From smoke to sweat: developing and evaluating an accessible virtual coach to support smoking cessation and physical activity

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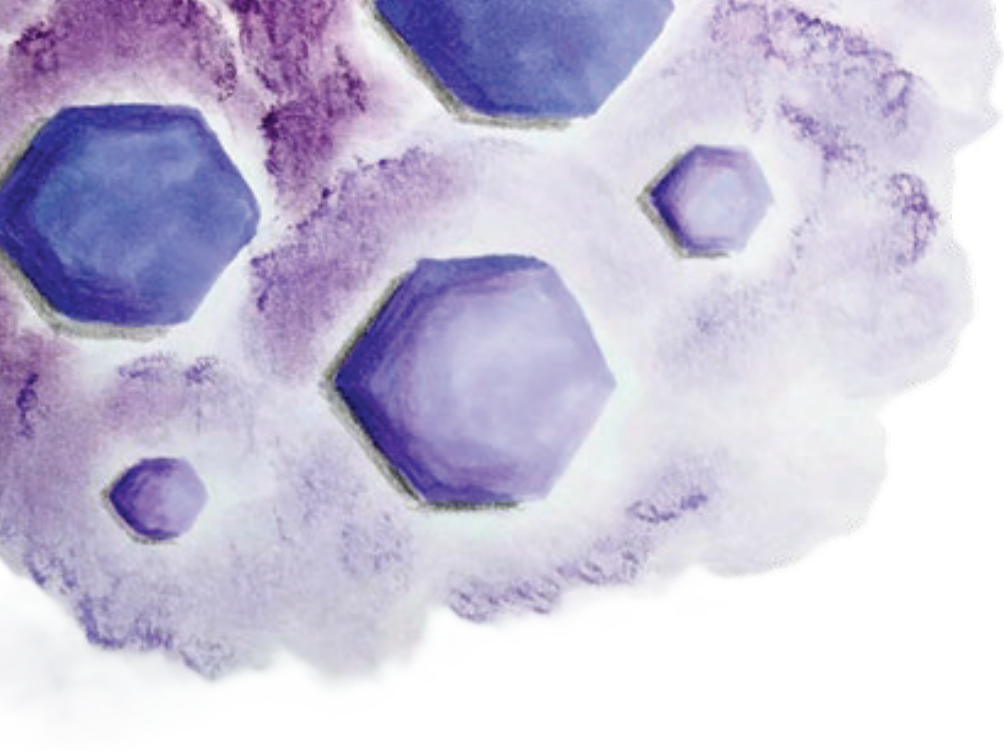

Chapter 8

Summary and general discussion

This dissertation, conducted as part of the six-year Perfect Fit (PF) project [1], addressed key challenges for mobile health (mHealth) interventions with virtual coaches. At the outset of the PF project, our team conducted a broad synthesis of evidence to identify a range of knowledge gaps and challenges in this field. These findings guided the development of PF, a smartphone-based intervention featuring a virtual coach that provides real-time, personalized, text-based, and visual feedback to support both smoking cessation and physical activity (PA) promotion. Building on the collective work of the PF team, this dissertation focused on several of these challenges that were considered particularly important to address based on prior literature. The resulting studies aimed to answer the following research questions:

Part 1: **Content development and design**

- **Research question 1**: *How can end-users be meaningfully involved in the design, development, and evaluation of virtual coach interventions?*
- **Research question 2:** *How can emerging behavior change techniques be evaluated and incorporated into virtual coach interventions?*

Part 2: **Real-world evaluation**

- **Research question 3:** *What is the feasibility, acceptability, and two-month effectiveness of a virtual coach intervention for smoking cessation and PA promotion?*

In this general discussion, important insights addressing these research questions are summarized and discussed in relation to the key challenges described in the general introduction. These insights are interpreted in light of the literature, reflecting on what has been learned from the research presented in this dissertation, what appears most promising, and under which conditions these findings may apply. Finally, remaining or newly emerged knowledge gaps are outlined, and directions for future research are proposed.

