoking within one month, the intervention focused on transforming intention into action. To this end, the factor action planning of the action phase of the I-Change model was addressed, specifically coping plans and preparatory plans. For coping planning, participants were asked to select from a list of situations associated with lapse risk (e.g., drinking coffee) those that were personally relevant to them. Participants were then asked if they had made plans to cope with such situations, and if not, support was offered to help them formulate coping plans. Preparatory plans included, for example, removing ashtrays

or asking close people not to smoke in their presence and were addressed in a similar manner. For participants who were not ready to quit smoking within one month, the focus was on influencing attitude and perceived social support, as motivational factors such as attitude and perceived social support must first change before intention can be transformed into action (de Vries et al., 2013). To this end, the advantages (e.g., better fitness) and disadvantages of quitting (e.g., withdrawal symptoms) and the influence of the social environment (e.g., the role of the partner, especially if the partner smokes) was discussed.

This intervention is also an example of a computer-tailored intervention. Computer tailoring is a behavior change method that is explained in more detail in the following section. Starting with the difference between tailored and generic health communication, which is then followed by an explanation of computer tailoring specifically.

TAILORING INTERVENTION CONTENT TO INDIVIDUAL CHARACTERISTICS

Traditional health education often relies on disseminating the same information to an entire target population (e.g., through mass media), often to the general population or a demographic subgroup. There is ample evidence that mass media campaigns are beneficial in the context of tobacco control, as their use has been associated with increases in smoking cessation among adults (Bala et al., 2008; Wakefield et al., 2010). However, the greatest strength of generic approaches (i.e., disseminating information to a large number of people) is also related to their greatest weakness, since in generic materials for a large group of people it is almost impossible to account for differences in beliefs between individuals that may be relevant for effective communication (Kreuter et al., 1999). Information that is relevant to one smoker may be irrelevant to another, for example, because the two individuals are in different motivational states.

Tailoring allows to address individual beliefs within an intervention. Tailoring involves gathering information about a given individual and providing feedback based on this information (Hawkins et al., 2008; Kreuter et al., 1999). For example, a person who reports having low confidence in quitting smoking would receive self-efficacy enhancing messages (e.g., about using implementation intentions). As another example, a person who lacks social support from their partner would receive messages about how to talk to their partner about quitting smoking. Usually, the content is tailored, but other message components, such as the source, delivery channel, message frame, or delivery mode can also be tailored.

There are several explanations regarding the working mechanisms of tailoring (Hawkins et al., 2008). One explanation draws on the Elaboration Likelihood Model, a dual process theory that distinguishes between a ‘central route’ and a ‘peripheral route’ of persuasion (Petty &

Cacioppo, 1986). Whereas the central route is characterized by thoughtful elaboration of information and in turn enduring attitudinal change, the peripheral route is characterized by quick processing of superficial stimuli and in turn short-lasting attitudinal change. Which route is taken depends on several factors, including the personal relevance of the information that is provided. It is assumed that the personal relevance of tailored communication is perceived as higher by individuals compared to non-tailored communication, as tailored communication eliminates unnecessary information. Therefore, it is assumed that tailored communication is processed through the central route and leads to greater and longer-lasting attitudinal change.

Tailoring is used primarily in digital behavior change interventions, which is referred to as computer tailoring (de Vries & Brug, 1999). In order to gather the information for the tailoring process, recipients usually fill out questionnaires, but novel possibilities (e.g., sensor data) are upcoming (Short et al., 2022). Based on tailoring rules (e.g., if-then constructs), the collected information is matched with the correct messages from a feedback library. Computer-tailored communication is often provided via websites, referred to as web-based or eHealth interventions, or in applications for smartphones, referred to as mHealth. International meta-analyses have demonstrated the effectiveness of computer tailoring for several health behaviors, including smoking cessation (Krebs et al., 2010; Lustria et al., 2013; Wolfenden et al., 2015). For the Dutch context, a recent review showed that Dutch computer-tailored smoking cessation interventions are both effective and cost-effective (Cheung, Wijnen, et al., 2017; Cheung et al., 2018). However, there are still many digital smoking cessation interventions that are disseminated without scientific evaluation, so their effectiveness is unknown, underscoring the importance of scientific scrutiny (Abroms et al., 2013; Cheung, Wijnen, et al., 2017). The previously described intervention by Stanczyk et al. (2011), was found to be effective and cost-effective in a randomized controlled trial (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016; Stanczyk, Smit, et al., 2014).

The following section describes the rationale for the conducted research described in this dissertation. A multidisciplinary approach is taken that examines both the weaknesses of digital behavior change interventions more broadly (e.g., user engagement) and specific factors underlying smoking cessation (e.g., the use of e-cigarettes for smoking cessation). All studies are characterized by innovative approaches to address these issues.

OUTLINE OF THE THESIS

User engagement

The use of the Internet, smartphone apps, or other digital vehicles has clear advantages for the end user. The only requirements for use are generally an Internet connection and a device on which the intervention can be used. This allows individuals to use digital behavior change

interventions whenever it fits their schedule and wherever they feel comfortable. However, as discussed in the previous section, the greatest strengths of approaches are often related to their greatest weaknesses, which are high attrition and low adherence in the case of digital behavior change interventions (Kelders et al., 2012; Kohl et al., 2013). The simplicity, discreteness, and voluntary nature of digital behavior change interventions, which are key strengths, also allow users to discontinue usage very easily (Eysenbach, 2005). Moreover, participation in digital behavior change interventions requires a sustained cognitive and time commitment, and when interest wanes, it may be easiest to stop. Although the effectiveness of digital behavior change interventions is well established, effect sizes are often small to modest (Kohl et al., 2013), which is likely related to suboptimal use as the effectiveness of interventions increases with increased use (Donkin et al., 2011).

In health psychology and related disciplines, the application of psychological theories, such as the theory of planned behavior, is paramount in the content development of (digital) behavior change interventions. However, there is another step in intervention development that seems to be less theoretically grounded, namely the transformation of intervention content into a technological end product (Aronson et al., 2013; Kelders et al., 2012). Paradoxically, the technological realization of digital behavior change interventions often seems to be taken for granted. Or, as described by Kelders et al. (2012), "(…) technology is often seen as a black box: a mere tool that has no effect or value and serves only as a vehicle for the delivery of intervention content."

The technological realization of an intervention is assumed to influence user engagement (Short et al., 2018). The conceptualization of engagement is still in its infancy, but there is consensus that engagement includes both psychological factors (e.g., interest) and behavioral factors (e.g., number of pages accessed) (Short et al., 2018). In this work, the user experience model of Crutzen et al. (2011) and the digital behavior change interventions engagement scale of Perski et al. (2017) were used to measure engagement. The user experience model is based on cognitive (e.g., relevance of information) and affective (e.g., enjoyment) perceptions that determine the intention to revisit and recommend an intervention to others (Crutzen et al., 2011). The engagement scale includes both the user's subjective experience, as measured by cognitive and affective perceptions, and behavioral indicators, such as the time spent on the intervention (Perski et al., 2017).

Experimental studies are needed to examine the effects of specific intervention characteristics on engagement (Vandelanotte et al., 2016). One of the intervention characteristics hypothesized to influence engagement is the delivery mode of the intervention (Short et al., 2018). It is hypothesized that adaptation of the delivery mode to the needs of the target population increases engagement, which ultimately leads to better adherence. In terms of the I-Change model, the channel factor is adapted in order to increase engagement. Digital behavior change

interventions, including computer-tailored interventions, traditionally present the content of messages in text form. However, studies have shown that interventions that include narrated videos in which facilitators present tailored feedback messages are more effective and more positively evaluated by participants than text-based versions with identical intervention content (Soetens et al., 2014; Stanczyk, Bolman, et al., 2014; Walthouwer et al., 2015). Another form of video is animated video, which can be developed relatively inexpensively and easily with the advent of computer programs for creating animated videos. In the field of medical health information, the use of narrated animated video has already been explored, with the conclusion that narrated animated videos are best suited to convey information to people with low health literacy without adversely affecting people with high health literacy (Meppelink et al., 2015). In the field of computer-tailored interventions, experimental studies into the effects of using animated video were lacking. **Chapter 2** reports on an experimental study that examined the effect of animation- versus text-based delivery of a computer-tailored smoking cessation intervention on engagement.

Is information missing? The use of e-cigarettes for smoking cessation

When specific information is withheld from interventions, the personal relevance of the intervention content can be diminished. This could be the case with information about e-cigarettes for smoking cessation. In the Netherlands, e-cigarettes are not recommended as a method for smoking cessation, according to the Dutch Guideline on Treating Tobacco Addiction and Smoking Cessation Support (Trimbos-instituut, 2016). According to this guideline, the use of e-cigarettes can be considered if proposed by the smoker themselves and if the smoker has had previous unsuccessful quit attempts (Trimbos-instituut, 2016). Although authorities in the Netherlands do not recommend e-cigarettes for smoking cessation, they were used by 44% of smokers in the Netherlands in 2016 to support quit attempts (Hummel et al., 2018). However, e-cigarette users possess limited knowledge about e-cigarettes (Coats et al., 2022; Coleman et al., 2016; Felicione et al., 2021; Gowin et al., 2016; Gravely et al., 2020; Katz et al., 2020) and have unanswered questions regarding the use of e-cigarettes (Coleman et al., 2016; Romijnders et al., 2019). Furthermore, e-cigarette users and smokers reported that they often obtain information about e-cigarettes from Internet searches, peers, and e-cigarette stores, which may not be credible sources (Bauhoff et al., 2017; Gowin et al., 2016; Romijnders et al., 2019). Because of all these aspects, information about the use of e-cigarettes for smoking cessation is usually not provided in smoking cessation interventions in the Netherlands.

Including information about e-cigarettes based on the current scientific evidence in public health interventions could help smokers to make better informed decisions about the use of e-cigarettes for smoking cessation. **Chapters 3 and 4** report the protocol and effect evaluation of a randomized controlled trial on the influence of providing tailored information about e-cigarettes in a digital smoking cessation intervention on decision making and smoking

behavior. This study addresses the message factor (i.e., message content and quality) of the I-Change model.

The COVID-19 pandemic

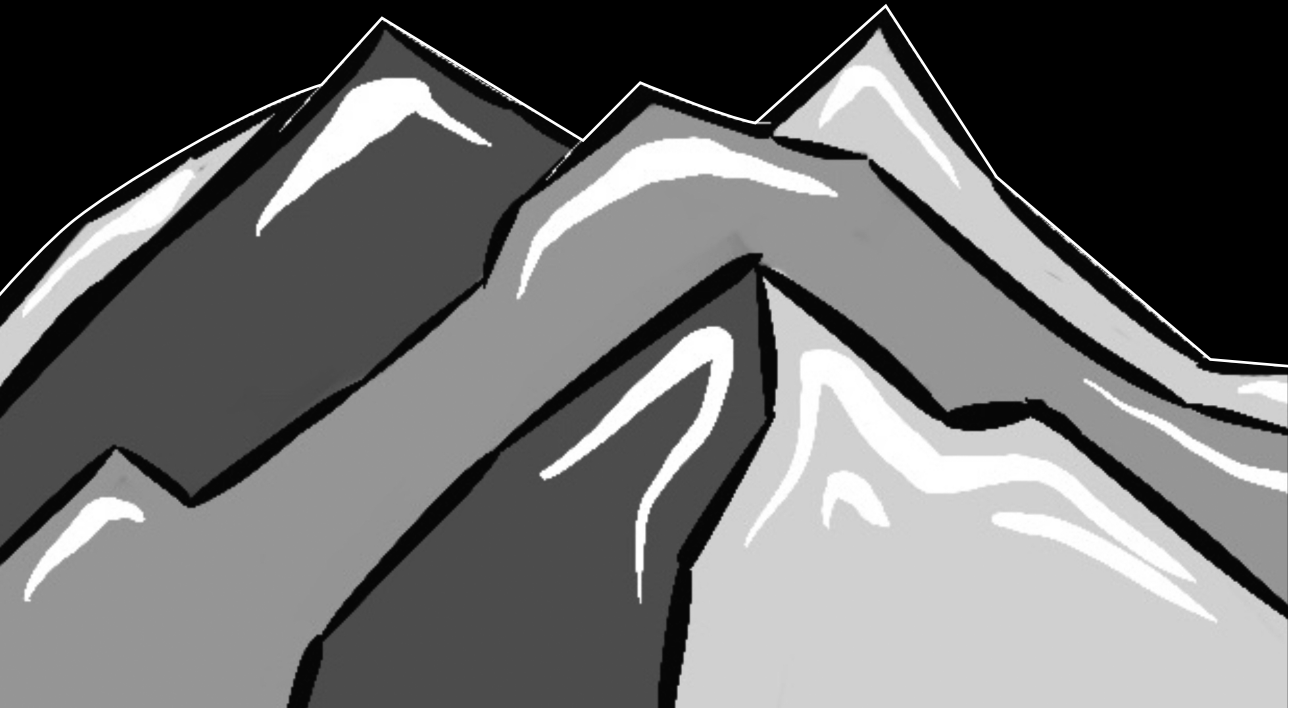
Most of the research reported in this thesis was conducted during the COVID-19 pandemic. Information about COVID-19 and smoking, and the measures taken to curb the number of infections, may have influenced smokers' beliefs toward smoking and quitting. To assess this potential influence, a questionnaire study was integrated in the randomized controlled trial presented in Chapters 3 and 4. This study was conducted during the early pre-vaccination phase of the COVID-19 pandemic in spring 2020. **Chapter 5** presents the results of this study on the potential influence of the COVID-19 pandemic on smoking behavior and beliefs about quitting smoking.

Contextual factors in smoking relapse

The focus of smoking cessation interventions is usually on changing motivational determinants and preparing for the quit attempt. However, making a quit attempt is only a first step. The most common outcome of assisted quit attempts is unfortunately still relapse (Robinson et al., 2019). Therefore, relapse prevention after the day of the quit attempt is critical to achieving long-term abstinence. Previous research suggests that (ex-)smokers usually relapse in the presence of specific contextual factors, such as being at a party, drinking coffee, or seeing other people smoke (Shiffman, 2006). Contextual factors have a situational, momentary character and include activities, the social environment, the consumption of food and drink, and the location. As described earlier, contextual factors have been classically conditioned to be associated with cigarette smoking (Benowitz, 2010). During the daily life as a smoker, this conditioning occurs constantly, so a smoker's environment is full of conditioned contextual factors that can trigger relapse.

These contextual factors could be the target of digital just-in-time adaptive interventions (JITAIs) (Naughton, 2016; Shiffman, 2006). The idea of such interventions is to intervene in the process between the conditioned contextual factor and relapse. Ideally, the support provided by the digital behavior change intervention (e.g., coping advice, distraction) helps the smoker – in the moment – to cope with the situation without smoking. After repeated exposure without a conditioned response (i.e., smoking), the response is gradually extinguished and the situation poses less risk of relapse (Lazev et al., 1999). Traditional face-to-face counseling attempts to prepare smokers in advance to cope well in high-risk situations, but the counselor cannot be present in high-risk situations, and the coping techniques learned may be easily forgotten in the heat of the moment (Shiffman, 2006). Just-in-time adaptive interventions, however, can provide tailored support independent of time and place which improves synchronization between the need for support and support delivery (Naughton, 2016).

However, before developing such interventions, it is important to know which contextual factors are associated with relapse. Therefore, we conducted an ecological momentary assessment study examining contextual factors associated with temptations and lapses among smokers trying to quit. We examined what participants did (activities), who they were with (social environment), and where they were (location), and how these factors related to temptations and lapses. The factors were included with the perspective that they are suitable as targets in future just-in-time adaptive interventions. **Chapter 6** presents the results of the ecological momentary assessment study.



CHAPTER 2

Influence of Animation- Versus Text-Based Delivery of a Web-Based Computer-Tailored Smoking Cessation Intervention on User Perceptions

This chapter has been published as:
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Abstract

Computer-tailored (CT) digital health interventions have shown to be effective in obtaining behavior change. Yet, user perceptions of these interventions are often unsatisfactory. Traditional CT interventions rely mostly on text-based feedback messages. A way of presenting feedback messages in a more engaging manner may be the use of narrated animations instead of text. The goal of this study was to assess the effect of manipulating the mode of delivery (animation vs. text) in a smoking cessation intervention on user perceptions among smokers and non-smokers. Smokers and non-smokers (N = 181) were randomized into either the animation or text condition. Participants in the animation condition assessed the intervention as more effective (η_p^2 = .035), more trustworthy (η_p^2 = .048), more enjoyable (η_p^2 = .022), more aesthetic (η_p^2 = .233), and more engaging (η_p^2 = .043) compared to participants in the text condition. Participants that received animations compared to text messages also reported to actively trust the intervention more (η_p^2 = .039) and graded the intervention better (η_p^2 = .056). These findings suggest that animation-based interventions are superior to text-based interventions with respect to user perceptions.

INTRODUCTION

Digital health stands for the utilization of digital and mobile technologies to support health and healthcare (World Health Organization, 2018). Digital health can facilitate the transmission of targeted health information to individuals. In computer-tailored (CT) interventions, this health information is matched to the individual behavioral and motivational characteristics through a computerized process (de Vries & Brug, 1999). In order to diagnose the necessary information for the tailoring process, the recipient usually fills out questionnaires which are then used to generate highly individualized information adapted to the needs and characteristics of the recipient. Information that is perceived as personally relevant enhances central processing according to the elaboration likelihood model of persuasion (Petty & Cacioppo, 1986). Information that is processed under the central route is in turn more likely to result in actual and sustained attitudinal changes and is thus more predictive of behavior. Ruiter et al. (2006) demonstrated that CT health information compared to generic health information motivates people into more attentive information processing. In the area of health promotion, CT interventions have been shown to be effective and cost-effective in motivating people to adopt health promoting behavior or change health detrimental habits (Krebs et al., 2010); also for Dutch smoking cessation interventions (Cheung, Wijnen, et al., 2017).

Smoking cessation

In this study, the digital health program under investigation was aimed at supporting people to quit smoking. The program was built on an earlier intervention that has proven effective in realizing smoking cessation (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016). Tobacco smoking is a major public health problem in the Netherlands. In 2015, 20,000 deaths were attributed to smoking-related diseases (Rijksinstituut voor Volksgezondheid en Milieu, 2018). In 2017, 23.1% of the Dutch adult population reported to smoke (Nationaal Expertisecentrum Tabaksontmoediging, 2018). In the group of smokers, 41.7% tried to quit smoking at least once (Nationaal Expertisecentrum Tabaksontmoediging, 2018). However, because of conditioned behavior and the highly addictive nature of nicotine (Benowitz, 2010), about 95% of smokers who try to quit without treatment fail in their cessation attempts (Hughes et al., 2004). Hence, developing effective smoking cessation interventions is of high societal relevance.

User experience and engagement

A fundamental problem of digital health interventions, including CT interventions, is attrition, i.e., participants not using the intervention and/or being lost to follow-up (Eysenbach, 2005). In the randomized controlled trial (RCT) of the smoking cessation intervention on which the program presented in this paper is based, 42.9% (591/1,378) of the respondents in the experimental conditions were lost to follow-up after 12 months (Stanczyk et al., 2016). In

more open settings than RCTs, even higher attrition rates can be expected (Eysenbach, 2005). For instance, an attrition rate of 78.2% (330/422) was found in a recent tailored digital health intervention for a healthy lifestyle change (van der Mispel et al., 2017).

High attrition may be caused by an unsatisfactory user experience (Crutzen et al., 2011; Crutzen et al., 2009). User experience comprises the user's cognitive and affective perceptions of a website or a web-based intervention during and after exposure to that service (Crutzen et al., 2011). A positive user experience is posited to lead to the intention to revisit a web-based intervention and to the intention to recommend the intervention to others, which is described by the term e-loyalty (Crutzen et al., 2011). The user experience model of Crutzen et al. (2011) is reported in Figure 1. Efficiency (ease of searching information), effectiveness (usefulness of the information), trustworthiness (information perceived as accurate and true), enjoyment (use of intervention elicits positive feelings), and active trust (feeling able to act purposefully on the information given) are all posited to have a positive influence on e-loyalty. The positive influence of effectiveness and trustworthiness is, respectively, partially and fully mediated by active trust. The relations in the user experience model have been tested in six web-based interventions, in which the importance of the model's constructs in predicting e-loyalty has been confirmed (Crutzen et al., 2014; Crutzen et al., 2011; Crutzen et al., 2012; Nunn et al., 2017).

Another theory proposes that a reason for high attrition may be that users are not engaged with the intervention (Perski et al., 2019; Perski et al., 2017; Short et al., 2018; Short et al., 2015). A certain level of engagement is considered a precondition for interventions to be effective (Donkin et al., 2011). Since engagement has been defined in various ways between disciplines, Perski et al. (2017) proposed an integrative definition and conceptual framework of engagement with digital health interventions, called the Digital Behavior Change Interventions (DBCI) Engagement Scale. They conceptualized engagement as a multidimensional construct consisting of behavioral dimensions (e.g., amount of usage) which are underpinned by the user's subjective experience (i.e., cognitive and emotional aspects) (Perski et al., 2017).

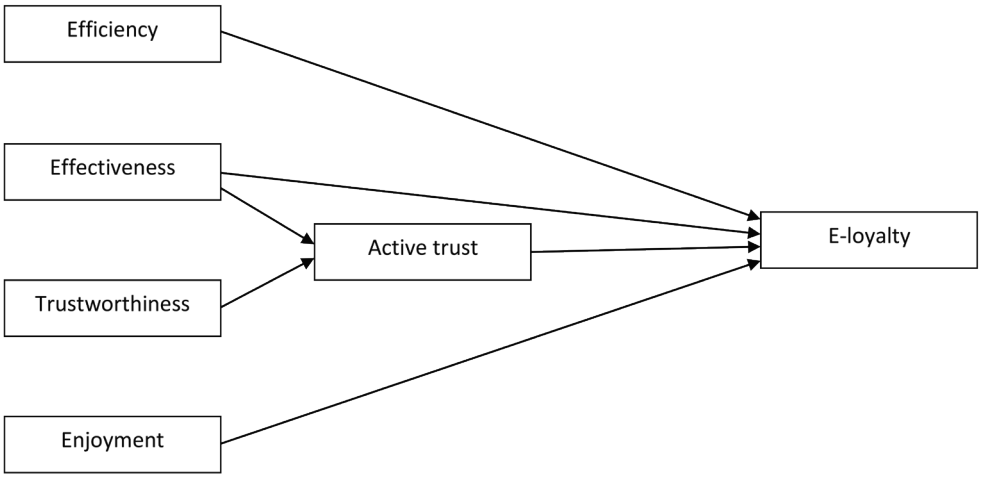


Figure 1. User experience model of Crutzen et al. (2011).

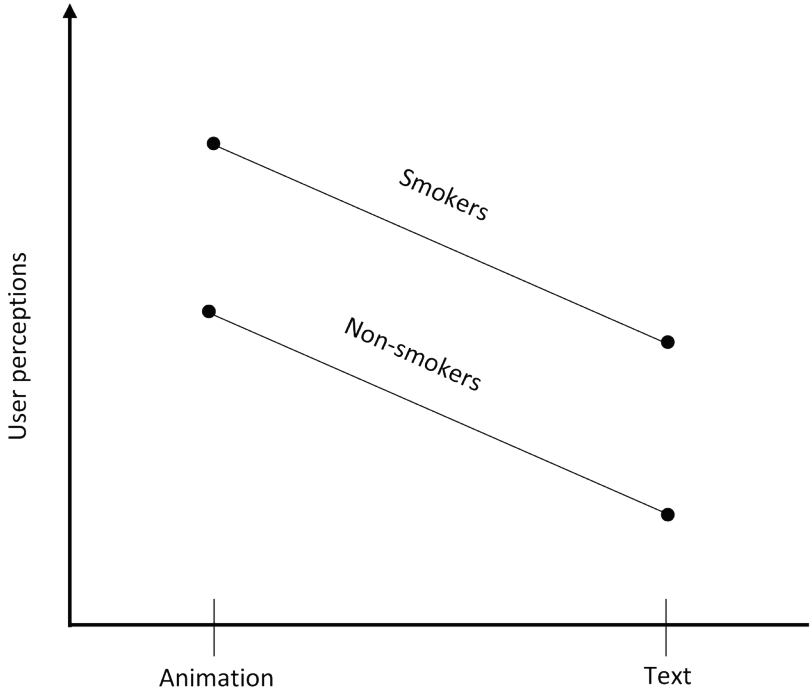


Figure 2. Hypothesized main effects of condition (Hypothesis 1) and smoking status (Hypothesis 2) on user perceptions.

Delivery mode: Animation vs. text

User experience and user engagement (jointly referred to as user perceptions) are both posited to be influenced by characteristics of the intervention, e.g., aesthetics, user control, mode of delivery (Crutzen et al., 2011; Perski et al., 2017). One way to improve user perceptions is thus to adapt the mode of delivery to the needs of the target population (Smit et al., 2015). It is hypothesized that adaptation of the delivery mode leads to changes in user perceptions, which ultimately result in better adherence.

A mode of delivery for communicating health messages is the use of narrated animation. Narrated animations make use of words (i.e., spoken text) and graphics (i.e., animations that move) and allow thus for more extensive information processing than text-based interventions that rely solely on written words. The cognitive theory of multimedia learning elucidates on the difference between animation and text for information processing (Mayer, 2018). The theory posits that people use separate channels to process visual and auditory information independently and that people can process only a limited amount of information in each channel at one time. An advantage of narrated animation compared to text is thus that recipients are able to process the information using the visual and auditory channel, whereas recipients of text-based messages are limited to the visual channel only. In this way, the cognitive load is balanced between the visual and auditory channel, so neither one is overloaded (Mayer, 2009). Research suggests that spoken animated videos that are simple, shorter than 5 minutes, positive in tone, and without the use of medical terminology are appreciated by participants in digital health interventions (van het Schip et al., 2020; Vandelanotte & Mummery, 2011). A recent experimental study showed that spoken animations are the most effective way to communicate information on colorectal cancer screening to people with low health literacy, without impairing high health literate people (Meppelink et al., 2015).

Research goal

The effects of using animations in CT interventions on user perceptions have not been explored yet. Thus, the goal of this study was to assess the effect of manipulating the mode of delivery (animation vs. text) on user perceptions among smokers and non-smokers. Statistically, interaction effects between condition and smoking status need to be tested first. However, we hypothesized that there would be no interaction effects between condition and smoking status, because there is no evidence and no reason to assume that smokers and non-smokers perceive animation and text differently. Therefore, we looked at main effects of condition and smoking status. The hypothesized pattern of the main effects of condition and smoking status on user perceptions is depicted in Figure 2. Regarding main effects of condition, it was hypothesized that user perceptions in the animation-based condition would be assessed significantly better than in the text-based condition (hypothesis 1). Regarding main effects of smoking status, it was hypothesized that user perceptions in the group of smokers would be assessed significantly better than in the group of non-smokers (hypothesis

2). This study was open to smokers and non-smokers in order to test if smokers and non-smokers differ in their evaluation of the two versions. We assumed that feedback messages in the CT intervention will be of higher personal relevance for smokers than for non-smokers, because non-smokers are usually not personally involved in the topic of smoking cessation. Past research has shown that perceived personal relevance significantly predicted higher appreciation of a CT digital health intervention (Kanera et al., 2016).

METHOD

Design

A between-subjects design with two experimental conditions was used. In one condition, participants received an animation-based version of a smoking cessation intervention. In the other condition, participants received a text-based version of the same intervention. Ethical approval was granted by the Ethical Review Committee Psychology and Neuroscience (ERCPN) at Maastricht University (Master_205_13_03_2019). The study is registered in the Netherlands Trial Register (NL7669, https://www.trialregister.nl/trial/7669).

Intervention

The web-based CT smoking cessation intervention that was used in this study was based on an existing intervention, which was subject to a RCT and has been found to be effective and cost-effective in the Netherlands (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016; Stanczyk, Smit, et al., 2014). The I-Change model was used as a theoretical framework for the development of the intervention (de Vries, 2017; de Vries et al., 2008). The present study used a shortened version of the intervention delivered in an animation-based version and a text-based version. The animation-based version made use of narrated animations with little onscreen text, see Appendix A. The text-based version consisted of text-based feedback messages without any graphics, see Appendix A. The content (i.e., messages) was exactly the same in both versions. Whereas the text-based version was readily available from prior research (Stanczyk et al., 2016), the animation videos for the animation-based version had to be developed. All animations were developed using the web-based animated video creation tool Vyond (GoAnimate, Inc., San Mateo, California, U.S.). The intervention website was developed employing responsive web design, implying that the website could be accessed on all common devices including smartphones, tablets, desktop computers, and laptops.

Recruitment

A power analysis for analysis of variance (ANOVA) was conducted using G*Power version 3.1 (Faul et al., 2007). Taking into account a modest effect size (*f*) of .22, a power of .80, and an alpha of .05, a minimum total sample size of 165 participants was required. Since we knew from prior research that about 32% of participants have to be excluded after data collection,

because they rush through the intervention without actively processing the information, we aimed at recruiting 243 participants (Stanczyk et al., 2013).

Inclusion criterion was that participants were at least 18 years old, as the sale of tobacco to persons under 18 years is illegal in the Netherlands (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2018). Various recruitment strategies were employed including posts on social media, survey exchange websites, posters, flyers, and a research participation credit system within the university. Posters were put up in public places and flyers were distributed door-to-door in the city of Maastricht. Psychology undergraduate students of Maastricht University were recruited through the research participation system of the Faculty of Psychology and Neuroscience. Students taking part in the research participation system received credits for their participation. All other participants could enter a raffle for 10 vouchers of €25 each.

Participants

During the study period from April 11, 2019 to December 6, 2019, data from 242 persons were collected. Participants who took less than 5 minutes to complete the study were excluded from data analysis, because in order to actively process the information of the intervention, a minimum amount of 5 minutes was deemed necessary. The original data file consisted of 125 participants in the animation condition and 117 in the text condition. In the animation condition, 37 participants (29.6%) did not take more than 5 minutes and were thus excluded. In the text condition, 24 participants (20.5%) were excluded because of the same reason. The final sample consisted of $N = 181$ participants. Seven student participants were recruited through the research participation system of Maastricht University.

People who were interested in taking part in the research were directed to an intervention website on which they could take part in the online study without registration. Participants were informed that they could leave the study at any time for any reason if they wish to do so without any consequences. Informed consent was obtained online from all participants. Participants were neither informed about the existence of two experimental conditions nor about the randomization process, in order to mitigate the effect of demand characteristics on the results.

Procedure

After giving informed consent, a baseline questionnaire had to be filled in asking for gender, age, educational level, and smoking status. Next, participants were informed that they receive a part of an existing smoking cessation intervention which was originally developed for smokers who are motivated to quit smoking (Stanczyk et al., 2016). Therefore, smokers were asked to fill out the questionnaire as if they wanted to quit smoking. For this purpose, smokers were asked to look back at a time in which they wanted to quit smoking and to answer the

questions from that perspective. Non-smokers were asked to immerse in the situation that they are smokers and want to quit smoking.

During the program, participants received tailored feedback on the pros and cons of quitting smoking (i.e., attitude), on preparatory action plans to effectively quit smoking, and on coping plans to deal with situations in which they think it is difficult not to smoke. All items of the tailoring process are reported in Appendix B. For the pros, cons, and coping plans, participants could choose three items each based on their personal preference for which they would like to receive feedback. In total, participants received 14 feedback messages, either as animations or text messages. The personal information for the tailored feedback was gathered by means of questionnaires in between the different sections of the intervention. The computer program TailorBuilder (OverNite Software Europe BV, Geleen, The Netherlands) employed if-then rules to match the personal answers with the relevant feedback messages from a file consisting of all possible feedback messages. After completing the program, participants were asked to fill out an evaluation questionnaire.

Measures

An overview of the complete questionnaire is reported in Appendix C. *Demographics* were measured by asking for gender (1 = *male*; 2 = *female*; 3 = *third gender*), age of the participant, and education level (1 = *low (primary or basic vocational school)*; 2 = *medium (secondary vocational school or high school)*; 3 = *high (higher vocational school or university)*). *Smoking status* was assessed by one item asking whether the participant smokes (1 = *not smoking*; 2 = *smoking*).

User experience (Crutzen et al., 2011) was measured by five constructs: *effectiveness*, *trustworthiness*, *enjoyment*, *active trust*, and *design aesthetics*. *Effectiveness* (e.g., "The program gives important information on smoking cessation") was measured by three items (Cronbach's alpha = .87) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). *Trustworthiness* (e.g., "The program is trustworthy") was measured by three items (Cronbach's alpha = .86) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). *Enjoyment* (e.g., "I found my visit to this program enjoyable") was measured by three items (Cronbach's alpha = .92) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). *Active trust* (e.g., "I know now how I can stop smoking") was measured by three items (Cronbach's alpha = .88) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). *Design aesthetics* (e.g., "I think the design of the program is attractive") was measured by three items (Cronbach's alpha = .90) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*).

E-Loyalty (Crutzen et al., 2011) was assessed by two constructs. First, the *intention to revisit* the intervention (e.g., "It is likely that I will visit the website again in the future") was

assessed by two items (r = .69) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). Second, the *intention to recommend* the intervention to others (e.g., "It is likely that I will recommend this website to others") was assessed by two items (r = .81) on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*).

The experiential dimensions of the Digital Behavior Change Interventions (DBCI) Engagement Scale (Perski, 2017) (e.g., "How strongly did you experience interest?") were measured by five items on a 7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*). The *amount of use* was measured by one item ("How much time (in minutes) did you spend on the website?"). Participants had to indicate the time in minutes entering free text. The "depth of use", which is originally part of the DBCI Engagement Scale, was not assessed in this study, as the "depth of use" in a CT intervention is not determined by the individual but by the tailoring process. In this CT intervention, all participants received the same number of sections and health messages. Z-score transformation was applied to all items of the DBCI Engagement Scale. Subsequently, a total sum score was calculated with equal weight given to each item (Cronbach's alpha = .88).

A *grade* for the received version of the intervention was measured on a scale ranging from 1 (*very bad*) to 10 (*very good*). *Time spent on website* was measured automatically.

Statistical analyses

Descriptive analyses and a two-way multivariate analysis of variance (MANOVA) were performed using IBM SPSS Statistics 27. Effectiveness, trustworthiness, enjoyment, active trust, design aesthetics, revisit, recommendation, engagement, and grade have been included as dependent variables. Condition and smoking status have been included as independent variables. Partial η^2 is reported as effect size with a 90% confidence interval (*CI*) around it. A 90% *CI* was chosen instead of a 95% *CI*, because a 95% *CI* around partial η^2 can include 0, even though the test reveals a statistical difference with $p < .05$ (Steiger, 2004). Partial η^2 cannot be smaller than zero (Steiger, 2004).

RESULTS

Sample characteristics

The mean age of the sample was 26.7 years (*SD* = 11.6; range = 18-82). More non-smokers (57.5%) than smokers participated in the study. The majority of participants was female (69.1%) and had a high level of education (95.6%). Sample characteristics are reported in Table 1.

Table 1. Sample characteristics and time spent on website

Constructs	Full sample		Condition				Smoking status			
			Animation		Text		Positive		Negative	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Total	181	100	88	100	93	100	77	100	104	100
Gender										
Male	55	30.4	30	34.1	25	26.9	32	41.6	23	22.1
Female	125	69.1	57	64.8	68	73.1	45	58.4	80	76.9
Third gender	1	0.6	1	1.1	0	0.0	0	0.0	1	1.0
Education level										
Low	2	1.1	2	2.3	0	0.0	1	1.3	1	1.0
Middle	6	3.3	3	3.4	3	3.2	4	5.2	2	1.9
High	173	95.6	83	94.3	90	96.8	72	93.5	101	97.1
Smoking status										
Smoking	77	42.5	33	37.5	44	47.3	–	–	–	–
Not smoking	104	57.5	55	62.5	49	52.7	–	–	–	–
Age *M* (*SD*)	26.7 (11.6)		27.8 (13.5)		25.7 (9.3)		26.1 (9.0)		27.2 (13.2)	
Time spent on website *M* (*SD*)	00:12:20 (00:08:01)		00:15:32 (00:08:54)		00:09:19 (00:05:38)		00:13:11 (00:09:04)		00:11:43 (00:07:08)	

Differences in user perceptions between conditions

Before testing main effects of condition and smoking status on user perceptions, condition × smoking status interaction effects need to be tested. No significant interaction effects between condition and smoking status were found (Pillai's Trace = .04, $F = 0.84$, $p = .585$, $\eta_p^2 = .043$). This implies that smokers and non-smokers were not affected differently by manipulation of the delivery mode. The absence of condition × smoking status interaction effects is reported in Appendix D. Since no interactions were found, main effects of condition and main effects of smoking status on user perceptions are reported in the following paragraphs.

Significant differences between the animation condition and text condition were found in the hypothesized direction (Pillai's Trace = .29, $F = 7.74$, $p < .001$, $\eta_p^2 = .292$). Participants who received the animation version in comparison to the text version reported higher ratings for most constructs. Main effects of condition on user perceptions are reported in Table 2. Participants in the animation condition judged the intervention as more effective, more trustworthy, more enjoyable, and more aesthetic. Participants who received animations in comparison to text messages also reported to actively trust the intervention more. Furthermore, participants receiving animations scored higher on engagement than those receiving text messages. The better evaluation of the animation condition was confirmed by a higher grade for the animation condition in favor over the text condition. Participants in the animation condition also stayed longer on the website compared to participants in the text condition. The effect sizes of the statistically significant differences in user perceptions between conditions ranged from small to large (range $\eta_p^2 = .022–.233$).

Differences in user perceptions between smoking status

Main effects of smoking status on the constructs of user perceptions are reported in Table 3 (Pillai's Trace = .12, $F = 2.66$, $p = .007$, $\eta_p^2 = .124$). Smokers reported to enjoy the intervention more and found the intervention more engaging compared to non-smokers. The effect sizes of the statistically significant differences in user perceptions between smoking status were small (range $\eta_p^2 = .030–.050$).

DISCUSSION

The aim of this study was to examine user perceptions toward an animation version and a text version of a CT smoking cessation intervention among smokers and non-smokers. Overall, results showed that participants who received animated videos evaluated the intervention more positively than participants who received text messages regardless of smoking status.

Table 2. Main effects of condition on constructs of user perceptions

User perception constructs	**Condition**						
	Animation ***n*** **= 88**		**Text** ***n*** **= 93**				
	M	***SD***	***M***	***SD***	***F***	***p***	η_p^2 **(90% *CI*)**
User experience							
Effectiveness	5.47	0.93	5.07	1.15	6.50	.012*	.035 (.004, .090)
Trustworthiness	5.67	0.84	5.24	0.99	9.01	.003*	.048 (.010, .108)
Enjoyment	4.88	1.18	4.55	1.27	3.90	.050*	.022 (.000, .068)
Active trust	5.18	0.93	4.78	1.08	7.11	.008*	.039 (.006, .095)
Design aesthetics	5.05	1.18	3.76	1.24	53.70	< .001**	.233 (.147, .316)
E-loyalty							
Revisit	4.55	1.51	4.26	1.53	1.72	.192	.010 (.000, .047)
Recommendation	4.94	1.40	4.68	1.32	1.18	.280	.007 (.000, .040)
Engagement							
DBCI Engagement Scale	0.92	4.82	-0.74	4.46	7.93	.005*	.043 (.007, .101)
Grade	7.25	1.12	6.67	1.34	10.42	.001*	.056 (.013, .118)

Note. The construct engagement is the sum of six z-scored items. The construct grade was measured on a scale from 1 (very bad) to 10 (very good). All other constructs were measured on a 7-point Likert scale ranging from 1 (I totally disagree) to 7 (I totally agree). $^{*}p < .05$, $^{**}p < .001$.

Table 3. Main effects of condition on constructs of user perceptions

User perception constructs	Smoking status						
	Positive *n* = 77		Negative *n* = 104				
	M	*SD*	*M*	*SD*	*F*	*p*	η_p^2 (90% *CI*)
User experience							
Effectiveness	5.26	1.07	5.27	1.07	0.06	.801	.000 (.000, .014)
Trustworthiness	5.47	0.87	5.43	1.00	0.27	.602	.002 (.000, .025)
Enjoyment	4.94	1.06	4.54	1.33	5.43	.021*	.030 (.002, .081)
Active trust	5.06	0.89	4.91	1.12	1.58	.210	.009 (.000, .045)
Design aesthetics	4.43	1.38	4.35	1.37	1.52	.219	.009 (.000, .044)
E-loyalty							
Revisit	4.41	1.52	4.39	1.53	0.05	.819	.000 (.000, .012)
Recommendation	4.68	1.33	4.89	1.38	0.90	.344	.005 (.000, .036)
Engagement							
DBCI Engagement Scale	1.15	3.89	-0.73	5.09	9.26	.003*	.050 (.010, .110)
Grade	7.09	1.14	6.85	1.35	2.62	.107	.015 (.000, .056)

Note. The construct engagement is the sum of six z-scored items. The construct grade was measured on a scale from 1 (very bad) to 10 (very good). All other constructs were measured on a 7-point Likert scale ranging from 1 (I totally disagree) to 7 (I totally agree). $^{*}p < .05$, $^{**}p < .001$.