Summary and main findings

Part 1: Content development and design

Certain groups, such as individuals with lower SEP, are underserved by mHealth interventions, including those with virtual coaches [2-5]. A valuable strategy to enhance intervention and research accessibility is involving end-users in the development and evaluation of interventions [2-4, 6-8], commonly referred to as patient and public involvement (PPI). PPI is a collaborative approach in which research is conducted with or even by representatives of the target population [9]. While its importance is increasingly recognized [10, 11], practical guidance on meaningful implementation remains limited [12]. To address this, **Chapter 2** presented a step-by-step, iterative approach for applying PPI in (eHealth) research. The approach was informed by three eHealth projects, including PF, and itera-

tively refined based on insights and feedback from other researchers and end-users. The approach consists of six steps: (1) *Where in the eHealth evaluation cycle is your research project positioned?*; (2) *Why do you want to use PPI?;* (3) *Who is your target population?*; (4) *How are you going to achieve your aims?*; (5) *What considerations and conditions need to be taken into account to facilitate PPI?*; (6) *How did the PPI process unfold?* Each step is accompanied by reflective questions, recommendations (i.e., practical suggestions for effectively carrying out each step), lessons learned (i.e., successes and challenges), and case examples. Additionally, an overview of relevant existing resources (e.g., literature, websites) is provided for each step. The aim of the approach was to inspire researchers and provide actionable guidance to implement meaningful PPI in research.

It is not only important that interventions are accessible to target populations, as emphasized in Chapter 2, but they should also be grounded in behavior change theories and techniques [3, 5, 8]. Identity-based strategies are promising for promoting smoking cessation and PA, as identity plays an important role in regulating behavior [13-18]. To explain, individuals tend to act in line with identities that reflect who they are or aspire to be [14, 19, 20]. Strengthening healthy identities (e.g., ex-smoker) or weakening unhealthy ones (e.g., smoker) has therefore been proposed as a promising strategy to promote smoking cessation and PA [21-24]. Despite growing interest, evidence on how identity can be effectively targeted in smoking cessation and PA promotion remains fragmented, and no systematic synthesis has yet examined such interventions across both behaviors. Using a mixed-methods systematic review, **Chapter 3** identified and examined interventions targeting smoking- and/or PA-related identities to promote smoking cessation and PA in individuals aged 12 years and over. Across 19 records (20 different studies), four types of identity-related interventions were identified: (1) possible-self interventions prompting imagery of (un)desired possible selves to influence identity [21-28], (2) multicomponent interventions incorporating identity components [29-33], (3) possible-self avatar games enabling interaction with a virtual self-representation to shape behavior [34AB, 35, 36] , and (4) identity-challenge interventions assessing reactions to hypothetical identity challenges based on participants' identity levels [37AB, 38]. Overall, intervention effectiveness was mixed: nearly half of the studies reported significant positive effects on smoking- and PA-related identities and behaviors [22, 25, 29, 30, 34AB, 35, 37A, 38], while the remainder found no significant effects [21, 23, 24, 26-28, 31-33, 36, 37B]. No adverse effects were reported. Results appeared comparable for smoking and PA, though more studies focused on PA, limiting direct comparisons. Moderators identified in the possible-self interventions for PA included task self-efficacy [22] and consideration of future consequences [21], while mediators included planning self-efficacy [27] and action planning [25]. Overall, identity-related interventions show promise for both smoking cessation and PA promotion, but optimal design and operationalization remain uncertain.

Tailoring these interventions to individual characteristics may enhance effectiveness and public health impact.