Our first hypothesis was that user perceptions in the animation-based condition would be assessed significantly better than in the text-based condition. Regarding the seven constructs of the framework of Crutzen et al. (2011), the results confirmed the hypothesis for the constructs of user experience but not for e-loyalty (i.e., the intention to revisit and recommend the intervention). In detail, the animation version was assessed as more effective, more aesthetic, more enjoyable, more trustworthy, and people also felt more able to act on the information given. Yet, no differences between conditions were found for the intention to revisit or the intention to recommend the intervention. The results also confirmed our hypothesis regarding the concept engagement of the framework of Perski et al. (2019). Participants in the animation-based condition indeed perceived engagement higher than participants in the text-based condition. Furthermore, we asked participants to give the intervention an overall grade. The animation version was, as hypothesized, rated higher than the text version.

Our second hypothesis was that user perceptions in the group of smokers would be assessed significantly better than in the group of non-smokers, because personal relevance of the intervention topic was deemed higher for smokers. This hypothesis was confirmed only for two out of nine investigated constructs. Statistically significant differences between smokers and non-smokers were only found for the constructs enjoyment and engagement, indicating that smokers found both versions more enjoyable and engaging than non-smokers. No significant differences between smokers and non-smokers were found for the constructs effectiveness, trustworthiness, active trust, design aesthetics, revisit, recommend, and grade. It is important to note that the two constructs that yielded statistical significance are affective constructs (i.e., enjoyment and engagement), whereas no differences were found for cognitive (e.g., effectiveness) and cognitive-affective constructs (e.g., trustworthiness). This suggests

that smokers and non-smokers evaluate the intervention similarly on a rational level, but are differently affected by the intervention on an emotional level (Crutzen et al., 2011).

Research on the use of animations in CT interventions is scarce, but multiple studies have examined the utilization of videos in a news-driven format in which, for example, professional presenters or actors read aloud the feedback messages of the intervention. The full intervention, on which the intervention presented in this paper is based, was tested in an RCT (Stanczyk et al., 2011). The original intervention compared a news-driven video version to a text version. The results of the RCT showed that the video version was more effective than the text version in obtaining smoking abstinence after 12 months (Stanczyk et al., 2016). The video condition was also slightly better appreciated, but the difference did not reach statistical significance (Stanczyk, Bolman, et al., 2014). However, another previous study on the same intervention found that manipulation of the delivery mode (video vs. text) had no influence on the processing of the information and on the intention to revisit and recommend the intervention (Stanczyk et al., 2013). Support for the higher evaluation of videos compared to text was in turn found in two experiments comparing a video and text version of a CT intervention for obesity prevention and physical activity (Soetens et al., 2014; Walthouwer et al., 2015). In sum, the results of this study contribute to a body of evidence that suggests that interventions that make use of videos with spoken text are more effective in obtaining smoking abstinence and better appreciated than interventions that rely solely on written feedback messages.

The results of this study have to be interpreted in the context of the fast-changing web. In the recent years, information on the internet is more and more presented in a rich and engaging manner containing videos and interactive features. In particular, there has been an exponential growth of videos on the internet and this trend is expected to keep up in the coming years (Kalogeropoulos et al., 2016). In the year 2017, video traffic accounted for 75% of all web traffic and it is estimated that this figure will increase to 82% by 2022 (Cisco, 2019). A driver for this growth in traffic is the omnipresence of video content on the internet, e.g., in news, ads, and social media. This growth of videos online suggests that internet users have become accustomed to receiving information on the internet in the form of videos. Thus, the expectation of internet users regarding the delivery mode of information may have changed. Whereas in the past, most users expected to receive information in the form of text, nowadays, more and more users may expect to be presented with videos when searching for information on the internet (Kalogeropoulos et al., 2016). This may be one explanation for the remarkable large effect size for the difference in the construct design aesthetics between participants in the animation condition and the text condition.

The results for the construct design aesthetics indicated that participants disapproved of the text version that was solely based on text without any visual elements, probably because

solely text-based websites do not meet modern standards. Furthermore, online reading and online information seeking is characterized by mostly browsing and scanning behavior and non-linear reading (Liu, 2005). Contemporary websites with hyperlinks and visuals encourage the user to switch between sections and to just allocate attention to information that seems interesting in that particular moment (Carr, 2011; Ryota & Kep Kee, 2016). The text-based version, however, was built for linear reading. The results of this study indicate that people favor more engaging websites.

Nonetheless, these results must be interpreted with caution and a number of limitations should be borne in mind. The major limitation of this study is the homogenous sample, which does not allow to generalize the findings to the general public. Most of the participants were in their twenties, female, and highly educated. Prior research does not suggest an influence of age or gender on the effectiveness of the smoking cessation intervention on which the intervention under investigation is based (Stanczyk, Bolman, et al., 2014). Yet, there is prior research showing that people with low and high health literacy have different information recall abilities depending on the mode of delivery in which the health information is presented. Meppelink et al. (2015) conducted a two (text format: written vs. spoken) by two (delivery mode: illustration vs. animation) experiment in which participants were randomly allocated to one of the four experimental conditions. The two modes of delivery were medical illustration (i.e., static graphics) and medical animation (i.e., moving graphics), both presenting information on colorectal cancer screening. Next to comparing two modes of delivery, the researchers added a second independent variable "text format", in the sense that the animations and illustrations were either spoken or written.

Participants' health literacy was also tested in order to assess whether health information recall and attitudes toward the health messages differed between people with different health literacy. Meppelink et al. (2015) found a three-way interaction effect between text format, delivery mode, and health literacy level on information recall. The results indicated that participants with a low health literacy level recalled significantly more information when confronted with spoken animations compared to spoken illustrations. Since health literacy is associated with education level (van der Heide et al., 2013), one may also expect interaction effects between condition and education level in studies on CT interventions delivered as video or text. However, in two RCTs of a CT smoking cessation intervention and a CT obesity prevention intervention, no differential effects per educational level were found (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016; Walthouwer et al., 2015). In sum, there is evidence to suggest that the efficacy of delivery modes may depend on health literacy; however, no moderating effects of education level were found in two CT interventions. More research in this field is needed to examine the role of health literacy and education level in CT interventions.

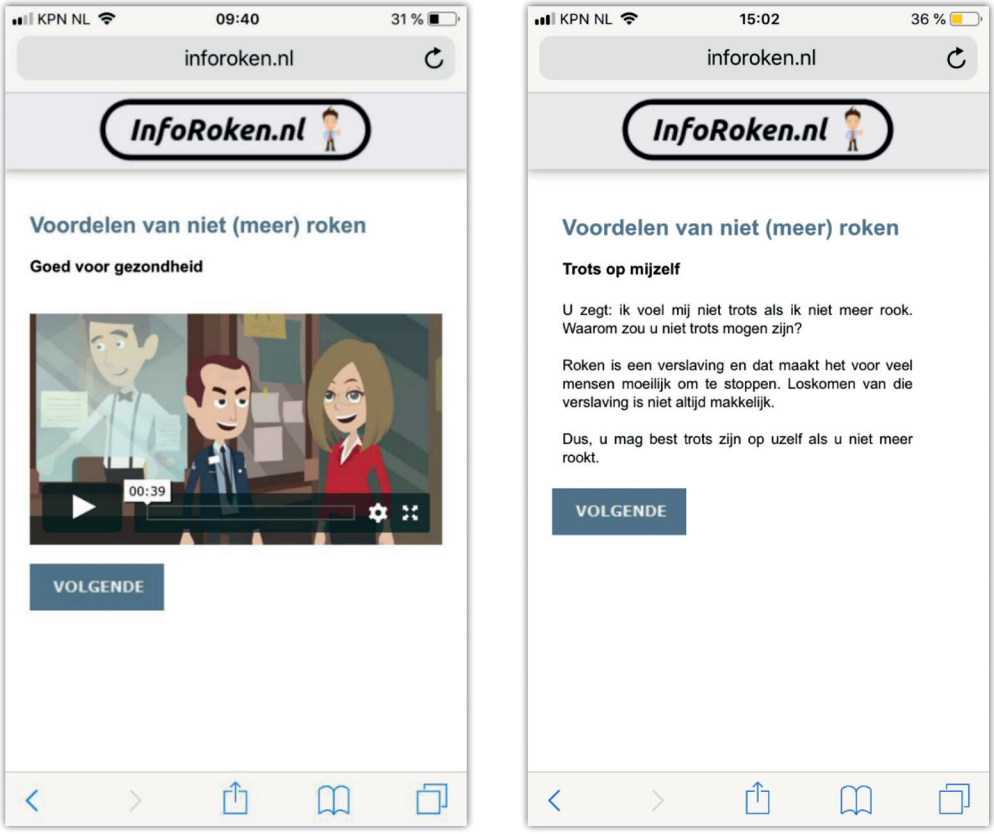
Another limitation of this study is that smokers were recruited in the light of testing an intervention. Thus, smokers did not necessarily head for the intervention website because they intended to quit smoking. Consequently, revisiting and recommending the intervention for smoking cessation purposes was not necessarily at stake, which may explain why there were no differences in e-loyalty between the two conditions. Moreover, research is needed in which the groups differ to a greater extent, for example one could compare smokers that are willing to quit within one month to a group of never-smokers. In larger samples of smokers, the intention to quit smoking needs to be examined as a moderating variable, because smokers in different stages of change may respond differently to evaluation questions (Prochaska & Velicer, 1997). Pre-contemplating smokers, for instance, tend to be defensive and may thus evaluate the intervention more negatively than smokers in the contemplation or preparation phase (Prochaska & DiClemente, 1983).

In closing, it is noteworthy to mention that information that is perceived as useful, trustworthy, interesting, and attractive is more likely to be processed under the central route of information processing and is in turn more predictive of behavior, according to the elaboration likelihood model (Petty & Cacioppo, 1986). Consequently, the higher evaluation by participants in the animation condition suggests that more processing of information and behavior change may occur in the animated version than in the text version. Unfortunately, we are not aware of any research assessing the association between user perceptions and actual use of the intervention or actual behavior change in the area of smoking cessation. In the context of an alcohol reduction intervention, self-reported engagement did not significantly predict the number of subsequent logins to the intervention program (Perski et al., 2019). Yet, only 3.7% of eligible users answered the questionnaire in this study (Perski et al., 2019). Hence, more research is needed to assess the association between user perceptions and program use as well as behavior change.

Conclusion

This study has shown that the animation version of the intervention was evaluated better than the text version, regardless of smoking status. In general, therefore, it seems advisable to not only rely on traditional text-based interventions in the future, but to explore the use of feedback messages that are presented as animations. Further experimental research needs to be conducted to establish that animations are superior in obtaining better adherence and actual behavior change compared to text-based interventions.

APPENDIX A – SCREENSHOTS OF THE INTERVENTION



Screenshots of the Animation-Based Version (left) and Text-Based Version (right). Displayed in Apple Safari on an iPhone 6s.

APPENDIX B – ITEMS FOR THE TAILORING PROCESS

Construct	Items
Attitude (pros)	Improvement of physical fitness
	Being an example to others
	Improvement of health
	Feeling more attractive
	Being proud
	Health of others
	Saving money
	Causing less nuisance to others
Attitude (cons)	Difficulties relaxing
	Gaining weight
	Being bored more often
	Feeling gloomy
	Feeling insecure
	Feeling stressed
	Being less sociable
	Getting withdrawal symptoms
Preparatory plans	I am planning…
	…to stop completely without cutting down on cigarettes first
	…to dispose all smoking related things from my house
	…to ask my guests to not smoke in my presence
	…to tell others that I will stop smoking
	…to make use of nicotine replacement therapy.
Self-efficacy & coping plans	I find it difficult not to smoke… & I have made plans to make sure that I will not smoke…
	…if I am stressed
	…if I am mad
	…if I am sad
	…if somebody offers me a cigarette
	…if I see somebody enjoying a cigarette
	…if I am at a party
	…if I am drinking tea or coffee
	…after I have eaten
	…if I am having a break
	…if I get up in the morning
	…if I feel like needing a cigarette

APPENDIX C – OVERVIEW OF THE QUESTIONNAIRE

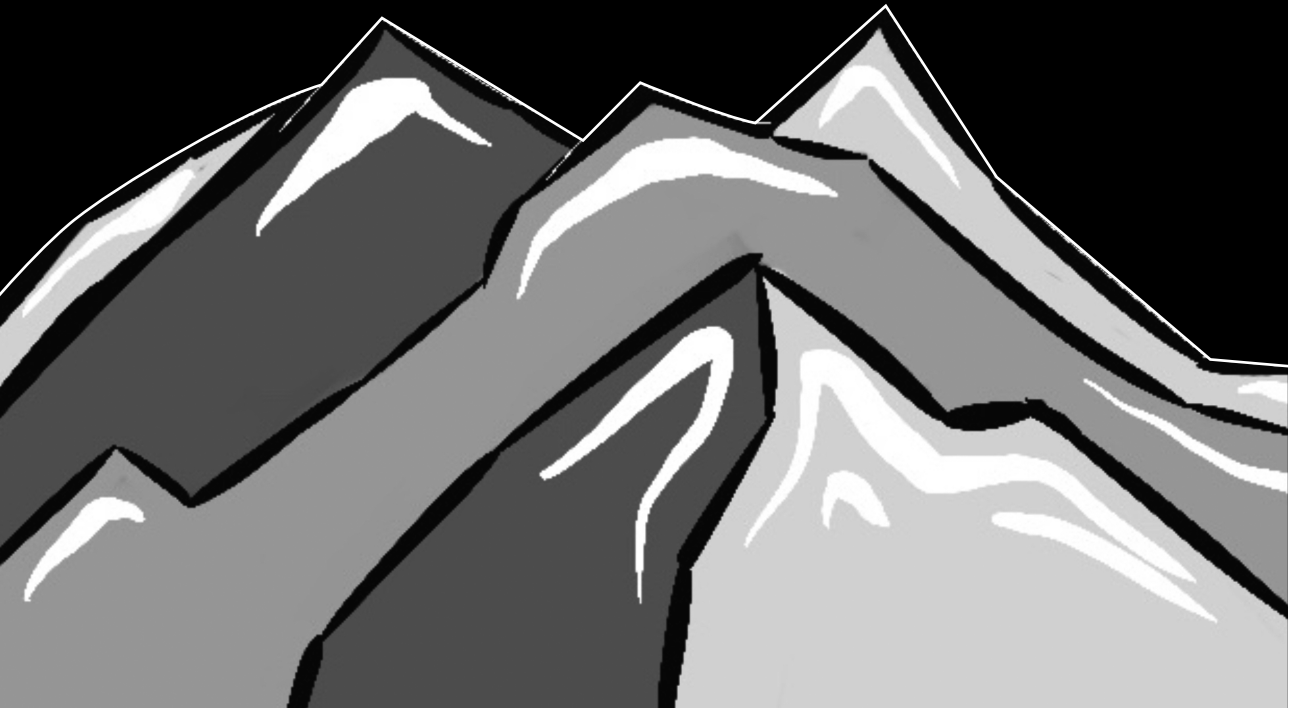
Construct	Question	Answer options
Gender	What is your gender?	[male] [female] [third gender]
Age	What is your age in years?	<age>
Education level	What is your highest completed education?	[Primary education, vmbo, havo-onderbouw, wvo-onderbouw, mbo1] [Havo, vwo, mbo] [Hbo-, wo-bachelor/master]
Smoking status	Do you smoke tobacco cigarettes?	[yes] [no]
Effectiveness	The program… … provides important information on smoking cessation … helps me how to prepare to quit smoking … helps me to deal with difficult moments when quitting smoking	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Trustworthiness	The program… … provides trustworthy information … offers good tips … is trustworthy	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Enjoyment	I found my visit to this program... … fun … enjoyable … interesting	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Active trust	To what extent do you agree with the following statements? I know now how I can stop smoking The advices are good to use I now know how to prepare my quit attempt	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Design aesthetics	I think the design of the program is… … attractive … beautiful … interesting	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Intention to revisit	To what extent do you agree with the following statements? Suppose the program were available. Then it is likely that I... … will visit the website again in the future … will use this website again for information about smoking cessation	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)

Intention to recommend	To what extent do you agree with the following statements? Suppose the program were available. Then it is likely that I... … will recommend this website to others … will recommend this website to others for information on quitting smoking	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Experiential dimensions (DBCI engagement scale)	How strongly did you experience the following? Interest Curiosity Focus Enjoyment Pleasure	7-point Likert scale ranging from 1 (*I totally disagree*) to 7 (*I totally agree*)
Amount of use (DBCI engagement scale)	How much time (in minutes) did you spend on the website?	<time in minutes>
Grade	What is the overall score you would award the program?	Scale ranging from 1 (*very bad*) to 10 (*very good*)

APPENDIX D – INTERACTION EFFECTS OF CONDITION AND SMOKING STATUS ON CONSTRUCTS OF USER PERCEPTIONS

User perception constructs	Condition				Smoking status						
	Animation		Text		Positive		Negative				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η_p^2
Effectiveness	5.47	0.93	5.07	1.15	5.26	1.07	5.27	1.07	0.04	.839	.000
Trustworthiness	5.67	0.84	5.24	0.99	5.47	0.87	5.43	1.00	0.41	.524	.002
Enjoyment	4.88	1.18	4.55	1.27	4.94	1.06	4.54	1.33	0.12	.734	.001
Active Trust	5.18	0.93	4.78	1.08	5.06	0.89	4.91	1.12	0.27	.606	.002
Design Aesthetics	5.05	1.18	3.76	1.24	4.43	1.38	4.35	1.37	0.97	.327	.005
Revisit	4.55	1.51	4.26	1.53	4.41	1.52	4.39	1.53	0.09	.768	.000
Recommendation	4.94	1.40	4.68	1.32	4.68	1.33	4.89	1.38	0.32	.570	.002
Engagement	0.92	4.82	-.74	4.46	1.15	3.89	-.73	5.09	0.46	.499	.003
Grade	7.25	1.12	6.67	1.34	7.09	1.14	6.85	1.35	0.15	.701	.001

Note. The construct engagement is the sum of six z-scored items. The construct grade was measured on a scale from 1 (very bad) to 10 (very good). All other constructs were measured on a 7-point Likert scale ranging from 1 (I totally disagree) to 7 (I totally agree).



CHAPTER 3

Effects of Providing Tailored Information About E-Cigarettes in a Web-Based Smoking Cessation Intervention: Protocol for a Randomized Controlled Trial

This chapter has been published as:

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Background: There is an ongoing debate whether electronic cigarettes (e-cigarettes) should be advocated for smoking cessation. Because of this uncertainty, information about the use of e-cigarettes for smoking cessation is usually not provided in governmental smoking cessation communications. However, there is an information need among smokers because despite this uncertainty, e-cigarettes are used by many smokers to reduce and quit tobacco smoking.

Objective: The aim of this study is to describe the protocol of a randomized controlled trial that assesses the effect of providing tailored information about e-cigarettes compared to not providing this information on determinants of decision making and smoking reduction and abstinence. This information is provided in the context of a digital smoking cessation intervention.

Methods: A randomized controlled trial with a 6-month follow-up period will be conducted among adult smokers motivated to quit smoking within 5 years. Participants will be 1:1 randomized into either the intervention condition or control condition. In this trial, which is grounded on the I-Change model, participants in both conditions will receive tailored feedback on attitude, social influence, preparatory plans, self-efficacy, and coping plans. Information on 6 clusters of smoking cessation methods (face-to-face counselling, eHealth interventions, telephone counselling, group-based programs, nicotine replacement therapy, and prescription medication) will be provided in both conditions. Smokers in the intervention condition will also receive detailed tailored information on e-cigarettes, while smokers in the control condition will not receive this information. The primary outcome measure will be the number of tobacco cigarettes smoked in the past 7 days. Secondary outcome measures will include 7-day point prevalence tobacco abstinence, 7-day point prevalence e-cigarette abstinence, and determinants of decision making (i.e., knowledge and attitude regarding e-cigarettes). All outcomes will be self-assessed through web-based questionnaires.

Results: This project is supported by a research grant of the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). Ethical approval was granted by the Ethics Review Committee Health, Medicine and Life Sciences at Maastricht University (FHML-REC/2019/072). Recruitment began in March 2020 and was completed by July 2020. We enrolled 492 smokers in this study. The results are expected to be published in June 2021.

Conclusion: The experimental design of this study allows conclusions to be formed regarding the effects of tailored information about e-cigarettes on decision making and smoking behavior. Our findings can inform the development of future smoking cessation interventions.

Abstract

INTRODUCTION

Background

Tobacco smoking is a major public health threat, contributing to increased morbidity and mortality (U.S. Department of Health and Human Services, 2014). In the Netherlands, tobacco smoking is responsible for more than 19,000 deaths per year (Rijksinstituut voor Volksgezondheid en Milieu, 2018). Many smokers report that they want to quit smoking, but only about 4% of smokers trying to quit without assistance succeed in their cessation attempts (Cohen et al., 1989; Hughes et al., 2004). Most smokers find it hard to quit smoking because of the highly addictive nature of nicotine (Benowitz, 2010), and while they smoke for the nicotine, their probability of dying prematurely increases owing to the by-products of burnt tobacco (e.g., tar) (Russell, 1976). In this paper, we will describe the study protocol for a randomized controlled trial assessing an intervention aimed at quitting combustible cigarette smoking and the potential added effects of providing tailored information on electronic cigarettes (e-cigarettes).

E-Cigarettes for smoking cessation

E-Cigarettes, also called as electronic nicotine delivery systems, are handheld electronic devices that generate aerosols by heating a liquid that usually contains nicotine, flavorings, and other compounds (Hartmann-Boyce et al., 2021). Because e-cigarettes do not burn tobacco, users are not exposed to the damaging substances of combustible tobacco (Hartmann-Boyce et al., 2021). However, it is important to note that, although e-cigarette aerosols generally contain fewer toxic chemicals than cigarette smoke, all tobacco (and related) products, including e-cigarettes, carry risks (U.S. Department of Health and Human Services, 2020). Smokers who want to quit smoking can use e-cigarettes as an aid for smoking reduction, cessation, and relapse prevention (Hartmann-Boyce et al., 2021; Notley et al., 2018). E-Cigarettes may be advantageous over nicotine replacement therapy because they are able to provide nicotine effectively and mimic the smoking experience (Dawkins & Corcoran, 2014). Using e-cigarettes for smoking cessation can be considered as a tobacco harm reduction strategy (Beaglehole et al., 2019). There is an ongoing debate whether e-cigarettes should be advocated for smoking cessation (Warner, 2019). A recent Cochrane systematic review concluded that the current evidence provides moderate certainty that e-cigarettes with nicotine are superior to e-cigarettes without nicotine and nicotine replacement therapy concerning smoking cessation (Hartmann-Boyce et al., 2021). Reviews on the effectiveness of using e-cigarettes for smoking cessation stress that more evidence is needed to be confident about the effects (Hartmann-Boyce et al., 2021; Leduc & Quoix, 2016; SCHEER Scientific Committee on Health, 2020; U.S. Department of Health and Human Services, 2020). Furthermore, e-cigarettes developed quickly in recent years and findings from studies conducted with past generations of e-cigarettes (e.g., cigalikes, battery pens) are not applicable to state-of-the-art e-cigarettes (e.g., pod mods) (U.S. Department of

Health and Human Services, 2020). Hence, more randomized controlled trials are needed to gain insight into the effectiveness of e-cigarettes for smoking cessation.

Information need on e-cigarettes

In line with this ongoing debate, e-cigarette users, smokers, and nonusers reported that they have unanswered questions regarding e-cigarettes (Romijnders et al., 2019). They raised questions about the harmfulness of e-cigarettes, especially compared to cigarette smoking, about the long-term health effects of e-cigarette use, and about e-cigarettes as a smoking cessation method. E-Cigarette users also report a lack of knowledge regarding the ingredients of e-cigarettes and its health effects (Coleman et al., 2016). Furthermore, incorrect risk perceptions regarding e-cigarette use and tobacco smoking are held by smokers. For instance, only half of the smokers believe that the use of e-cigarettes is less harmful than smoking tobacco (McNeill et al., 2018), and fruit or candy flavors in e-cigarettes are perceived as less risky compared to tobacco flavors (Romijnders et al., 2018). Thus, there is an information need regarding e-cigarettes, especially among smokers who may benefit from e-cigarettes as an aid in smoking cessation.

Decision making on e-cigarettes

Owing to the uncertainty surrounding e-cigarettes, it is important that smokers have sufficient knowledge about e-cigarettes when deciding whether to use them. An informed choice is often defined based on relevant knowledge and the congruence between attitudes and conducted behavior (Marteau et al., 2001). These conceptualizations of informed decision making employ cut-off points in order to dichotomize constructs into positive and negative outcomes (e.g., sufficient knowledge or not). These cut-off points are chosen arbitrarily, indicating that there is neither evidence for the choice of these cut-off points nor evidence that there is an underlying dichotomy at all (Altman & Royston, 2006). Furthermore, individuals who score values close to the cut-off points but on opposite sites (e.g., on a scale from 1-10, if 5 is considered to be the cut-off point, individuals who score values close to the cut-off point but on opposite sites would then for instance score 4.9 and 5.1) are categorized as being very different, while in reality being quite similar (Altman & Royston, 2006). In this research, we will avoid dichotomizing continuous variables by examining the constructs of decision making separately.

Research goal

The goal of this study will be to assess the effect of tailored communication about e-cigarettes in a digital smoking cessation intervention on determinants of decision making, smoking reduction, and smoking cessation. In the context of a tailored eHealth program, smokers will be randomized into 1 of the 2 conditions—either receiving detailed tailored information about e-cigarettes or not. Information provision about e-cigarettes can have differential effects on smoking behavior, including favorable effects (e.g., decreased number of tobacco cigarettes

smoked, increased number of tobacco-abstinent participants) as well as unfavorable effects (e.g., decreased number of tobacco-abstinent participants). Differences between conditions in the number of dual users (i.e., people using e-cigarettes and smoking tobacco cigarettes) will be examined as well. Regarding decision making, we hypothesize that participants in the intervention condition will have more knowledge about e-cigarettes directly after the intervention compared to participants in the control condition. We did not formulate a hypothesis for the determinant attitude as neither a more positive nor a more negative attitude is directly associated with improved decision making. Regarding smoking behavior, we hypothesize that participants in the intervention condition will have smoked less tobacco cigarettes (adjusted for baseline measurement) in the past 7 days at the 6-month follow-up compared to participants in the control condition.

METHOD

Study design

A randomized controlled trial will be conducted and the results will be reported according to the CONSORT-EHEALTH checklist (Eysenbach, 2011). Participants will be 1:1 randomized into either the intervention condition or the control condition. Participants in both conditions will receive the same underlying digital smoking cessation intervention. The 2 conditions differ in the provision of information about e-cigarettes. Smokers in the intervention condition will receive detailed tailored information on e-cigarettes whereas smokers in the control condition will not receive that information. Measurements will be conducted at 3 points in time. A baseline questionnaire will be conducted at the start of the intervention. A first follow-up questionnaire will be conducted directly after completion of the intervention (i.e., postintervention). A second follow-up questionnaire will be conducted at 6 months from the baseline. All questionnaires will be web-based and self-assessed. Figure 1 shows the study design.

Participants and recruitment

Inclusion criteria were that participants are at least 18 years old, have sufficient command of the Dutch language, have necessary internet literacy to use the intervention, have smoked tobacco in the past 7 days, and are motivated to quit tobacco smoking within 5 years. Participants were recruited using multiple strategies. A Dutch research agency was consulted in order to recruit smokers from their participant pool. Google Ads were used to recruit people who were searching the Google search engine for terms around smoking cessation. Social media and smoking-related forums were approached to recruit members of those channels. Moreover, flyers were distributed door-to-door in the Maastricht region, the Netherlands. Incentives were provided to participants who took part in the intervention and who answered all the questionnaires (baseline, postintervention, 6-month follow-up). Ten gift vouchers of €25 (US $1=€0.83) were raffled off among all participants who were recruited organically.

Participants stemming from the research agency collected points within the system of the research agency, which could be exchanged for gift vouchers or donations. Interested individuals were directed to an external intervention website. Potential participants were informed that they would receive tailored smoking cessation advice during the intervention. The nature of tailoring was explained to clarify that the advice will be based on the answers participants provide to the questions during the intervention. The aim of this study was stated as exploring the opinion of smokers on the intervention. E-Cigarettes were not mentioned in the participant information text. Potential participants were informed about the possibility to withdraw from the study at any time without providing any reason. Participants did not need to register on the intervention website in order to limit the participation burden. After giving web-based informed consent, the inclusion criteria were verified by a short questionnaire. The intervention would take about 20 minutes (including the baseline and postintervention questionnaire). Answering the 6-month follow-up questionnaire will take about 3 minutes.

Sample size calculation

The sample size was calculated using the ufs package (Peters, 2019) in R. Acknowledging that the accurate estimation of effect sizes is more important than relying on *p* values, we based our sample size calculation on accuracy in parameter estimation for Cohen *d* (Peters & Crutzen, 2020). Unfortunately, we cannot infer the effect size from earlier research since we are not aware of any prior studies assessing the influence of providing information about e-cigarettes in a digital intervention on decision making and smoking cessation. Thus, we assumed a small effect size as it is usually found in digital health research on smoking cessation interventions (Taylor et al., 2017). Taking into account the small effect size of Cohen *d* of 0.2, a margin of error (half-width) of 0.15, and a confidence level of 95%, a total sample size of 687 participants is required.

Intervention

The intervention will be a digital computer-tailored smoking cessation intervention that will be partly based on an earlier developed intervention at Maastricht University (Stanczyk et al., 2011; Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016). Compared to generic information, computer-tailored interventions provide highly individualized information that is tailored to the motivational and behavioral characteristics of the recipient (de Vries & Brug, 1999). According to the elaboration likelihood model, information that is perceived as personally relevant is expected to lead to more in-depth processing and, in turn, to more sustained attitudinal and behavioral changes (Petty & Cacioppo, 1986). The computer-tailored intervention will be based on the I-Change model (Cheung et al., 2020; de Vries, 2017), a comprehensive model that integrates various social-cognitive theories (see Figure 2). During the intervention, participants in both conditions will receive tailored advice on the pros and cons of quitting smoking (i.e., attitude), social influence, preparatory plans, self-efficacy, and coping plans concerning smoking cessation. Participants will be able to decide

based on their own interests and needs on which determinants of smoking cessation they would like to receive tailored advice. The information for the tailoring process is gathered by means of questionnaires that the recipient has to fill in during the intervention. Subsequently, a computerized process, employing if-then rules, selects appropriate feedback messages from a pool of all messages based on the answers that the recipient has given in the questionnaires (de Vries & Brug, 1999; Lustria et al., 2009).

The items of the questionnaires are based on previous research (Elling & de Vries, 2021; Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016) and are reported in Appendix A. The pros and cons of quitting smoking (e.g., "If I stop smoking, my physical fitness will improve") will be assessed by 16 items. Social influence will consist of 2 components with 2 items each: social modeling (e.g., "Does your partner smoke?") and social support (e.g., "Does your partner support you when you decide to quit smoking?"). Figure 3 illustrates an example of tailored advice for social support. Preparatory plans (e.g., "I am planning to stop smoking completely without cutting down on cigarettes first") will be assessed by 5 items. Self-efficacy (e.g., "I find it difficult not to smoke if I am stressed") will be assessed by 11 items. Coping plans (e.g., "I have made clear plans to make sure that I will not smoke if I am stressed") will be assessed by 11 items, reflecting the same situations as assessed for self-efficacy. After answering and receiving information on the determinants of smoking cessation, participants in both conditions will be able to indicate about which 6 clusters of smoking cessation methods they want to receive information (face-to-face counselling, eHealth interventions, telephone counselling, group-based programs, nicotine replacement therapy, and prescription medication).

All advices concerning the pros and cons of quitting smoking, social influence, preparatory plans, self-efficacy, and coping plans will be presented in the form of spoken animations with little on-screen text in order to increase user experience and user engagement (Elling & de Vries, 2021; van het Schip et al., 2020). A screenshot of an example of a webpage of the intervention with an animation is shown in Figure 4. All texts will be written in simple language and no hyperlinks to other resources will be presented. The website will be developed employing responsive web design and will thus be accessible on all common devices (e.g., computer, smartphone) with all types of screen sizes. A second screenshot of a typical webpage presenting 2 questions of the tailoring process is shown in Figure 5.

Tailored information on e-cigarettes

Participants in the intervention condition will receive tailored information on e-cigarettes based on 5 items (Do you know what an e-cigarette is? How harmful do you think e-cigarettes are compared to tobacco cigarettes? Do you think e-cigarettes are helpful in quitting smoking? Do you think using e-cigarettes is difficult or easy? Have you seen reports in the media about illnesses and deaths in the United States related to the use of e-cigarettes?). These items

were developed by the research team and evaluated for comprehensibility and clarity by a communication expert of the National Institute for Public Health and the Environment. In general, the information will convey the message that, for smokers, the use of e-cigarettes is less harmful than continuing smoking tobacco cigarettes. However, it will be highlighted that this does not mean that using e-cigarettes is harmless. Regarding smoking cessation, it will be stressed that e-cigarettes are especially interesting for smokers who have tried to quit several times but have not succeeded. The possibility to (gradually) decrease the nicotine content of the e-cigarette liquid in order to cope with nicotine withdrawal symptoms will be discussed. The outbreak of lung injury associated with e-cigarette use in the United States of America will be discussed in detail. Participants in the control condition will receive a short text explaining that e-cigarettes are not actively recommended for smoking cessation ("A rather recent method that can be used to quit smoking is the e-cigarette. There is still a lot of uncertainty surrounding the e-cigarette. The e-cigarette is therefore not actively recommended as a method to quit smoking in the Netherlands."). This short text is aimed to resemble the status quo of communication on e-cigarettes in smoking cessation interventions in the Netherlands.

Measures

All items of the baseline questionnaire, postintervention questionnaire, and 6-month follow-up questionnaire are reported in Appendix B.

Smoking reduction and abstinence

The primary outcome of this study will be the number of tobacco cigarettes smoked in the past 7 days (Ramo et al., 2015). Secondary outcomes will be the average number of tobacco cigarettes smoked per day (Bommelé et al., 2017), 7-day point prevalence tobacco abstinence (Cheung, de Ruijter, et al., 2017), and 7-day point prevalence e-cigarette abstinence (Cheung, de Ruijter, et al., 2017). If participants indicate to have used an e-cigarette, the nicotine content of the e-cigarette will be assessed. All outcomes will be assessed at baseline and at 6-month follow-up.

Smoking cessation methods

The *intention to use a smoking cessation method* (split-up per method) will be assessed directly after the intervention on a 5-point Likert scale ranging from 1=definitely do not to 5=definitely do. At the 6-month follow-up, we will assess which smoking cessation methods were actually utilized (i.e., *smoking cessation method chosen*) on a dichotomous scale (yes/no). The following methods will be assessed: face-to-face counselling, eHealth interventions, telephone counselling, group-based programs, nicotine replacement therapy, prescription medication, and e-cigarettes. Participants can also indicate to have used another smoking cessation method or to not have used any smoking cessation method at all.

Determinants of decision making

Determinants of decision making will be assessed by 2 constructs: knowledge and attitude. Knowledge about e-cigarettes (e.g., There are less harmful substances in e-cigarettes compared to tobacco cigarettes) will be measured by 7 items with response options being 1=True, 2=False, and 3=I do not know. Correct answers will be coded as 1 and incorrect answers and the option I do not know as 0. The sum of the correct answers is the overall score for the construct knowledge. Attitude on e-cigarettes (e.g., I think that using e-cigarettes is better for my health than smoking cigarettes) will be measured by 10 items on a 5-point Likert scale ranging from 1=I totally disagree to 5=I totally agree. All items will be assessed directly after the intervention.

Process evaluation

A process evaluation will be conducted by assessing an *overall grade* for the intervention (Stanczyk, Bolman, et al., 2014), asking open questions about positive and negative aspects of the intervention, and by analyzing system usage data (Stanczyk, Bolman, et al., 2014). An *overall grade* will be measured by 1 item on a scale ranging from 1=very bad to 10=very good. The open questions (e.g., What do you like about the intervention?) will be asked to capture aspects that are perceived as both positively and negatively. The overall grade and the open questions will be assessed directly after the intervention. The time spent on the intervention website and the device (e.g., smartphone, tablet, desktop) of the users will be measured using the TailorBuilder software (OverNite Software Europe BV). The time spent on the website will be provided per condition, whereas the device used will be reported for all participants together.

Demographics and smoking characteristics

We will assess the demographics by asking for *gender* (0=male, 1=female, 3=not on the list), *age*, and *education level* (1=low, 2=intermediate, 3=high). *Addiction level* will be assessed by the Fagerström Test for Nicotine Dependence (Heatherton et al., 1991). The 6 items of the scale will be summed into an overall score ranging from 0 to 10. We will classify the dependence level as 0-2=low, 3-4=moderate, 5-6=strong, and 7-10=very strong. Addiction level will be measured at baseline. The *intention to quit smoking* will be assessed by 2 items. First, participants will be asked when they are planning to quit smoking (1=within 1 month, 2=within 6 months, 3=within 1 year, 4=within 5 years) (Dijkstra et al., 1996). Second, participants will be asked to indicate whether they are planning to quit smoking within 1 year on a 5-point Likert scale ranging from 1=definitely do not to 5=definitely do. The intention to quit smoking will be measured at baseline and after the intervention for every participant and at 6-month follow-up for participants who indicated that smoking cessation was not successful.

COVID-19 pandemic and smoking behavior

The COVID-19 pandemic coincides with the recruitment and follow-up period of this research project. Participants are influenced by the pandemic in numerous ways, including the information that tobacco smoking may increase susceptibility to and severity of COVID-19 (Elling et al., 2020). Thus, we included 15 items about smoking-related beliefs and behavior in times of COVID-19. These items are reported in Appendix C.

Analyses

The focus of all the analyses will be on the effect size accompanied by the confidence interval (Thompson, 2002). Multiple imputations will be conducted to account for the missing observations at 6-month follow-ups. Sensitivity analyses will be conducted for complete cases and intention-to-treat (Blankers et al., 2015). The primary outcome (number of tobacco cigarettes smoked in past 7 days) will be tested by analysis of covariance (O'Connell et al., 2017; van Breukelen, 2006). The dependent variable will be the number of tobacco cigarettes smoked weekly at the 6-month follow-up. The number of tobacco cigarettes smoked weekly at baseline will be included as the covariate. The independent variable will be the condition. The average number of tobacco cigarettes smoked per day will be tested similarly. Logistic regression analyses will be performed to assess the effect of the intervention condition and control condition on 7-day point prevalence tobacco abstinence and 7-day point prevalence e-cigarette abstinence. Analyses of variance will be performed to test for differences in the determinants of decision making (knowledge and attitude on e-cigarettes) between conditions. Addiction level will be included as a covariate in additional sensitivity analyses. Previous research suggests that the addiction level needs to be considered when assessing the effectiveness of e-cigarettes for smoking reduction and cessation (Selya et al., 2018). The open questions will be analyzed per question. Codes for recurrent themes will be created and reported in a table with example quotes and the number of times a theme was addressed.

RESULTS

The study is registered in the Netherlands Trial Register (Trial 8330). Ethical approval was granted by the Ethics Review Committee Health, Medicine and Life Sciences (FHML-REC) at Maastricht University (FHML-REC/2019/072). This project is supported by a research grant of the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). Recruitment began in March 2020 and was completed by July 2020. We enrolled 492 smokers in this study. The results are expected to be published in June 2021.

DISCUSSION

Governmental public health institutes inform the public about smoking cessation. Usually, only information on the *best* option to quit smoking is provided, which is complete smoking cessation using evidence-based smoking cessation methods. Smokers may not follow this advice and they may do nothing about cessation, thereby making it the *worst* option. Smokers may also seek alternative advices for the *second best* option, which can be using e-cigarettes for smoking reduction and cessation. However, information about e-cigarettes is mostly not included in governmental smoking cessation interventions. Including information on e-cigarettes in smoking cessation interventions can yield different effects, which can be both favorable and detrimental to smokers specifically and public health in general. On the one hand, communication about e-cigarettes could lead to more people quitting smoking with the help of e-cigarettes, thereby reducing the number of people choosing the worst option. On the other hand, communication about e-cigarettes could lead to more people choosing the second best option who would otherwise have chosen the best option. This protocol describes a randomized controlled trial that aims to investigate the effects of including tailored information about e-cigarettes on decision making and smoking behavior. These findings can inform the development of future smoking cessation interventions, in particular, and communication about the second best option, in general.