Building on the investigation of identity-based behavior change techniques in Chapter 3, **Chapter 4** explored how such techniques could be applied within a virtual coach intervention to support individuals in high-risk situations for smoking (re)lapse. Although numerous smoking cessation interventions exist, relapse remains common [39, 40], particularly among individuals with a lower SEP [41, 42]. In addition to the fact that interventions often do not meet the needs of the target population (as highlighted in Chapter 2)[2-4], another reason for their limited effectiveness may be that they fail to provide timely support in high-risk situations [43, 44]. Understanding how to effectively support people who smoke in these critical moments, when smoking-related cues increase craving and relapse likelihood [43-45], is therefore crucial for achieving long-term cessation. Chapter 4 presented a proof-of-concept virtual coach intervention for smoking cessation, delivered via a simulated smartphone, designed to provide just-in-time support in high-risk situations. This virtual reality experiment examined the intervention's preliminary effectiveness, acceptance, and usability in a controlled yet ecologically valid way [45], simulating a real-life high-risk situation in which participants interacted with the virtual coach through mobile text messages. Three (re)lapse-prevention dialogs were tested in a within-subjects design: (1) boosting motivation and self-efficacy, (2) future-self intervention with implementation intentions, and (3) identity-focused positive self-talk. While all dialogs were grounded in established behavior change techniques, the latter two identity-based strategies are relatively novel. A fourth, neutral dialog, humorously presenting animal facts, served as an attention-control condition. Results showed no significant differences between the four dialogs on abstinence self-efficacy (primary outcome), subjective craving, or positive and negative affect (secondary outcomes). This suggests that the identity-based dialogs had similar effects as the more traditional dialog, boosting motivation and self-efficacy. Although unintended, the neutral dialog also yielded effects similar to the three relapse-prevention dialogs, possibly serving as a distraction. Overall usability and acceptance of the virtual coach were rated positively. Planned exploratory analyses for SEP groups were not possible, as the lower-SEP group was too small despite targeted recruitment efforts. In conclusion, virtual coach interventions show promise for smoking cessation, as they are usable, acceptable, and can deliver immediately available relapse-prevention support in high-risk situations. Insights from this study can guide the development of virtual coach interventions and the operationalization of different behavior change technique clusters in smoking cessation interventions.

Part 2: Real-world evaluation

mHealth interventions with virtual coaches can support health behavior change by simulating human support through automated text- or speech-based interactions [5,

46, 47], thereby enhancing engagement while offering the benefits of digital delivery [48, 49], such as high scalability and 24/7 availability [5]. Evidence indicates that these interventions hold promise for smoking cessation [5, 50] and PA promotion [46]. Smoking and low PA often co-occur [51, 52], and improvements in one behavior may positively reinforce the other [53-55]. Specifically, increasing PA can reduce nicotine cravings [53] and withdrawal symptoms [54], while smoking cessation can improve fitness, supporting PA engagement [55]. Therefore, we developed PF, a theory-based, smartphone-delivered virtual coach intervention providing real-time, personalized support for both smoking cessation and PA promotion, leveraging their behavioral synergy. **Chapters 5-7** focused on the evaluation of the first functional prototype of PF, reporting on different aspects of the same study. **Chapter 5** outlined the intervention content and study protocol, while **Chapters 6 and 7** presented findings on feasibility and acceptability, and short-term (two-month follow-up) effectiveness, respectively.

As highlighted in Chapters 3 and 4, many existing mHealth interventions with virtual coaches lack grounding in established behavior change techniques or theoretical frameworks [5, 46], while this is crucial for increasing the likelihood of success and for understanding the mechanisms underlying behavior change [3, 5, 56]. To address this, PF integrates behavior change techniques commonly used in smoking cessation [57] and PA promotion [58], as well as relevant behavioral theories, such as identity theories [59] and the Relapse Prevention Model [60, 61]. Furthermore, as described in Chapter 2, accessibility for underserved populations is crucial. PF was therefore developed collaboratively with end-users and experts, iteratively incorporating feedback to better align the intervention with the needs of individuals with lower (eHealth) literacy, SEP, or limited digital skills. **Chapter 5** described the first functional prototype of PF, detailing its components, features, and theoretical and empirical foundations. In addition, this chapter outlined the study protocol for the real-world evaluation of PF using a single-arm, concurrent mixed-methods design to assess its feasibility, acceptability, and two-month effectiveness.