APPENDIX A – DETERMINANTS OF SMOKING CESSATION TACKLED IN THE INTERVENTION

Attitude (Pros)

1. Improvement of physical fitness
2. Being an example to others
3. Improvement of health
4. Feeling more attractive
5. Being proud
6. Health of others
7. Saving money
8. Causing less nuisance to others

Attitude (Cons)

1. Difficulties relaxing
2. Gaining weight
3. Being bored more often
4. Feeling gloomy
5. Feeling insecure
6. Feeling stressed
7. Being less sociable
8. Getting withdrawal symptoms

Social influence (Social modeling & social support)

Does … smoke? & Does … support you if you decide to quit smoking?

1 Smoking behavior of partner
2 Smoking behavior of people in the social environment

Preparatory plans

I am planning…

1 …to stop completely without cutting down on cigarettes first
2 …to dispose all smoking related things from my house
3 …to ask my guests to not smoke in my presence
4 …to tell others that I will stop smoking

Self-efficacy & Coping plans

I find it difficult not to smoke… & I have made plans to make sure that I will not smoke…

1 …if I am stressed
2 …if I am mad
3 …if I am sad
4 …if somebody offers me a cigarette
5 …if I see somebody enjoying a cigarette
6 …if I am at a party
7 …if I am drinking tea or coffee
8 …after I have eaten
9 …if I am having a break
10 …if I get up in the morning
11 …if I feel like needing a cigarette

APPENDIX B – ITEMS OF THE BASELINE, POST INTERVENTION, AND 6-MONTH FOLLOW-UP QUESTIONNAIRES

Baseline Questionnaire				
Part	**Title**	**Question**	**Answer options**	**Coding**
Informed Consent	Informed Consent	Do you want to participate?	[Yes, I want to participate and I give Maastricht University permission to use my data for scientific research] [No, I do not give Maastricht University permission to use my data for scientific research and therefore do not participate in the study]	(1) (2)
Inclusion criteria	Age	What is your age in years?	<age>	
	7-day tobacco PPA	Have you smoked in the past 7 days?	[yes] [no]	(1) (2)
	Motivation to quit	Do you want to quit smoking within 5 years?	[yes] [no]	(1) (2)
	E-Mail	What is your e-mail address? We need it to send you an invitation for a second questionnaire after 6 months.	Free text input	
Demographics	Gender	What is your gender?	[man] [woman] [not on the list]	(1) (2) (3)
	Education level	What is your highest completed education?	[Primary education, vmbo, havo-onderbouw, wvo-onderbouw, mbo1] [Havo, vwo, mbo] [Hbo-, wo-bachelor/master]	(1) (2) (3)
Source	Source	How did you end up on this website?	[Google] [Facebook] [Flycatcher] [Heard from family, friends, colleagues] [Flyer] [Anders]	(1) (2) (3) (4) (5) (6)
Experience	Participated in interventi-on before	Have you participated in an online smoking cessation program before?	[yes] [no]	(1) (2)
	Pop-up when people tick “Yes”			
	Name program	Which program did you participate in?	Free text input	
Addiction level	Fagerström 1	How soon after you wake up do you smoke your first cigarette?	[Within 5 minutes] [6 to 30 minutes] [31 to 60 minutes] [After 60 minutes]	(3) (2) (1) (0)
	Fagerström 2	Do you find it difficult to refrain from smoking in places where it is forbidden (e.g., in church, at the library, in the cinema)?	[yes] [no]	(1) (0)
	Fagerström 3	Which cigarette would you hate most to give up?	[The first one in the morning] [Any other]	(1) (0)

	Fagerström 5	Do you smoke more frequently during the first hours after waking than during the rest of the day?	[During the first hours] [During the rest of the day]	(1) (0)
	Fagerström 6	Do you smoke when you are so ill that you are in bed most of the day?	[yes] [no]	(1) (0)
Smoking behavior	Number of tobacco cigarettes smoked per day	How many regular cigarettes and/or roll-your-own cigarettes do you smoke on average per day?	<number>	
	Number of tobacco cigarettes smoked in the past 7 days	How many regular cigarettes and/or roll-your-own cigarettes have you smoked in the past 7 days?	<number>	
	7-day e-cigarette PPA	Have you used an e-cigarette in the past 7 days?	[yes] [no]	(1) (2)
	Pop-up when people tick “Yes”			
	Nicotine	Have you mainly used a liquid with or without nicotine?	[With nicotine] [Without nicotine] [I do not know]	(1) (2) (3)
Intention to quit smoking	TTM	When do you want to stop smoking? Choose the option that applies most to you.	[Within 1 month] [Within 6 months] [Within 1 year] [Within 5 years]	(1) (2) (3) (4)
	TPB	Are you planning to quit smoking within 1 year?	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
Quit attempts	Quit attempts	Have you tried to quit smoking in the past year?	[yes] [no]	(1) (2)

Post Intervention Questionnaire				
Part	**Title**	**Question**	**Answer options**	**Coding**
Intention to quit smoking	TTM	You may have changed your mind about quitting smoking after using this program. That is why we ask you again when you want to stop smoking? Choose the option that applies most to you.	[Within 1 month] [Within 6 months] [Within 1 year] [Within 5 years]	(1) (2) (3) (4)
	TPB	Are you planning to quit smoking within 1 year?	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
	Intention to use specific smoking cessation method	Are you planning to use the following smoking cessation methods?		
		Face-to-face counselling	[Nee, zeker niet] [Nee, niet] [Misschien] [Ja, wel] [Ja, zeker wel]	(1) (2) (3) (4) (5)
		eHealth intervention	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		Telephone counselling	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		Group-based program	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		E-cigarette (mainly with nicotine)	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		E-cigarette (mainly without nicotine)	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		Nicotine replacement therapy	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		Prescription medication	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)
		Another cessation method, namely...		
Knowledge	Knowledge regarding e-cigarettes	In your opinion, are the following statements false or true?		
		E-cigarettes contain tobacco (R)	[False] [I do not know] [True]	(1) (2) (3)
		E-cigarettes contain less harmful substances than regular cigarettes	[False] [I do not know] [True]	(1) (2) (3)

		E-cigarettes with nicotine are addictive	[False] [I do not know] [True]	(1) (2) (3)
		The vapor of e-cigarettes consists only of water (R)	[False] [I do not know] [True]	(1) (2) (3)
		The use of e-cigarettes can cause irritation and damage to the respiratory tract	[False] [I do not know] [True]	(1) (2) (3)
		For smokers, the use of e-cigarettes is less harmful than continuing to smoke	[False] [I do not know] [True]	(1) (2) (3)
		The long-term effects of the use of e-cigarettes have not been sufficiently researched	[False] [I do not know] [True]	(1) (2) (3)
Attitude	Attitude toward substituting e-cigarettes for cigarettes	To what extent do you agree with the following statements?		
		I think that it is wise to use e-cigarettes instead of smoking regular cigarettes	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that the use of e-cigarettes is better for my health than smoking regular cigarettes	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that the use of e-cigarettes is better for the health of the people around me than smoking regular cigarettes	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
	Attitude toward e-cigarettes for smoking reduction and cessation	To what extent do you agree with the following statements?		
		I think that e-cigarettes can help me to smoke less	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that e-cigarettes can help me to quit smoking	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that the use of e-cigarettes increases my chances of successfully quitting smoking	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
	Attitude toward e-cigarettes in general	To what extent do you agree with the following statements?		
		I think that e-cigarettes can help me to quench my cravings for regular cigarettes	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)

		I think that e-cigarettes taste good	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that e-cigarettes are easy to use	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I think that I smell less like smoke when I use e-cigarettes instead of regular cigarettes	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
Process evaluation	Overall grade	What is the overall grade you would give to the online program? (where 10 is the best)	<number>	1-10
	Positive aspects	What did you like about the online program?	Free text input	
	Negative aspects	What did you dislike about the online program?	Free text input	

6-Month Follow-up Questionnaire				
Part	**Title**	**Question**	**Answer options**	**Coding**
Smoking cessation	Quit attempt	Since you participated in the study (6 months ago), have you seriously tried to quit smoking (at least 24 hours without smoking a regular cigarette and/or roll-your-own cigarette)?	[yes] [no]	(1) (2)
	Pop-up if participants tick "Yes"			
	Number of quit attempts	How many times have you seriously tried to quit smoking since you took part in the study (at least 24 hours without smoking a regular cigarette and/or roll-your-own cigarette)?	<number>	
	24-hour tobacco PPA	Have you smoked one or more regular cigarettes and/or roll-your-own cigarettes in the last 24 hours?	[yes] [no]	(1) (2)
	7-day tobacco PPA	Have you smoked one or more regular cigarettes and/or roll-your-own cigarettes in the past 7 days?	[yes] [no]	(1) (2)
	Pop-up question if participants tick "Yes", otherwise automatically #cigarettes = 0			
	Average number of tobacco cigarettes smoked per day	How many regular cigarettes and/or roll-your-own cigarettes have you smoked on average per day?	<number>	
	Number of tobacco cigarettes smoked in the past 7 days	How many regular cigarettes and/or roll-your-own cigarettes have you smoked in the past 7 days?	<number>	
	If participants still smoke (7-day tobacco PPA) but have tried to quit (quit attempt)			
	Time to first relapse	How many days after you seriously tried to quit smoking for the first time have you smoked on 7 consecutive days?	<number>	
	7-day e-cigarette PPA	Have you used an e-cigarette in the past 7 days?	[yes] [no]	(1) (2)
	If participants have used an e-cigarette			
	Frequency	How often have you used an e-cigarette in the past 7 days?	[Every day] [Several times] [Once]	(1) (2) (3)
	Nicotine	Have you mainly used a liquid with or without nicotine?	[With nicotine] [Without nicotine] [I do not know]	(1) (2) (3)
Intention to quit smoking	*Only when people are still smoking (7-day tobacco PPA)*			
	TTM	When do you want to quit smoking? Choose the option that applies most to you.	[Within 1 month] [Within 6 months] [Within 1 year] [Within 5 years] [I don't want to quit smoking anymore]	(1) (2) (3) (4) (5)
	TPB	Are you planning to quit smoking within 1 year?	[No, definitely not] No, probably not] [Maybe] [Yes, probably] [Yes, definitely]	(1) (2) (3) (4) (5)

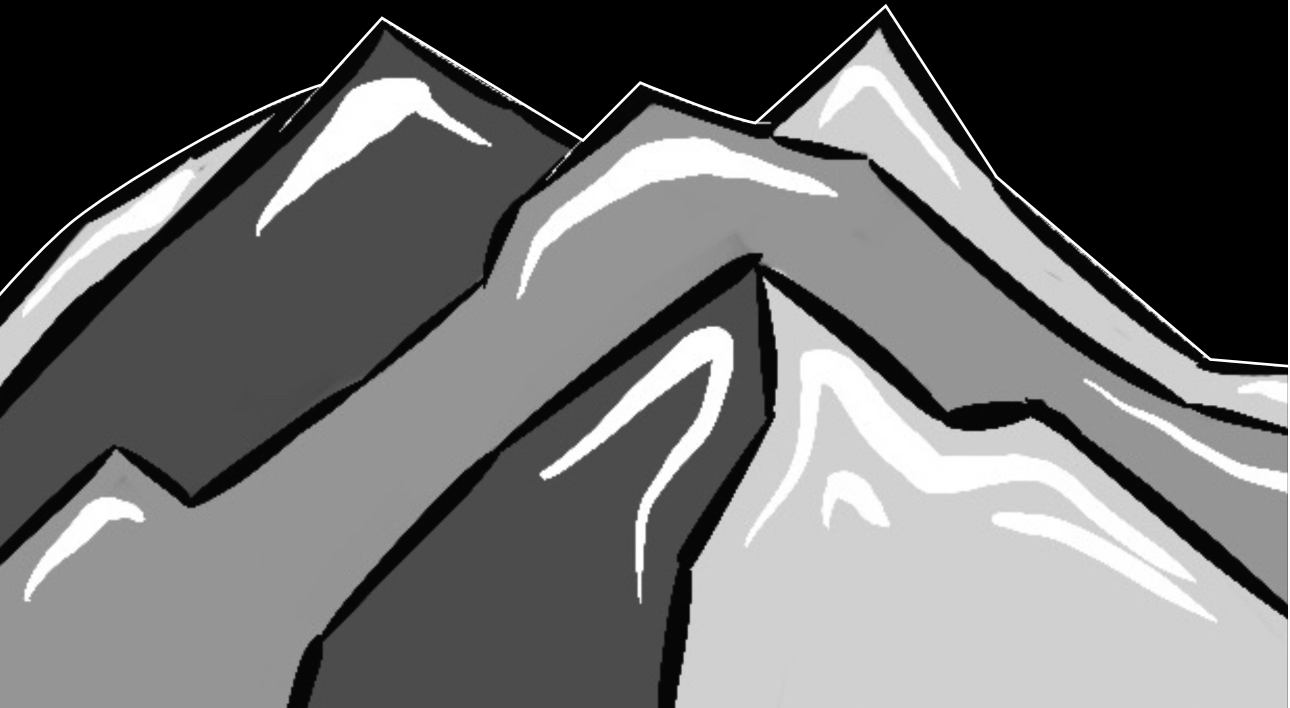
Smoking cessation methods chosen	Smoking cessation methods chosen	Which smoking cessation methods did you use?		
		Face-to-face counselling	[yes] [no]	(1) (2)
		eHealth intervention	[yes] [no]	(1) (2)
		Telephone counselling	[yes] [no]	(1) (2)
		Group-based program	[yes] [no]	(1) (2)
		E-cigarette	[yes] [no]	(1) (2)
		Nicotine replacement therapy	[yes] [no]	(1) (2)
		Prescription medication	[yes] [no]	(1) (2)
		Another smoking cessation method, namely…	Free text input	
E-cigarette	*Only if people have used an e-cigarette*			
	Nicotine	Have you mainly used a liquid with or without nicotine?	[With nicotine] [Without nicotine] [I do not know]	(1) (2) (3)
		To what extent do you agree with the following statement? I have tried to reduce my nicotine addiction by using less and less nicotine in the liquid.	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
	Experience	To what extent do you agree with the following statements?		
		The e-cigarette helped me to quit smoking	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		I would recommend the e-cigarette to a friend who wants to quit smoking	[Strongly disagree] [Disagree] [Neither agree nor disagree] [Agree] [Strongly agree]	(1) (2) (3) (4) (5)
		What did you like about the e-cigarette?	Free text input	
		What did you dislike about the e-cigarette?	Free text input	

APPENDIX C – QUESTIONNAIRE ITEMS ABOUT SMOKING RELATED BELIEFS AND BEHAVIOR IN TIMES OF COVID-19

Items 1-11 will be measured at baseline. Items 1-10 will be measured on a 5-point Likert scale ranging from 1= 'Strongly disagree' to 5= 'Strongly agree'. Item 11 will be measured with response options being 1= 'Less cigarettes', 2= 'Unchanged', and 3= 'More cigarettes'. For response options 1 and 3, the exact number of cigarettes smoked less or more will be measured as well.

Items 12-15 will be measured at 6-month follow-up. Item 12, 13, 15 will be measured on a 5-point Likert scale ranging from 1= 'Strongly disagree' to 5= 'Strongly agree'. Item 14 will be measured with response options being 1= 'Less cigarettes', 2= 'Unchanged', and 3= 'More cigarettes'.

1. The coronavirus is a serious threat to my health
2. Compared to non-smokers, I have a higher risk of getting severe complaints from the coronavirus
3. The chances that I will get the coronavirus are high
4. Compared to non-smokers, the chances are higher that I will get the coronavirus
5. If I stop smoking, I reduce the chances of serious complaints due to the coronavirus
6. My environment thinks that I should quit smoking because of the coronavirus
7. Since the coronavirus outbreak, I experience more stress in my daily life
8. Because of the coronavirus, I find it hard to quit smoking
9. Because of the coronavirus, I am now more motivated to make plans to quit smoking
10. Because of the coronavirus, I am now more motivated to quit smoking
11. Because of the coronavirus, I now smoke more/less a day
12. I stopped smoking (mainly) because of the coronavirus
13. I had stopped smoking but I started again (mainly) because of the coronavirus
14. Because of the coronavirus, I now smoke more/less a day
15. I started using an e-cigarette because of the coronavirus



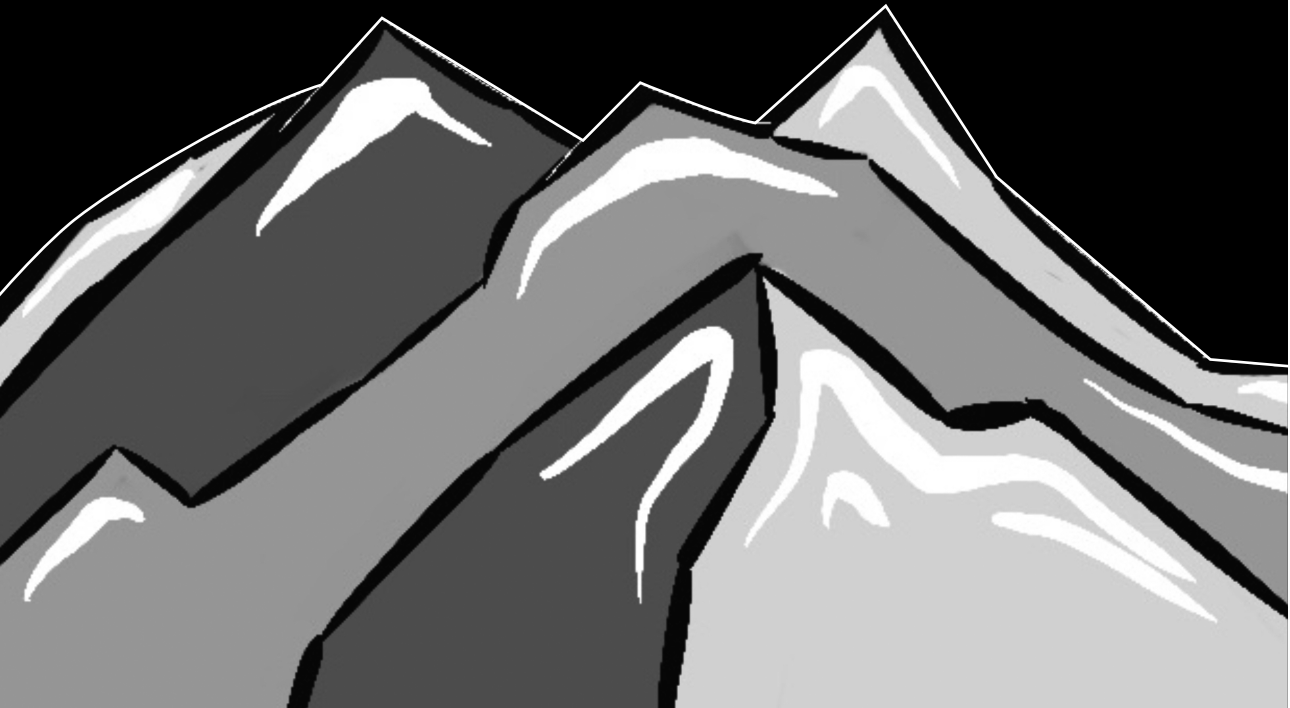
CHAPTER 4

Effects of Providing Tailored Information about E-Cigarettes in a Digital Smoking Cessation Intervention: Randomized Controlled Trial

This chapter is under review:

Elling, J. M., Crutzen, R., Talhout, R., & de Vries, H.

Effects of Providing Tailored Information about E-Cigarettes in a Digital Smoking Cessation Intervention: Randomized Controlled Trial.



CHAPTER 5

Tobacco Smoking and Smoking Cessation in Times of COVID-19

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Tobacco Smoking and Smoking Cessation in Times of COVID-19.
Tobacco Prevention & Cessation, 6.
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Abstract

Introduction: Tobacco smoking may increase susceptibility to and severity of coronavirus disease 2019 (COVID-19). This information may influence smoking cessation related beliefs in smokers.

Methods: Online questionnaires were answered from 26 March to 3 April 2020 in the Netherlands by 340 smokers willing to quit smoking. Beliefs regarding (quitting) smoking and (consequences of) the coronavirus are described and associations with motivation to quit due to the coronavirus are reported.

Results: While 67.7% of the smokers indicated that the coronavirus did not influence the number of cigarettes smoked per day, 18.5% smoked less cigarettes and 13.8% smoked more cigarettes per day due to the coronavirus. One third of the smokers were more motivated to quit smoking due to the coronavirus. Motivation to quit due to the coronavirus was positively associated with beliefs about the coronavirus as a serious threat, being at high risk of catching the coronavirus and developing severe illness, smokers being at higher risk than non-smokers, quitting smoking reducing complaints, the social environment endorsing quitting, and perceived stress.

Conclusion: Subgroups of smokers may be receptive to smoking cessation advice due to COVID-19. Because of the measures taken to slow the spread of the virus (e.g., stay at home as much as possible), personalized digital health interventions may be particularly suitable to reach smokers at home.

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a respiratory infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as coronavirus. The COVID-19 pandemic has determined daily life in most countries in the past weeks/months and there is no end in sight yet.

The current situation may influence (beliefs about) smoking behavior. Smokers may smoke more tobacco because of higher stress levels due to the crisis situation (Kassel et al., 2003). Yet, smokers may also perceive increased susceptibility to and severity of COVID-19, potentially increasing motivation to quit.

The coronavirus may pose an additional threat to smokers. First, the hand-to-mouth movement while smoking can facilitate viral infection. Public health measures strongly advise to avoid touching eyes, nose, and mouth, since hands can transfer the virus to the face and from there enter the body. Second, tobacco smoke damages the lungs of the smoker and compromises the immune system resulting in an increased risk for respiratory infections and negative disease progressions (Arcavi & Benowitz, 2004).

There is distinct evidence that smoking status is associated with severity and mortality of COVID-19. A recent meta-analysis revealed that current smoking increases the risk of severe COVID-19 by around twofold (pooled *OR* 1.98, 95% *CI* 1.29–3.05) (Zhao et al., 2020). Mehra et al. (2020) evaluated the relationship of smoking status and in-hospital mortality among 8910 hospitalized COVID-19 patients. Current smoking status was found to be independently associated with an increased risk of death (*OR* 1.79, 95% *CI* 1.29–2.47) (Mehra et al., 2020).

Smokers may be influenced by (news) reports on these findings about the link between smoking and COVID-19. Therefore, this study describes Dutch smokers' perceptions regarding susceptibility to and severity of COVID-19 and its effect on smoking behavior (i.e., number of cigarettes smoked) and difficulty to quit smoking. Associations between beliefs and motivation to quit due to the (consequences of) the coronavirus are reported. As there may be gender differences in psychological responses to crises, differences in beliefs between men and women are also described (Lachlan et al., 2010).

METHOD

From 26 March to 3 April 2020, a questionnaire was distributed to smokers willing to quit smoking. Inclusion criteria were that participants were at least 18 years old, have smoked cigarettes in the past 7 days, and were motivated to quit smoking within 5 years. The sample

was provided by Flycatcher, a Dutch ISO certified internet research agency with more than 10,000 voluntary members. In return for full participation, panel members received a lottery ticket and points, which can be redeemed for gift vouchers. Informed consent was obtained online. The questionnaire was part of an overarching project on digital smoking cessation interventions for which ethical approval was granted by the institutional ethical review committee (FHML-REC/2019/072). Potential participants were selected for invitation based on the inclusion criteria. Flycatcher sent an invitation e-mail to 463 members of their panel, of which $N = 340$ completed the questionnaire (response rate: 73%).

The I-Change model, aimed at explaining motivational and behavioral change by integrating various social-cognitive theories, served as a theoretical framework for the beliefs about smoking and the coronavirus and covered risk perception, attitude, social norms, self-efficacy, and action planning (Figure 1) (de Vries, 2017). All items were measured on a 5-point Likert scale ranging from 1=”Strongly disagree” to 5=”Strongly agree”. Means and 99.99% confidence intervals for the beliefs were calculated and are reported as diamonds in the left-hand panel of Figure 1.

Correlations between the individual items and motivation to quit (MTQ) due to (consequences of) the coronavirus were calculated. MTQ due to the coronavirus (i.e., “Because of the coronavirus, I’m now more motivated to quit smoking”) was measured on a 5-point Likert scale ranging from 1=”Strongly disagree” to 5=”Strongly agree”. The association strength is reported in the right-hand panel of Figure 1. The diamonds visualize the correlation coefficients with 95% confidence intervals. The confidence interval-based estimation of relevance (CIBER) approach was employed to visualize the results (Crutzen et al., 2017). The tool is part of the “userfriendlyscience” package (Peters, 2019) for the statistical computing environment R.

Furthermore, changes in smoking behavior due to the coronavirus (i.e., “Because of the coronavirus, I now smoke more/less a day”) were measured with response options being 1=”Less cigarettes”, 2=”Unchanged”, and 3=”More cigarettes”. For response options 1 and 3, the exact number of cigarettes smoked less or more was measured as well.

Demographics were assessed by age, gender, and education level (low, intermediate, high). Cigarette dependence was assessed by the Fagerström Test (Heatherton et al., 1991). The six items of the scale were summed into an overall score ranging from 0 to 10. Willingness to quit smoking was assessed by asking participants when they are planning to quit smoking (within 1 month, within 6 months, within 1 year, within 5 years).

RESULTS

Sample characteristics

The mean age of participants was 49 years (*SD* = 13; range = 21-80) and the majority was female (60.9%). Of the participants, 21.8% had a low level of highest completed education (i.e., no education or primary education), 42.6% an intermediate level (i.e., secondary education), and 35.6% a high level (i.e., tertiary education). The mean cigarette dependence was moderate (*M* = 3.8, *SD* = 2.5). Participants smoked an average of 88.8 (*SD* = 67.9) cigarettes in the past 7 days. Sixty-three participants (18.5%) were willing to quit within 1 month, 124 (36.5%) were willing to quit within 6 months, 91 (26.8%) were willing to quit within 1 year and 62 (18.2%) were willing to quit within 5 years.

Smoking and the coronavirus

Of the participants, 33.8% were more motivated to quit smoking because of the coronavirus and 66.2% were not more motivated to quit due to the coronavirus. Of our sample, 18.5% indicated that they smoke less cigarettes due to the coronavirus (*M* = 4.1 cigarettes/day, *SD* = 3.3), 13.8% indicated that they smoke more cigarettes (*M* = 7.3 cigarettes/day, *SD* = 8.2), and 67,7% did not alter the number of cigarettes.

The CIBER analyses (Figure 1) reveal that MTQ due to the coronavirus was positively associated with beliefs about the coronavirus as a serious threat, being at high risk of catching the coronavirus and developing severe illness, smokers being at higher risk than non-smokers, quitting smoking reducing complaints, the social environment endorsing quitting, and perceived stress. All beliefs reported in Figure 1, except for self-efficacy ("Because of the coronavirus, I find it hard to quit smoking"), were significantly ($p < .01$) positively associated with MTQ due to the coronavirus. These items together explained 66% – 77% of the variance in MTQ due to coronavirus. Analysis of variance also confirmed that smokers motivated to quit were significantly ($p < .01$) more convinced of all these items than smokers not motivated to quit.

Differences in beliefs about smoking and the coronavirus between men and women

Men and women differed statistically significant on two items. Women compared to men indicated that they experience more stress in their daily life because of the coronavirus ($F_{1,338} = 11.94$, $p < .001$, $\eta_p^2 = .034$, 95% *CI* .006–.080) and that they find it more difficult to quit smoking because of the coronavirus ($F_{1,338} = 11.47$, $p < .001$, $\eta_p^2 = .033$, 95% *CI* .006–.078).

DISCUSSION

One third of our smokers were more motivated to quit smoking due to the coronavirus. Our results reveal which beliefs may be especially important to incorporate in smoking cessation interventions in times of COVID-19, such as the risks of being a smoker, and support from their social environment.

Since people are advised to stay at home in many countries to slow the spread of the coronavirus, digital health smoking cessation interventions form an effective way to reach smokers (Cheung, Wijnen, et al., 2017). In order to reach as many smokers as possible and slow the spread of the coronavirus, we advocate evidence-based (digital health) interventions that are easily accessible for all citizens and include the latest evidence about the relation between smoking and COVID-19.

A limitation of this study is that we included all smokers willing to quit smoking within 5 years. Thus, the sample consists of smokers highly motivated to quit and smokers less motivated to quit. Inclusion criteria of only smokers who are contemplating or preparing to quit may lead to different results.

Conclusion

The results of the present study provide evidence that perceiving the coronavirus as a serious threat and acknowledging that smokers are at higher risks than non-smokers is associated with motivation to quit. Believing that quitting decreases that risk and that friends and family endorse quitting is also associated with motivation to quit.

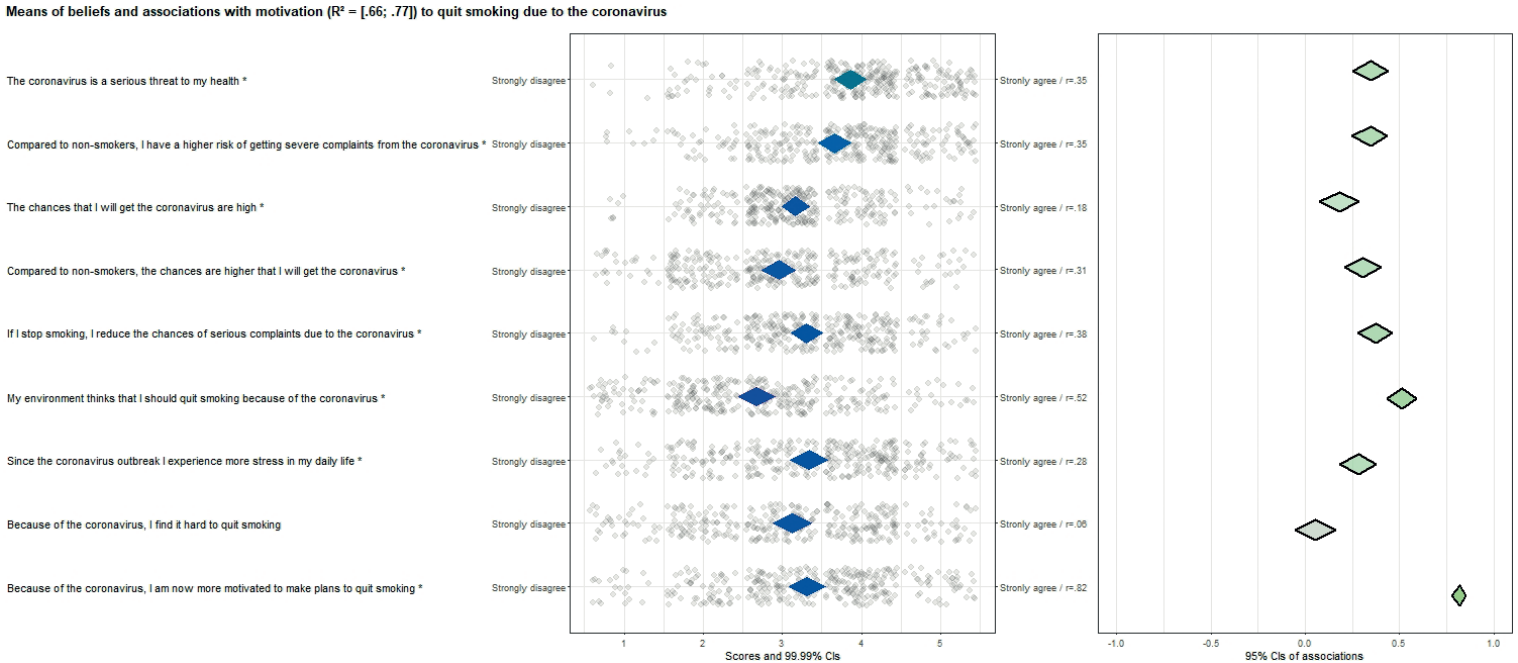
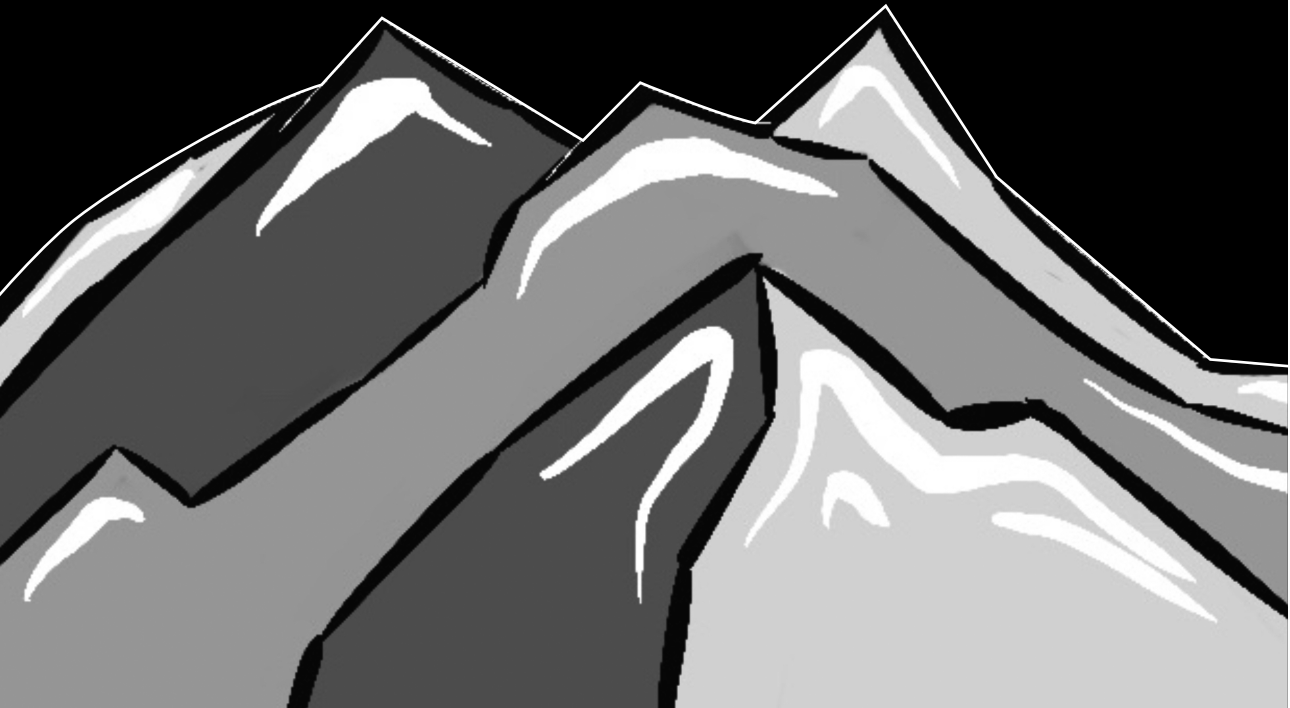


Figure 1. Means of beliefs and associations with motivation to quit smoking due to the coronavirus (R^2=0.66–0.77).

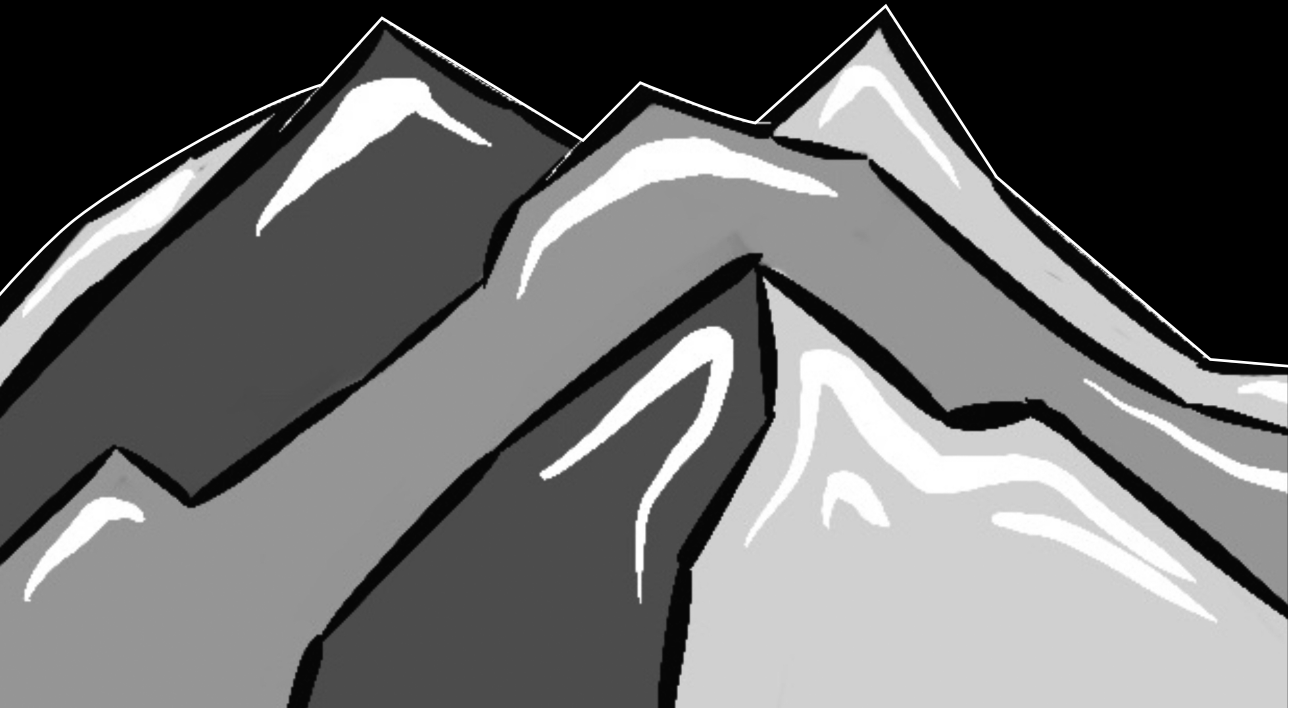


CHAPTER 6

Contextual Factors Associated With Temptations and Lapses Among Smokers Trying to Quit: An Ecological Momentary Assessment Study

This chapter is in preparation for submission:

Elling, J. M., de Vries, H., Candel, M. J. J. M., & Crutzen, R. Contextual Factors Associated With Temptations and Lapses Among Smokers Trying to Quit: An Ecological Momentary Assessment Study.



CHAPTER 7

General Discussion

The main goal of the studies presented in this dissertation was to analyze how to optimize digital smoking cessation interventions using different strategies. First, the use of animated video to increase user engagement was examined. Second, the effects of providing information about e-cigarettes in a digital smoking cessation intervention on knowledge and smoking behavior were investigated. Third, the role of contextual factors on smoking relapse was explored. In addition, the influence of the early pre-vaccination phase of the COVID-19 pandemic on smoking behavior and beliefs about smoking and COVID-19 was examined. This cross-sectional study was embedded in the trial about e-cigarettes that was part of the second strategy. In this chapter, the findings of the studies are discussed and integrated with previous research and methodological considerations are provided.

THE USE OF ANIMATED VIDEO TO INCREASE USER ENGAGEMENT

Chapter 2 addressed a common problem that many digital behavior change interventions face, including digital smoking cessation interventions, namely low user engagement with the intervention (Short et al., 2018; Short et al., 2015). As a potential improvement to increase engagement, we examined the impact of adapting the delivery mode of the intervention on engagement. While content delivered by means of text format prevails in digital behavior change interventions, we tested the use of animated video, because previous research has shown favorable results for interventions that employed videos with presenters (Stanczyk, Bolman, et al., 2014; Walthouwer et al., 2015). In terms of the I-Change model, this means that one of the informational factors, the channel factor, is adapted to better meet the needs of the target population. This adaptation of the channel factor is intended to increase engagement, which in turn is expected to lead to greater use of the intervention and increased effectiveness. In an experimental study, participants were randomized to either receive an animated video or a text version of the same intervention content. The results showed that participants who received animated video (versus text) assessed the intervention as more effective, more trustworthy, more enjoyable, more aesthetic, and more engaging. These are encouraging results that suggest that the use of animated video should be considered in the development of future digital behavior change interventions.

Implications for practice and future research

Although the results clearly indicated that animated video was perceived as more engaging than text, the parameters for effectiveness of animated video in digital behavior change interventions have not yet been explored. Thus, it is not known under which conditions animated video will be effective. Clearly, the use of animated video is not effective per se. For example, the inherent pacing of animated video could interfere with the viewer's sense of control (e.g., compared to text, which can be read and scrolled through at its own pace) (Aronson et al., 2013). Further research is needed. First, there is very little evidence on what features (e.g., length, use of on-screen text) animated video must meet to be perceived as engaging. One exception is an interview study by van het Schip et al. (2020), that found

that "spoken animated video messages should be simple, short, concrete, and without the use of medical terminology". We followed these, albeit general, guidelines in the study presented in Chapter 2 and the results support the recommendations of van het Schip et al. (2020). However, experimental studies manipulating and comparing specific features of animated video are needed to complement these findings (Vandelanotte et al., 2016). Second, in addition to engagement, experimental studies should also examine attention and recall. For videos with a presenter delivering feedback messages, Alley et al. (2014) found that videos (versus text) lead to greater attention but not recall, suggesting that attention and recall also need to be assessed for animated video. Third, it is unknown whether animated video in digital behavior change interventions is more engaging for all users or only for specific target groups (e.g., depending on health literacy) (Meppelink et al., 2015). Finally, studies need to examine whether increased engagement through the use of animated video translates into increased use of interventions and, as a final step, favorable behavioral outcomes such as increased smoking cessation. In a randomized controlled trial of a video-based physical activity intervention, participants who received videos (versus text) spent more time on the intervention (which is presumably associated with increased effectiveness (Donkin et al., 2011)), but no between-condition differences were found for behavioral outcomes. This suggests that the increased time spent on the intervention did not translate into behavior change (Vandelanotte et al., 2021), and underscores the importance of assessing behavioral outcomes in experimental studies.