Limited research has examined the feasibility and acceptability of mHealth interventions with virtual coaches [46, 50], which are essential for long-term adoption [5, 7, 47, 62, 63]. It also remains unclear who benefits the most from these interventions and under which conditions [5, 46, 47], whereas such insights are key for enhancing engagement and inclusivity [47, 64, 65]. **Chapter 6** reported on the feasibility and acceptability of PF, as well as associations between individual characteristics and these outcomes, and on the feasibility of the study procedures. This final aim is particularly important for advancing inclusive mHealth research, as many studies face high dropout rates [50] and difficulties recruiting individuals from lower-SEP groups [4]. Results showed that PF usage varied substantially. On average, satisfaction was moderate to high, usability was okay to good, and virtual coach acceptance was somewhat negative. Higher usage was associated

with greater satisfaction, usability, and coach acceptance. Frequent connection issues with the smartwatch emerged as a disruptive factor. Qualitative findings revealed both positive and negative experiences, such as appreciation for the coach's anonymity and low-threshold access, but also a desire for more varied and adaptive content. Exploratory analyses suggested that high PF users were older than moderate and low PF users, and that PF was perceived as similarly feasible and acceptable across SEP groups. Research procedures and recruitment strategies proved feasible. Overall, PF demonstrated adequate feasibility and acceptability and shows potential as an accessible multi-behavior intervention. Findings provide practical directions for improving future virtual coach interventions and optimizing engagement across diverse populations.

Despite promising findings in previous research, evidence on the real-world effectiveness of virtual coaches for smoking cessation and PA promotion remains limited and heterogeneous [46, 50]. **Chapter 7** reported on the two-month effectiveness of PF in terms of smoking abstinence and PA levels, as well as associations of effectiveness outcomes with baseline characteristics (e.g., SEP), changes in psychosocial factors (e.g., self-identity), and PF usage. Additionally, it reported on participants' experiences with the combined focus on smoking cessation and PA promotion. Findings showed that seven-day point prevalence smoking abstinence was 36.4% post-intervention and 35.4% at two-month follow-up. Self-reported PA more than doubled immediately after the intervention and remained above baseline at follow-up, despite some decline. Participants with lower SEP and those who reported increases in smoking abstinence self-efficacy during the intervention showed higher smoking abstinence probability, while increases in PA self-efficacy were linked to higher PA levels. Changes in non-smoker and PA self-identity showed little association with effectiveness outcomes. Qualitative findings suggested that participants generally appreciated PF's multi-behavior focus and reflection on high-risk situations for relapse prevention, but in actual high-risk moments, they preferred brief distraction and coping tips rather than elaborate exercises or information. To conclude, PF demonstrated potential as an accessible, scalable, multi-behavior intervention with public health relevance. Lessons learned, such as the importance of smartwatch integration and targeted support in high-risk situations, provide guidance for refining PF and developing future virtual coach interventions.

Key insights

Building on the studies summarized above, three key insights emerged. For each of these, promising directions, conditions under which findings may apply, and implications for future intervention design and research are discussed. The first key insight that emerged is as follows:

Insight 1: Virtual coach interventions for smoking cessation and PA promotion can be feasible, acceptable, and effective for lower-SEP and older individuals when developed in close collaboration with the target population.

Interdisciplinary collaboration and PPI

Both interdisciplinary collaboration and PPI were valuable approaches for the development and evaluation of PF, helping to better align the intervention and research with the needs, preferences, and capabilities of the target population.

Interdisciplinary collaboration within the PF team involved researchers from different disciplines, software developers, end-users, healthcare professionals, and other experts [1]. This collaboration fostered innovative solutions while supporting practical feasibility and accessibility. For PF, it enabled the development of features (e.g., the personalized, interactive 'First-aid Kit' designed for use in high-risk situations) that were technically feasible and tailored to potential end-users' needs. In addition, involving end-users and other stakeholders throughout the design and research process particularly contributed to developing the intervention and study procedures with the target population in mind. This is particularly relevant in light of the '**Limited digital inclusion'** challenge mentioned in the General Introduction: mHealth interventions, including those with virtual coaches, often fail to adequately reach and meet the needs of certain populations, such as individuals with lower SEP [2-5]. Findings presented in **Chapter 2** contribute to understanding how end-users (and other stakeholders) can be meaningfully involved in the design and development of virtual coach interventions, addressing **Research question 1**. Some important recommendations and lessons learned from our experience with PPI include: (1) Involve end-users early and allocate sufficient resources and budget for meaningful PPI; (2) tailor participatory activities to end-users' needs, use creative methods to uncover implicit needs, and step into their world; and (3) carry forward knowledge, methods, and networks established through collaboration to support sustained use of PPI in research.

Based on the experiences from the studies in this dissertation, the collaboration with end-users, and the findings presented in Chapter 2, several future directions and recommendations for PPI are proposed. First, researchers are encouraged to foster meaningful collaboration when implementing PPI. While PPI is increasingly recognized [10, 11] and even required by many funders, it often appears to be implemented minimally in practice, primarily to meet external requirements rather than to foster meaningful collaboration. In such cases, PPI may fail to create value for all stakeholders or hinder equitable participation. Achieving meaningful PPI requires a culture change within research, including an open attitude, a genuine willingness to collaborate, and workflows that may differ from traditional long-term research timelines. PPI is a collaborative journey in which researchers are not expected to have all the answers at the start; the process is co-created with

end-users. Researchers may need to embrace flexible, iterative approaches with short cycles, allowing adjustments based on insights gained from close collaboration with end-users. Structured yet adaptable frameworks can guide researchers while allowing adjustments based on insights emerging from collaboration with end-users. Furthermore, fruitful collaboration requires not only that end-users engage with the researchers' world, but also that researchers immerse themselves in the end-users' world to gain a firsthand understanding of their lived experience.

Second, future research should focus on consolidating and expanding PPI practices. Many researchers still implement PPI in isolation from developments within the field of PPI, often reinventing approaches. Researchers are encouraged to prioritize knowledge and network sharing to strengthen the broader adoption of meaningful PPI. Transparent reporting is essential in this regard, for example by using the Guidance for Reporting Involvement of Patients and the Public (GRIPP2) checklist [66]. A key strength of this dissertation is that it not only presents a structured approach to PPI and highlights the importance of transparent reporting, but also consistently applies this in practice. PPI was integrated into the studies where it was applicable, with GRIPP2 short-form checklists included as appendices (in **Chapters 2, 4, and 6**) to support accountability, reproducibility, and knowledge sharing. Sustaining PPI impact beyond individual projects may additionally involve sharing resources openly, connecting end-users to future projects, or embedding PPI more structurally through approaches such as Participatory Action Research [67] or Community-Based Participatory research [68].

Third, engaging target populations in research can be facilitated by actively bridging the gap between research and society. By connecting more closely with the broader public, researchers can create opportunities for interaction, dialogue, and mutual learning, which may help make research more inclusive and better aligned with the needs of target populations. This can be supported, for example, by disseminating research through accessible channels, such as social media, podcasts, blogs, or by participating in public science events (e.g., Lowlands' science program [69] or 'Weekend van de Wetenschap' [70]). Furthermore, PPI approaches such as citizen science (in Dutch: 'burgerwetenschap'), which involves collaboration between citizens and researchers to generate knowledge that benefits citizens, research, and society [71, 72], offer valuable ways to strengthen connections between research and society. Finally, creative participatory methods, including artistic methods such as music, dance, or other cultural activities [73], may further enhance engagement and inclusivity. Bringing research closer to society can facilitate more meaningful PPI and promote research that is both accessible and relevant.