An additional issue is the implementation of digital smoking cessation interventions in practice once they have been shown to be effective and cost-effective in a randomized controlled trial. In many cases, interventions are not made available to the public after a long development and evaluation process due to a lack of funding (Cheung, Wijnen, et al., 2017). For instance, the intervention that served as the basis for the animated video study (Chapter 2) was shown to be effective and cost-effective (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016; Stanczyk, Smit, et al., 2014), but was not adopted by NGOs to deliver them to a wider audience. This is unfortunate not only for the individual smoker, who is deprived of an opportunity to quit smoking, but also for society at large, considering the costs that are invested in development and evaluation that then fails to take full effect due to a lack of continued funding. Creating business models during the development process of digital smoking cessation interventions may be a prerequisite for subsequent large-scale implementation (van Gemert-Pijnen et al., 2011; van Gemert-Pijnen et al., 2013; van Limburg et al., 2011). Business modeling originates from strategic management and emphasizes the collaboration of all relevant stakeholders to identify critical factors for a successful implementation of the intervention (van Gemert-Pijnen et al., 2011). Whereas implementation is often considered only after development and evaluation of an intervention, there is probably potential in integrating business modeling early in the development phase of the intervention.

PROVIDING INFORMATION ABOUT E-CIGARETTES IN A DIGITAL SMOKING CESSATION INTERVENTION

Chapter 3 and 4 addressed another information factor of the I-Change model, namely the message factor (i.e., message content and quality). Although 44% of smokers in the Netherlands tried e-cigarettes for smoking cessation in 2016 (Hummel et al., 2018), their use is not typically discussed in digital smoking cessation interventions and knowledge about e-cigarettes among smokers is low (Gravely et al., 2020). Hence, we assessed whether providing information about e-cigarettes and their use for smoking cessation could improve participants' knowledge and what impact this has on smoking cessation. Negative consequences of disseminating information about e-cigarettes are also conceivable. For example, participants who could otherwise have chosen long-established cessation methods (e.g., nicotine patches) might opt for e-cigarettes (Yong et al., 2022). This could lead to fewer participants succeeding in quitting with these proven methods and the intervention thus being less effective than a comparable intervention that does not offer information about e-cigarettes. Chapter 3 and 4 described a randomized controlled trial in which participants in the intervention and control condition received a computer-tailored smoking cessation intervention which was developed based on a previous (cost-) effective intervention (Stanczyk, Bolman, et al., 2014; Stanczyk et al., 2016). The use of animated video, as described in Chapter 2, was incorporated into this intervention. The difference between the intervention and control condition concerned the provision of information about e-cigarettes. While participants in the intervention condition received detailed tailored information about e-cigarettes (e.g., about the harmfulness of e-cigarettes compared to smoking, the use of e-cigarettes for smoking cessation), participants in the control condition received no such information.

The results showed that intervention participants were more knowledgeable about e-cigarettes (e.g., about the harmfulness, constituents, addictive potential) than control participants after the intervention. Of note, control participants' knowledge levels were low, particularly regarding the relative harmfulness of e-cigarette use compared to smoking. This finding confirms previous research on smokers' perceptions (Gravely et al., 2020; Huang et al., 2019; McNeill et al., 2021; Wilson et al., 2019). The results indicate that smokers need to be informed about the relative harmfulness of both products to correct misperceptions. The intervention had no effect on behavior; intervention participants did not use e-cigarettes as a cessation method more often than control participants, and no differences in smoking abstinence were found between the two conditions.

Among smokers in the United Kingdom, Svenson et al. (2021) examined the effects of informational videos about e-cigarettes on perceptions of the relative harmfulness of e-cigarette use compared with smoking. Participants were randomly allocated to (1) a video featuring interviews with e-cigarette experts on common e-cigarette misperceptions, (2) a

text-only video showing statements about e-cigarettes, or (3) a control condition. Participants in both video conditions, and particularly in the expert video condition, had more accurate perceptions of the relative harmfulness than participants in the control condition (Svenson et al., 2021). While this result is consistent with our findings, Svenson et al. (2021) also found an effect of condition on the intention to use an e-cigarette in a future quit attempt. Whereas 67% of participants in the expert video condition reported the intention to use an e-cigarette in a future quit attempt, 51% in the text-only video condition, and 35% in the control condition did so (Svenson et al., 2021). This contrasts with our results, which found no effect of condition on the use of e-cigarettes as a cessation method. Although intention is an imperfect predictor of behavior (Sheeran & Webb, 2016), the results of Svenson et al. (2021) suggest that such large differences in intention should also be evident in changes in behavior. The differences in the results of the two studies may be due to the different context of the studies – the United Kingdom and the Netherlands – as the regulation and public health status of e-cigarettes differ between the United Kingdom and the Netherlands, with greater public health endorsement of e-cigarettes for smoking cessation in the United Kingdom than in the Netherlands (McNeill et al., 2021; Trimbos-instituut, 2016). However, also in the United States, where e-cigarettes are less endorsed by public health authorities for smoking cessation than in the United Kingdom (U.S. Department of Health and Human Services, 2016), presenting messages to smokers in an online experiment about the relative risks of e-cigarettes increased participants' intention to switch to e-cigarettes (Yang et al., 2019). A systematic review similarly found that messages about the relative harmfulness of e-cigarette use compared to smoking corrected misperceptions and increased smokers' intentions to purchase, try, or switch to e-cigarettes (Erku et al., 2021). Another explanation for the finding that intervention participants did not use e-cigarettes more frequently could be beliefs about the effectiveness of e-cigarettes for smoking cessation. Our results showed that there were no differences between conditions in beliefs about the effectiveness of e-cigarettes for smoking cessation. Thus, participants' beliefs about e-cigarettes provide an interesting picture. More intervention participants believed that e-cigarette use was less harmful than smoking. However, the intervention did not affect participants' beliefs about the usefulness of e-cigarettes for smoking cessation. This could be one reason why intervention participants did not try e-cigarettes more often than control participants in their quit attempts. More current research is needed, possibly using qualitative research methods, to assess the different beliefs (e.g., harmfulness, effectiveness for smoking cessation) of smokers in the Netherlands. For example, it could be that many smokers who are motivated to quit have already tried e-cigarettes and were not satisfied with them.

The public health impact of e-cigarette use

A broader perspective can be taken when assessing the public health value of e-cigarette use, as e-cigarette use may have completely different public health impacts on different groups. While e-cigarette use can lead to smoking cessation in smokers, it can also lead to and

reinforce nicotine dependence and result in smoking initiation in tobacco-naïve individuals (especially among adolescents and young adults) (Martinelli et al., 2021). Both effects should be considered when evaluating the overall impact of e-cigarettes on public health. The debate about the impact of e-cigarettes on public health is unfortunately often conducted in an unobjective manner. Black-and-white thinking often prevails, and some arguments seem to be guided more by feelings and ideologies than by scientific findings (Fairchild et al., 2019; Warner, 2019). While some researchers emphasize exclusively the risks of any form of nicotine product and see no room for harm reduction, other researchers emphasize the impact on smoking cessation and neglect any impact on tobacco-naïve individuals. The following section reviews research on the overall public health effects of e-cigarettes.

For the United States, a population simulation study estimated the influence of e-cigarette use on smoking-related mortality by 2100 (Mendez & Warner, 2020). Different assumptions were made about the impact of e-cigarette use on smoking cessation and initiation. Estimates of life-years saved due to e-cigarette use ranged from 143,000 to 65 million (Mendez & Warner, 2020). Although the assumptions of the model are explicated and based on previous research, not all researchers would likely agree with them, as studies in this field have reached different conclusions. For England, West et al. (2016) estimated that 16,000 to 22,000 people who quit in 2014 would not have quit if e-cigarettes had not been available. West et al. (2016) did not include any effect of e-cigarette use on smoking initiation in their estimation. They argued that in England and the United States, regular use of e-cigarettes by tobacco-naïve individuals was very rare and that the prevalence of smoking in young people was declining at a similar or greater rate than in earlier years (McNeill et al., 2015). However, this assumption was not confirmed in a recent meta-analysis that examined the association between e-cigarette use (versus non-use) and subsequent smoking among young adult non-smokers (Khouja et al., 2021). The meta-analysis found strong evidence for an association between e-cigarette use among non-smokers and later smoking (Khouja et al., 2021). However, heterogeneity was high, suggesting that the results should be interpreted with caution (Khouja et al., 2021). Furthermore, the results do not provide sufficient evidence for a causal relationship between e-cigarette use and subsequent smoking (the so-called gateway hypothesis) (Khouja et al., 2021; Vanyukov et al., 2012). Another explanation could be that e-cigarette users and smokers share common risk factors (the so-called common liability hypothesis) (Vanyukov et al., 2012). The common liability hypothesis could explain the results of a study among adolescents in the Netherlands and Flanders that found positive associations between both e-cigarette use and subsequent smoking and between smoking and subsequent e-cigarette use (Martinelli et al., 2021). In conclusion, a causal relationship between e-cigarette use and smoking has not yet been established, and it remains unclear whether the gateway hypothesis or the common liability hypothesis better explains the associations between e-cigarette use and smoking. In this area, further research using different methods is needed to triangulate the evidence, for example, by including negative controls (i.e., factors that may have a

common liability but for which there is no biological causal link, such as gambling) (Khouja et al., 2021).

In general, e-cigarette aerosol contains harmful constituents and most commonly nicotine, which can cause addiction and damage the developing brain in adolescents (U.S. Department of Health and Human Services, 2016). Therefore, from a public health perspective, the use of e-cigarettes among non-smokers should be discouraged. However, for smokers who are motivated to quit, e-cigarettes can be used as a cessation tool, promising public health benefits. I argue for a more nuanced view of e-cigarettes that can have different policy implications. On the one hand, plain packaging and display bans can be used to discourage youth use. On the other hand, information campaigns that inform smokers who want to quit smoking about the relative harmfulness of e-cigarette use and smoking can correct misperceptions and help smokers to make an informed decision about using e-cigarettes for smoking cessation.

THE COVID-19 PANDEMIC

Chapter 5 examined the impact of the COVID-19 pandemic on smoking behavior and beliefs about smoking and COVID-19 among smokers willing to quit within 5 years. The study was embedded in the trial described in Chapter 3 and 4 and was conducted during the early pre-vaccination phase of the COVID-19 pandemic in spring 2020. Results showed that 19% of the participants smoked less, 14% smoked more, and 68% smoked unchanged due to COVID-19. A recent meta-analysis confirmed that some smokers decreased and others increased their smoking during the early phase of the COVID-19 pandemic (Sarich et al., 2022). This meta-analysis found that more people smoked more (27% of smokers) than less (21% of smokers), while 50% did not change their smoking behavior (Sarich et al., 2022). The meta-analysis also found that 4% of smokers reported quitting (Sarich et al., 2022). The differences between our study and the meta-analysis may be explained by the different samples; the meta-analysis included all smokers regardless of their motivation to quit whereas our study included only smokers willing to quit within 5 years. In general, smokers appear to have been affected very differently by the COVID-19 pandemic. The high number of smokers who increased their smoking requires sustained public health policies and interventions to ensure that not the current nor future pandemics exacerbate smoking and its associated health consequences.

COVID-19 health risk beliefs and motivation to quit smoking

The results of Chapter 5 also showed that one-third of the smokers were more motivated to quit smoking due to COVID-19. Chapter 5 examined which health risk beliefs were associated with motivation to quit smoking due to COVID-19. Both smoking-related COVID-19 health risk beliefs (e.g., "Compared to non-smokers, the chances are higher that I will get the coronavirus") and general COVID-19 health risk beliefs (e.g., "The chances that

I will get the coronavirus are high") were analyzed. The results showed that motivation to quit smoking due to COVID-19 was positively associated with smoking-related and general perceived probability of SARS-CoV-2 infection and COVID-19 severity. These findings suggest that the COVID-19 pandemic constitutes an opportunity for some smokers to quit. The following sections discuss which COVID-19 health risk beliefs should be best addressed through public health interventions to increase smokers' motivation to quit and build on the window of opportunity that the COVID-19 pandemic may offer to help smokers quit.

In a cross-sectional study among adults in the United States, smoking-related and general perceived COVID-19 severity was also positively associated with readiness to quit smoking (Nyman et al., 2021). Yet, contrary to our findings, no associations were found between smoking-related or general perceived probability of SARS-CoV-2 infection and readiness to quit smoking (Nyman et al., 2021). These differences in beliefs between the results of Chapter 5 and Nyman et al. (2021) may be explained by the difference time periods in which the studies were conducted. Whereas our study was conducted at the beginning of the COVID-19 pandemic in March and April 2020, the study of Nyman et al. (2021) was conducted later in October and November 2020. While there was uncertainty about the effect of smoking on COVID-19 health risks at the onset of the pandemic, current evidence indeed shows that smokers are at higher risk for severe COVID-19, but not for SARS-CoV-2 infection (Reddy et al., 2021; Simons et al., 2021). The association between smoking and probability of SARS-CoV-2 infection is controversial (van Westen-Lagerweij et al., 2021), with some studies finding negative associations between smoking and the probability of SARS-CoV-2 infection, but these associations are not causal (Simons et al., 2021). The findings of Nyman et al. (2021) suggest that public health interventions for smokers should emphasize the link between smoking and COVID-19 severity rather than susceptibility.

Brown (2021) examined the relationship between general COVID-19 health risk beliefs and motivation to quit in more detail. The study was conducted in September and October 2020 (Brown, 2021). In addition to perceived probability and severity, fear of COVID-19 (Ahorsu et al., 2022) was assessed. Importantly, only general COVID-19 health risk beliefs (e.g., "I think I could be infected with COVID-19 in the future") were assessed. The results of Brown (2021) confirmed our findings (Chapter 5) in the sense that perceived probability of SARS-CoV-2 infection predicted motivation to quit. Yet, contrary to our findings, perceived COVID-19 severity did not predict motivation to quit. Fear of COVID-19 predicted motivation to quit only indirectly through the probability of SARS-CoV-2 infection (Brown, 2021). This is unexpected because evidence indicates the contrary (i.e., increased severity, but not probability of infection (Simons et al., 2021)). An explanation for these unexpected findings may be that Brown (2021) only assessed general COVID-19 health risk perceptions, and smokers did not reflect on the potential influence of smoking on COVID-19 health risks. For the field of health promotion, the findings of Brown (2021) imply that communication

aimed at influencing smokers to quit may best emphasize the overall high risk of exposure to and infection with SARS-CoV-2 for everyone. While the results of Chapter 5 suggested that both perceived probability of SARS-CoV-2 infection and COVID-19 severity were associated with motivation to quit, the studies of Nyman et al. (2021) and Brown (2021) reach different conclusions and contradict each other. The findings of this dissertation suggest that it is relevant to address both beliefs, probability and severity, in public health interventions, emphasizing the increased risk of greater COVID-19 severity for smokers and the overall high risk of infection for all. However, threatening communication about smoking and COVID-19 should also include sufficient coping information in order to lead to behavior change (Peters et al., 2013). Communication about severity of COVID-19 and susceptibility to infection (which together determine the threat of COVID-19) will only lead to behavior change if smokers have an effective response (i.e., smoking cessation) and the self-efficacy to carry out that response (Peters et al., 2013; Witte, 1992).

CONTEXTUAL FACTORS IN SMOKING RELAPSE

Chapter 6 explored the role of contextual factors in smoking relapse in an ecological momentary assessment (EMA) study among smokers trying to quit during the first 14 days after a quit attempt. Ecological momentary assessment involves the repeated collection of data in participants' daily life (i.e., the natural environment) (Schüz et al., 2015). Contextual factors included activities (e.g., leisure, alcohol consumption), the social environment (e.g., being with friends), and the location (e.g., being in a bar), and were assessed in temptation and lapse episodes as well as at random during the day. The results showed that various contextual factors were associated with lower or increased risk of temptation and lapsing. This suggests that contextual factors play a key role in the occurrence of smoking relapse. Due to the large number of contextual factors examined, I refer the reader to Chapter 6 for a complete overview and limit this section to a few findings. Whereas work was associated with lower risk, leisure was associated with increased risk of temptation and lapsing relative to random assessments. Activities associated with increased risk of lapsing included watching television, using social media, and drinking coffee and alcohol. Sexual intercourse was particularly strongly associated with increased risk of temptation. Moreover, social contextual factors (e.g., being with friends) appeared to play an important role in smoking relapse.

Implications for practice and future research

Research is needed on how contextual factors can be addressed in smoking relapse prevention interventions. The potential mechanism of action is that ex-smokers use cognitive-behavioral coping strategies to avoid lapsing in situations where contextual factors are present that are associated with increased risk of temptation and lapsing (Naughton, 2016). The formation of coping plans in advance, for example as part of counseling or digital interventions, has been

shown to be effective in reducing smoking relapse (Ferguson & Shiffman, 2009; van Osch et al., 2008). However, the extent to which ex-smokers can draw on what they have planned and apply these strategies in high-risk situations, often involving stress and strong emotions, is uncertain and may depend on the time frame between formation of the coping plans and the need to apply them. As people are more likely to be influenced by proximal and immediate rather than distant information (Shiffman, 2006), the effectiveness of coping strategies could potentially be improved by providing them in high-risk situations (referred to as "just-in-time") triggered through a context-aware system and tailored to the context. Interventions that aim to accomplish this are called just-in-time adaptive interventions (JITAIs) and are mainly delivered via smartphone applications (hereafter apps) (Nahum-Shani et al., 2018; Perski et al., 2022).

Support in just-in-time interventions can be user-initiated (e.g., by clicking a help button in an app) or based on predetermined rules (e.g., fixed schedules), but the most advanced interventions use unobtrusive context sensing (i.e., just-in-time *adaptive* interventions) (Naughton, 2016). One example is a context-aware smoking relapse prevention app by Naughton et al. (2016) that delivers support tailored to the user's real-time location. First, the app must be trained by the user during a period of ad libitum smoking prior to the quit date (Naughton et al., 2021). The user has to report each smoking episode in the app and answer a short assessment of contextual factors, while the app records the geolocation. For locations where the user tends to smoke, geofences (i.e., virtual fences around locations) are created by the app. Second, after the quit date, the app sends support messages when the user enters a geofence, tailored to the context of the location. Only pilot data are available, but the system appears to be working and the geofence-triggered support was appreciated by participants (Naughton et al., 2016). Whereas location monitoring is relatively straightforward through the use of GPS, Wi-Fi, and network data on the smartphone (Naughton et al., 2021), it is more difficult to capture other contextual factors such as activities and the social environment with the smartphone. Activity could be captured by the accelerometer and the GPS sensor in smartphones (Rabbi et al., 2015), possibly in combination with the use of smartwatches that track heart rate, heart rate variability, and other activity-related metrics. The social environment could potentially be captured through the use of Bluetooth on the smartphone, which could provide information on whether a person is alone, with another person, or in a group, and the presence of friends/family/partners could be inferred by integrating the personal contact book on the smartphone (McClernon & Choudhury, 2013). In addition to exploring the use of such data, careful ongoing ethical considerations are required. The unobtrusive sensing of physiological and environmental contextual factors can compromise user privacy and understanding of what is being collected and for what purpose (Perski et al., 2022). Therefore, user consent and ease of control over user data are critical. Previous developments of digital health interventions where sensitive data was collected and processed can be used as a starting point for ethical considerations, such as the use of COVID-19 tracing apps.

Morley et al. (2020) devised 16 questions (e.g., "Can users erase the data?") that stakeholders working with COVID-19 tracing apps should consider in order to answer whether the app is ethically justifiable. A similar approach early in the development of unobtrusive sensing of contextual factors is ethically imperative and may increase the acceptability of subsequent just-in-time adaptive interventions.

METHODOLOGICAL CONSIDERATIONS

Major strengths of the studies presented in this dissertation were their scientific rigor and strict pre-registered protocols (e.g., randomized controlled trial design, use of ecological momentary assessments rather than retrospective questionnaires). However, the studies were also subject to some limitations. As three independent main studies were conducted as part of this dissertation, the various methodological considerations are organized by topic but discussed per study. The methodological considerations relate to the external validity of the studies and self-report data.