Broad accessibility of interventions and research procedures

By combining interdisciplinary collaboration with the involvement of end-users and other experts [1], PF was developed to meet the needs of individuals who are often underserved by mHealth interventions, such as those with lower (eHealth) literacy or SEP [2-5]. The mixed-methods findings of **Chapters 6 and 7** provide valuable insight into the accessibility of the first functional prototype of PF for these groups. Results showed that PF was moderately feasible and acceptable across different SEP groups and among a relatively older population, with a mean age of approximately 52 years. Interestingly, participants with lower SEP reported even higher satisfaction with PF compared to those with middle or higher SEP. However, this difference was not statistically significant, likely due to limited power to detect small effects. Furthermore, participants with high PF usage were significantly older than those with low or moderate usage. In terms of short-term effectiveness, descriptive results suggested that lower-SEP participants showed higher smoking abstinence rates at the different timepoints compared to middle- or higher-SEP participants. However, these differences did not reach statistical significance and should therefore be interpreted with caution. Still, the consistent pattern across timepoints suggests a potentially meaningful trend worth examining in larger trials. No SEP-related differences were observed for self-reported PA levels. These findings are noteworthy in light of the **'Limited digital inclusion'** challenge, as they suggest that PF was not only feasible, acceptable, and effective for lower-SEP groups but may have been particularly well suited to their needs. The intervention also appeared suitable for older adults, who often have lower digital skills compared to younger individuals. Several design strategies likely contributed to accessibility in these groups. Collaborative development resulted in design choices such as the use of clear, easy-to-understand language (B1-level Dutch) and animated educational videos to support comprehension and user-friendliness; features that were generally positively evaluated in the qualitative interviews. Overall, these findings indicate that virtual coach interventions for smoking cessation and PA promotion can be feasible, acceptable, and effective for lower-SEP and older individuals when developed in close collaboration with the target population (**Insight 1**).

The findings also underscore that efforts to improve accessibility for underserved groups do not automatically translate into suitability for all users, which is an important consideration for future intervention design. The results from **Chapters 6 and 7** suggest that PF may have been somewhat less suited for higher-SEP participants, possibly because its design and content were intentionally simplified to enhance accessibility for those with lower (eHealth) literacy or digital skills. Moreover, qualitative findings from **Chapter 6** suggested that engagement with the intervention required a certain level of challenge and personal relevance. Specifically, participants reported the need for evolving goals and content to maintain relevance, challenge, and a sense of progress. Although designing for inclusivity is essential to reduce health inequalities, these efforts should be

accompanied by the awareness that increasing accessibility for one group may simultaneously reduce engagement in other groups. This raises an important strategic question for future virtual coach intervention development: should interventions aim to serve a broad and heterogeneous audience, or be intentionally designed for a clearly defined primary target population? In practice, this requires balancing the level of personalization needed to reach diverse users, the potential use of different interventions or adaptations for distinct populations, and the efficient allocation of resources while ensuring that no groups are underserved. In some cases, it may be more effective to offer different versions or delivery formats for specific user groups, rather than striving for a single highly personalized solution that attempts to suit all. For instance, Chapter 6 showed that some participants valued the virtual coach for its anonymity, low-threshold access, and the sense of control they experienced, while others preferred a human coach for increased accountability. Such insights emphasize the importance of identifying who benefits most from which type of support and under which conditions, an area where current evidence for virtual coach interventions remains limited [5, 46, 47]. At the same time, resource constraints must be considered, particularly given increasing pressure on healthcare systems [3] and the need to avoid exacerbating – and preferably mitigating – health inequalities. Beyond inclusive research and intervention design, practical strategies are needed to balance accessibility with resource allocation. Examples include offering interventions such as PF as a stand-alone intervention to users who prefer self-guided support or face barriers to human care, while adding low-level human support (e.g., brief human feedback messages [74]) for those who need additional guidance. Adaptive designs that escalate from low-intensity digital support to human involvement at certain moments [75] may further support this balance. Future research should explore how virtual coach interventions can be equitably designed, adapted, or differentiated to meet the needs of diverse user groups, while considering resource allocation.

While the findings from **Chapters 6 and 7** offer promising indications of the accessibility and effectiveness of the first functional prototype of PF, they also highlight several limitations and considerations for the generalizability of the results. Discussing generalizability is particularly important, as transparent reporting of sample characteristics and reflection on the generalizability of virtual coach interventions is often lacking in the literature [47]. A first limitation concerns the SEP measurement. Due to a measurement error in the baseline questionnaire, lower-level (1-2) and middle-level (3-4) vocational education were merged into a single response category. Consequently, all participants with vocational education were classified as having middle SEP, likely leading to an underestimation of the lower-SEP group size and an overestimation of the middle-SEP group size. Moreover, only educational level was used as an indicator of SEP, rather than including additional indicators such as income or occupation. Nevertheless, education is a commonly used SEP indicator and more strongly associated with smoking behavior than other SEP

measures [76, 77]. Furthermore, the findings in Chapters 6 and 7 may not generalize to individuals with low eHealth literacy. The sample generally demonstrated moderate to high eHealth literacy with limited variation, and self-selection may have resulted in the inclusion of participants who were already more comfortable with or interested in digital tools. As a result, the findings likely reflect a group that is more digitally engaged, limiting the generalizability to individuals with lower digital skills. In addition, this first functional prototype of PF was developed only in Dutch, which excludes non-Dutch-speaking users. Therefore, while PF shows promise in improving accessibility and inclusivity, these findings should be interpreted within these contextual boundaries. Future research on virtual coach interventions should clearly specify the populations to which their findings apply to build a more nuanced understanding of who benefits most and under what conditions.

In terms of accessibility, the findings from **Chapters 4 and 6** also provide valuable insights into the accessibility of research procedures. **Chapter 6** showed that recruitment was most successful through newsletters distributed by health insurance companies, followed by social media advertisements (mainly Facebook) and recruitment via personal networks. Importantly, recruitment effectiveness did not differ significantly across SEP groups, suggesting that these strategies reached both lower- and higher-SEP participants equally well. This is encouraging, given the documented challenges of recruiting individuals from lower-SEP groups into digital health research [4]. However, recruitment challenges were encountered in the study described in **Chapter 4**. Although the original aim was to explore the acceptance, usability, and preliminary effectiveness of the prototype virtual coach across SEP groups, this could not be evaluated because most participants in the sample had middle SEP, despite targeted recruitment efforts to include more lower-SEP individuals. A key lesson learned is that inclusive interventions cannot be designed or evaluated without inclusive research procedures. For example, the virtual reality study involved extensive experimental procedures and equipment, necessitating data collection at the Leiden University Medical Center. In hindsight, barriers to study participation could have been reduced by simplifying procedures and conducting the study at more accessible or familiar locations, such as community centers. Integrating the study into local events, workshops, or neighborhood activities might have further enhanced accessibility. Hence, research designs and recruitment should be tailored to underserved groups, and such considerations should be addressed early in the research process. PPI can provide valuable insights into the daily realities of the target population and help researchers adjust study procedures to enhance accessibility. Lessons learned were summarized in Chapter 4 to guide future research and support more inclusive study procedures in virtual coach interventions.

Insight 2: mHealth interventions with virtual coaches can be suitable for supporting individuals in high-risk situations for smoking relapse by providing personalized and timely support.

Support for high-risk situations

Virtual coach interventions have the potential to support individuals in high-risk situations, when relapse to unhealthy behaviors is most likely, due to their ability to provide timely and personalized support. Findings from **Chapters 4 and 7** provide insight into how such support can be delivered. This addresses the challenge **'Insufficient relapse-prevention support in smoking cessation interventions'** discussed in the General Introduction: despite the availability of many smoking cessation interventions, high relapse rates suggest that support in these critical moments is often inadequate [39, 40]. The first functional prototype of PF includes weekly dialogs with the virtual coach to encourage users to reflect on past high-risk situations and (re)lapses, and to anticipate high-risk situations in the upcoming week. This approach was grounded in the Relapse Prevention Model [60, 61]. Qualitative findings from **Chapter 7** indicated that participants found these weekly reflection dialogs valuable, as they provided guidance in preparing for future difficult moments. These findings highlight that incorporating theoretical foundations can increase the likelihood of intervention success, as suggested in prior literature [3, 5], thereby also addressing the challenge **'Lack of evidence-based virtual coach interventions'.**