External validity

In the study on the influence of the delivery mode on user engagement (Chapter 2), smokers and non-smokers were recruited to test a computer-tailored smoking cessation intervention. Next to differences between participants receiving the two delivery modes (animated video versus text), differences between smokers and non-smokers were also examined. The hypothesized effect of smoking status was that smokers would be more engaged by the intervention than non-smokers, because of the personal relevance of the topic. The final sample of participants was very homogenous in this study. Nearly all participants were highly educated and disproportionately young and female in comparison to the Dutch adult population. Therefore, the main limitation of this study is the homogenous sample, which does not allow generalization of the results to a general population of smokers and non-smokers. It should also be noted that smokers could take part irrespective of their motivation to quit smoking. Future studies could be improved by stricter inclusion criteria, recruiting only smokers who are motivated to quit (e.g., within 1 month), because differences in perceptions between the smoker and non-smoker groups are expected to increase when only smokers who are motivated to quit are included.

A limitation to the results of the randomized controlled trial on the effects of information about e-cigarettes in a digital smoking cessation intervention (Chapter 3 and 4) was dropout attrition (i.e., participants being lost to follow-up regardless of whether they participated in the intervention). Participants for this study were recruited through a Dutch research agency, Google Ads, social media, smoking-related Internet forums, and flyers. A follow-up questionnaire was distributed after 6 months from baseline. Four hundred and ninety-one participants were recruited, of whom 331 came from the research agency and 160 from the

other channels. Unfortunately, only about one in five participants (35/160, 21.9%) recruited through channels other than the research agency responded to the six-month follow-up questionnaire. In addition, differences in baseline characteristics were found between participants recruited through the research agency and participants recruited through other channels. For example, participants recruited through other channels exhibited higher nicotine dependence and were more motivated to quit smoking than participants recruited through the research agency. In randomized controlled trials of digital behavior change interventions, missing data are often replaced with estimated values using multiple imputation techniques (van Buuren, 2018). However, due to the described issues, data from participants recruited through the research agency and participants recruited through other channels could not be combined to conduct multiple imputation analyses. Therefore, to avoid bias, participants recruited through channels other than the research agency had to be excluded from the analyses. This is unfortunate because, the smaller sample resulted in less precise confidence intervals around some effect sizes of interest.

Self-report data

In the studies presented in this dissertation, we relied on self-report data. Self-report data were used for research purposes (e.g., baseline and follow-up questionnaires, ecological momentary assessments) as well as for the computer-tailoring process. In general, participant burden in digital health studies should be kept low to avoid attrition (Eysenbach, 2005). In terms of computer-tailoring, although this is the usual procedure, studies have shown that participants can be burdened by answering (lengthy) questionnaires for the tailoring process (Alley et al., 2016; Vandelanotte & de Bourdeaudhuij, 2003; Vandelanotte et al., 2004). Therefore, Short et al. (2022) discussed new approaches in computer tailoring to increase user engagement and reduce participant burden by reducing or avoiding answering (lengthy) questionnaires, such as by assessing online behavior or sensor data. While data for the tailoring process has generally been collected purposively (e.g., disseminating a questionnaire at baseline), novel ways to use routinely collected data are emerging (Short et al., 2022). For instance, psychological constructs such as attitude could be inferred based on routinely collected data on online behavior, such as browsing history (Short et al., 2022). Records of social media use could also be informative, as personality has been shown to be predictable based on Facebook profile features (e.g., number of friends, number of photos uploaded) (Kosinski et al., 2014) and Facebook likes (e.g., companies, artists, sports clubs) (Kosinski et al., 2013). Records of social media use may also be informative in predicting (smoker) identity in digital smoking cessation interventions that address identity change. The rationale behind identity-related smoking cessation interventions is based on the finding that successful smoking cessation is associated with smokers seeing themselves as quitters or non-smokers rather than smokers (Meijer et al., 2017; Penfornis et al., 2022).

Another strand of research is moving in the direction of using machine learning (a type of artificial intelligence) for the tailoring process itself (i.e., what feedback is given to whom), referred to as recommender systems (Cheung et al., 2019; Hors-Fraile et al., 2019; Sadasivam et al., 2016). Such approaches likewise aim to reduce the burden on participants by reducing the need to fill out questionnaires. Contrary to traditional computer-tailored interventions, recommender systems are not human- but data-driven. Data-driven in the sense that intervention content is tailored by machine learning algorithms that consider feedback of the user (e.g., short questionnaires) and similarity between users (e.g., user profiles) (Sadasivam et al., 2016). Importantly, recommender systems are able to learn, so recommendations should become more sophisticated over time. In Taiwan, a study compared a recommender system-based smoking cessation intervention that considered user profiles in addition to self-reported (smoking) characteristics to a system that relied on self-reported (smoking) characteristics only (Hors-Fraile et al., 2022). The more advanced system that considered user profiles did not perform better than the system that relied on self-report data only (Hors-Fraile et al., 2022). Further research needs to be conducted to evaluate the potential of recommender systems in digital smoking cessation interventions.

New approaches could also be used in the future to measure variables for research purposes, independent of a computer-tailored intervention. This could prevent attrition by reducing participant burden. An example of an approach that could be used for research similar to that described in Chapter 6 is a wristband that can detect smoking hand-to-mouth gestures (Parate et al., 2014), which may soon be possible with off-the-shelf smartwatches (Naughton, 2016). In relation to the study described in Chapter 6, participants would then not have to indicate when they smoke a cigarette themselves in a smartphone app, but the smartwatch would register this. An important note of caution lies in the ethical considerations that must be taken into account when working with routinely collected data (Short et al., 2022). For example, the research team of the study described in Chapter 6 initially planned to capture GPS data for situations in which participants recorded temptations and lapses. However, during pilot testing of the smartphone app, it became evident that many participants were skeptical about providing GPS data due to privacy concerns, so no GPS data was collected in the study. This underscores the need for careful ethical considerations, as discussed earlier in the context of unobtrusive sensing of contextual factors for just-in-time adaptive relapse prevention interventions.

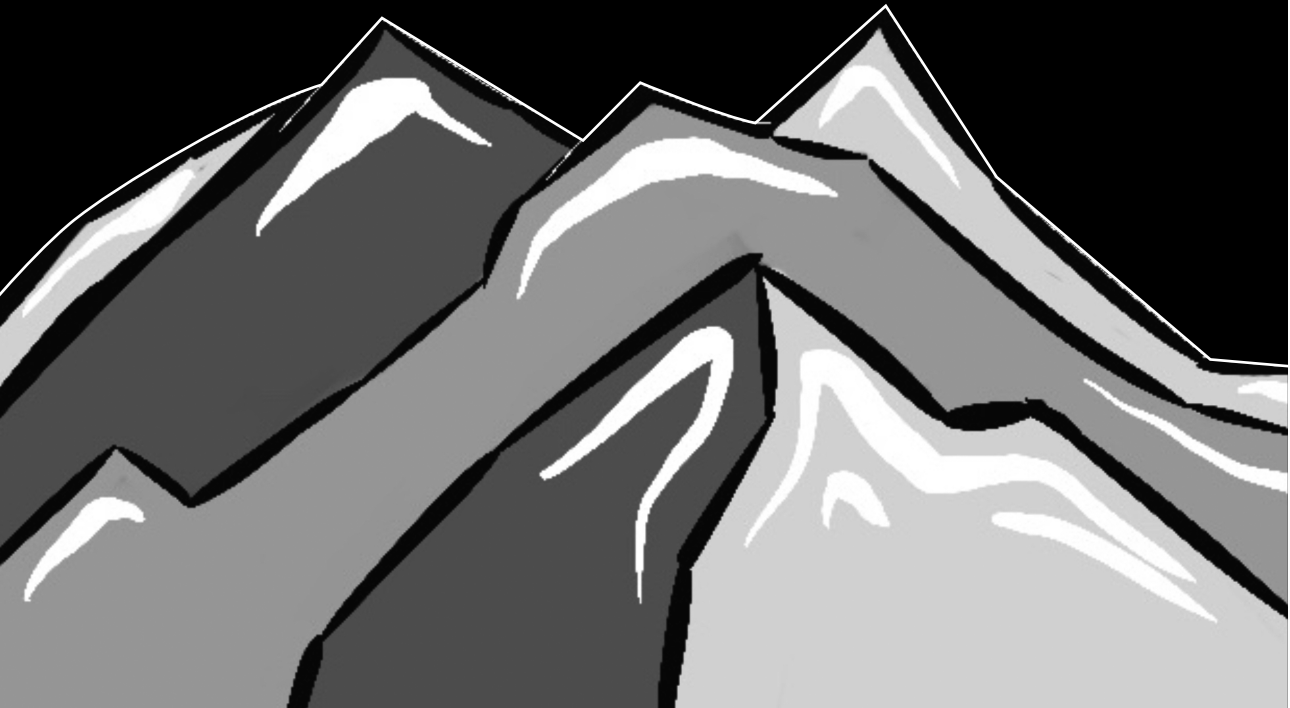
In the randomized controlled trial described in Chapter 3 and 4, smoking abstinence was self-reported and not biochemically verified (i.e., tested for biomarkers of smoking to identify deceivers) (Benowitz et al., 2019). The study team decided against biochemical verification for two reasons. First, sensitive data (e.g., residential address) would have had to be collected from participants. Based on the experience of previous similar studies, the need to provide sensitive data may be a reason for participants not to participate in a study or not to respond to

a follow-up measurement (Smit, 2012). Second, studies have shown that the validity of self-reported smoking cessation is consistently high (Rebagliato, 2002), raising ethical concerns about allocating costly resources to biochemical verification.

GENERAL CONCLUSION

The studies presented in this dissertation showed that optimization of digital smoking cessation interventions can be achieved through different strategies. The strategies addressed the technological realization of digital smoking cessation interventions from a user engagement perspective (Chapter 2), the provision of information about e-cigarettes from an intervention development perspective (Chapter 3 and 4), and the behavioral process of smoking cessation and its associated context from a health psychological perspective (Chapter 6).

The use of animated video in a digital smoking cessation intervention was found to be effective in increasing user engagement, but future research should examine the use of animated video in greater depth. It is not yet clear which criteria animated video must meet to be effective, whether they are well suited for everyone, and whether increased engagement transfers into favorable behavioral outcomes. Providing information about e-cigarettes as part of a digital smoking cessation intervention increased participants' knowledge about e-cigarettes and had no effect on smoking cessation. The results of the study on contextual factors in smoking relapse showed that several contextual factors were associated with temptation and lapsing, which could make them suitable targets for just-in-time adaptive relapse prevention interventions. The best approach to address contextual factors in digital interventions is largely unexplored at present, but should be the focus of future studies.



APPENDICES

Impact Paragraph, References, Summary, Curriculum Vitae, Dankwoord

Impact Paragraph

Smoking is the leading cause of disease and death in the Netherlands. Every year, about 19,000 people die in the Netherlands from a disease caused by smoking. Yet, in 2021, 20.6% of the adult population in the Netherlands still smoked. The health, societal, and economical benefits of developing policies and interventions to reduce smoking, and with it the illnesses and deaths caused by smoking, is very high. This is reflected in the Dutch National Prevention Agreement (in Dutch: Nationaal Preventieakkoord). This agreement aims to achieve a smoke-free generation by 2040, in which "children won't know what tobacco smoke smells like anymore." Interventions that help smokers quit benefit the health of the individual smoker primarily. Yet, they also play an important role in preventing youth from taking up smoking, because every adult who quits is one less adult who models smoking behavior to youth. Thus, effective and accessible smoking cessation interventions also contribute to create a smoke-free generation. This dissertation focused on the use of digital interventions for smoking cessation and potential ways to optimize them.

Digital smoking cessation interventions can be offered in the form of smartphone apps or on websites. People who are motivated to quit smoking can use such interventions to prepare their quit attempt and/or receive help during and after the quit attempt. The digital smoking cessation interventions that have been shown to be effective in the Netherlands were based on psychological models (e.g., the I-Change model) and were mostly computer-tailored. Computer tailoring means that participants complete questionnaires about their demographics, smoking behavior, and psychological constructs (e.g., pros and cons of smoking), which is used to yield tailored intervention content. In other words, the feedback that individuals receive is adapted to their individual characteristics. While the effectiveness of digital smoking cessation interventions has been established, low use by participants hinders the realization of their full potential. The studies presented in this dissertation share the common goal of exploring ways to optimize digital smoking cessation interventions using a variety of strategies.

First, we found that using animation instead of text in digital smoking cessation interventions increased user engagement. User engagement describes how positively people perceive a digital intervention and how intensively they use the intervention. Second, we found that informing participants in a digital smoking cessation intervention about e-cigarettes and their use for smoking cessation increased knowledge about e-cigarettes, but had no effect on behavior. In other words, individuals who received information compared with individuals who did not receive such information were better informed, but they did not use e-cigarettes more frequently as a method of smoking cessation. Third, we found that the early pre-vaccination phase of the COVID-19 pandemic in spring 2020 affected smokers who were motivated to quit within 5 years in several ways. On the one hand, some smokers (14%)

smoked more because of the COVID-19 pandemic; on the other hand, one-third of smokers were more motivated to quit smoking because of the COVID-19 pandemic. Fourth, we found that certain situations in an ex-smoker's daily life were associated with smoking relapse. For example, coffee drinking and sexual intercourse were found to be associated with increased risk of relapse.

SCIENTIFIC IMPACT

All articles published to date of this dissertation have been published in peer-reviewed open access journals. In particular, the article on smoking and smoking cessation in times of COVID-19 (Chapter 2) was well received by the scientific community, as indicated by the relatively large number of citations in the brief time that it is available. The findings of the research were presented at the annual congress of the Netherlands Network of Tobacco Control Researchers (in Dutch: Nederlands Netwerk voor Tabaksonderzoek) in 2020, 2021, and 2022. The congress provides an opportunity to exchange ideas and discuss current research results with other national researchers in the field of tobacco control. Furthermore, the results were presented in a symposium on digital health at the annual conference of the European Health Psychology Society in 2022.

For intervention development, the studies have high practical relevance, as we have developed and tested specific intervention features that can be used in future interventions. While many projects focus on developing entirely new interventions and then evaluating them, this PhD project focused on analyzing ways to optimize digital smoking cessation interventions, adapting several specific intervention features. Both types of projects are needed. One advantage of evaluating intervention features is its added value for intervention development, as other researchers can build on the findings and incorporate effective features into their own interventions. For example, the use of tailored animated video was incorporated in a digital intervention to support adherence to urate-lowering therapy among gout patients at the Department of Internal Medicine at Maastricht University Medical Center.

Key recommendations for future research in this dissertation are: (1) Investigate under what conditions animated videos increase user engagement, both in terms of target group (e.g., level of health literacy) and features of the animated video (e.g., length); (2) Examine the public health impact of e-cigarette use, combining potential effects on smokers and non-smokers; (3) Explore how support in situations of risk for relapse can be incorporated into digital (just-in-time) smoking relapse prevention interventions.

SOCIAL IMPACT

The main group benefiting from the studies presented in this dissertation are smokers. First, participation in the studies on animated video (Chapter 2) and information about e-cigarettes (Chapter 3 and 4) increased the likelihood of long-term abstinence. In fact, 22.4% (62/277) of participants in the overall sample of the study on information about e-cigarettes achieved smoking abstinence after six months. Many more smokers can be helped by future smoking cessation and smoking relapse prevention interventions that build on the findings of the studies conducted, and help achieve a smoke-free generation by 2040. In addition, people's self-efficacy for behavior change increases when they successfully quit smoking, which facilitates changing other health-risk behaviors or participating in health-promoting behaviors. In general, some findings (e.g., the use of animated video) can be applied to the development of interventions for other health behaviors such as physical activity, healthy eating, or sunscreen use, thereby increasing quality of life through more effective interventions.

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Summary

Smoking is the leading cause of preventable mortality worldwide. Smokers die on average 10 years earlier than non-smokers. Despite public health efforts to curb smoking prevalence, 20.6% of the adult Dutch population still smokes. One way to support smokers to quit is through digital smoking cessation interventions. Such interventions are the focus of this dissertation. While the effectiveness of such interventions is well established, low use by participants hinders the realization of their full potential. The studies presented in the various chapters of this dissertation aim to optimize digital interventions for smoking cessation by addressing research questions pertaining to digital interventions (e.g., user engagement) and the context of smoking cessation (e.g., use of e-cigarettes for smoking cessation).

Chapter 1 describes the background, rationale, and objectives of the studies conducted as part of this dissertation. It also describes the theoretical framework underlying most of the studies (i.e., the I-Change model, or short ICM) and explains how the various studies relate to the ICM. While the channel factor of the ICM was manipulated in the study described in Chapter 2, the message factor of the ICM was manipulated in the study described in Chapter 3 and 4. Furthermore, a key method for changing behavior, namely computer tailoring, is explained.

Chapter 2 reports the results of an experimental study that examined the impact of animated video- versus text-based delivery of a computer-tailored smoking cessation intervention on user engagement. The results showed that participants who received the animated video version evaluated the intervention more positively than participants who received the text version. These results suggest that enriching interventions with animated video increases user engagement, which may ultimately increase intervention use and effectiveness.

Chapter 3 provides the protocol for a randomized controlled trial that examined the effects of providing information about e-cigarettes in a digital smoking cessation intervention on decision-making about the use of e-cigarettes for smoking cessation and smoking behavior. Participants in the control condition received a computer-tailored smoking cessation intervention. Participants in the intervention condition received the same intervention but with additional information about e-cigarettes (e.g., the relative harmfulness of e-cigarettes and cigarettes) as part of the intervention content.

Chapter 4 describes the results of the randomized controlled trial introduced in Chapter 3. An important finding was that control participants' knowledge about e-cigarettes and the relative harmfulness compared to cigarettes was limited. Participants in the intervention condition possessed more knowledge after the intervention than participants in the control condition. No differences were found between the two conditions regarding the use of

e-cigarettes as a cessation method, nor on smoking cessation. The results suggest that such a digital intervention can improve knowledge, which can facilitate decision-making about the use of e-cigarettes for smoking cessation.

Chapter 5 describes a cross-sectional study of the influence of the COVID-19 pandemic on smoking behavior and beliefs about smoking cessation among a sample of smokers who were motivated to quit smoking within five years. This study was embedded in the trial described in Chapter 3 and 4 and was conducted during the early pre-vaccination phase of the COVID-19 pandemic in spring 2020. The results showed that motivation to quit smoking increased in one-third of smokers because of COVID-19. The study also examined which specific beliefs about COVID-19 and smoking were associated with motivation to quit.

Chapter 6 describes the results of an ecological momentary assessment study on the role of contextual factors (e.g., activities, social environment) in smoking relapse. For 14 days following the quit attempt, smokers used an application on their smartphone to indicate in the moment when they experienced temptations or lapses. Smokers also answered random assessments throughout the day. Generalized linear mixed models were used to calculate associations between contextual factors and temptations and lapses. Results indicated that various contextual factors (e.g., leisure, being social, drinking coffee, doing nothing, sexual intercourse) were associated with either increased or lower risk of temptation and lapsing. The results suggest that contextual factors are suitable intervention targets to change relapse behavior. In particular, digital just-in-time interventions have the potential to capture contextual factors and provide support (e.g., coping advice, distraction) in high-risk situations.

Chapter 7 discusses and integrates the major findings of the studies described in this dissertation, suggests directions for future research and practice, and offers methodological considerations. The results of the studies suggest that optimizing digital smoking cessation interventions can be successful by using animated video to increase user engagement, by providing information on e-cigarettes to increase knowledge and facilitate decision-making on the use of e-cigarettes for smoking cessation, and by addressing contextual factors in smoking relapse prevention interventions to help ex-smokers in risk situations. Future research is needed to better inform both practice (e.g., how can contextual factors be measured and addressed in digital relapse prevention interventions) and theory (e.g., why is animated video more engaging than text and for whom), as well as how to best foster implementation of evidence-based digital smoking cessation interventions.

Curriculum Vitae

Jan Mathis Elling was born on August 18, 1995 in Münster, Germany. In 2014, he graduated from Gymnasium "In der Wüste" in Osnabrück, Germany. He then studied BSc Health Sciences at the University of Twente from 2015 to 2018 and MSc Psychology (cum laude) at Maastricht University from 2018 to 2019. In his master, he specialized in health and social psychology. From 2019 to 2022, Mathis worked as a PhD candidate at the Department of Health Promotion at Maastricht University on the project described in this dissertation.

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