While a theory-based approach encouraging reflection and planning for high-risk situations appears effective for preparing participants in advance, qualitative findings from **Chapter 7** suggested that such elaborate strategies are not preferred in high-risk situations themselves. In these situations, users preferred brief, concrete, and immediately applicable support rather than extensive exercises, videos, or informational content. Participants expressed a need for short distractions, practical tips, or engaging messages to help them cope with short-term cravings. This finding was supported by **Chapter 4**, in which the neutral dialog with humorous animal facts, originally intended as a control condition, yielded outcomes comparable to the three smoking relapse-prevention dialogs grounded in behavior change techniques. Although the results were not statistically significant, the neutral dialog was associated with lower tobacco craving and higher positive affect compared to the other dialogs, possibly because the humorous animal facts served as a simple distraction from smoking urges. This aligns with previous literature suggesting that distraction-based strategies might help individuals manage cravings in the moment [78, 79]. Findings from Chapters 4 and 7, and the input from the PF end-users advisory panel, further indicate that in-the-moment support should be brief, enjoyable, and easily applicable, helping individuals endure cravings without lapsing. For example, an advisory panel member noted that peeling mandarins during cravings was a practi-

cal way to redirect attention from smoking. Together, these findings suggest that virtual coach interventions can support individuals in high-risk situations by providing personalized and timely support (**Insight 2**). Specifically, a combination of reflection on past high-risk situations and learning coping strategies before and after high-risk situations, and brief, distraction-based support in the moment may help individuals manage relapse risks and cravings effectively. Further research should explore which types of concrete tips, distractions, or other forms of in-the-moment support are most effective in helping users cope with cravings and maintain abstinence. It is also important to note that these findings primarily relate to support for smoking-related high-risk situations, as Chapter 4 focused solely on smoking, and participants in Chapter 7 mainly discussed this topic in relation to smoking cravings and relapses. This is expected, as smoking cravings are more salient and noticeable than fluctuations in PA motivation. Future studies could therefore investigate whether similar support strategies can also help individuals overcome barriers to engaging in PA.

The findings of this dissertation also provide insight into the potential of identity-related strategies for relapse-prevention support and their use in virtual coach interventions for smoking cessation and PA promotion in general. **Chapter 3** suggests that identity-related interventions show promise for both behaviors, but their optimal design and application remain unclear. **Chapter 4** further explored the application of identity-based strategies by examining their use within a proof-of-concept virtual coach in high-risk situations for smoking relapse. The results indicated that the two identity-based dialogs performed comparably to a more traditional motivation- and self-efficacy-boosting dialog. Although the identity-based dialogs did not perform worse than the more established dialog, the results might suggest that high-risk situations may not be the optimal context for applying identity-related strategies, at least in the form examined in this virtual reality study. These findings also align with the previously discussed observation that participants in such situations tend to prefer briefer and more distraction-based support, as illustrated by the outcomes of the neutral dialog with humorous animal facts. Furthermore, **Chapter 7** explored identity-related processes in the context of the first functional prototype of PF. Qualitative findings suggested that some participants experienced shifts in non-smoker self-identity, indicating potential effects of the identity-based strategies integrated into PF. However, qualitative feedback on this topic was limited and not observed for PA self-identity. In addition, quantitative analyses showed no significant association between self-identity changes and smoking abstinence or self-reported PA, but this may also be due to relatively high baseline non-smoking and PA self-identity in the sample, or the study being underpowered to detect such effects. Taken together, these findings indicate that identity-related strategies are promising, but further research is needed to clarify how and when they can be optimally integrated into virtual coach interventions.

A limitation of the research conducted for this dissertation concerns the lack of integration of the proof-of-concept virtual coach study results (**Chapter 4**) into the first functional prototype of PF (**Chapters 5-7**). Ideally, findings from Chapter 4 on the preliminary effectiveness of support strategies for high-risk situations would have informed the design of brief, distraction-based support in PF, co-created with end-users, and subsequently evaluated in the mixed-methods study. Although this was planned, it appeared unfeasible due to conflicting timelines. The experimental design and ethical approval process of Chapter 4 were time-intensive, and recruitment of lower-SEP participants was challenging, resulting in delays. Meanwhile, the development of the first functional prototype of PF had already progressed, as intervention content creation, software development, testing, refinement, and evaluation required multiple years. This reflects a broader challenge in eHealth research: the rapid, iterative development cycles of digital interventions often do not align with the more rigid and lengthy timelines of traditional research designs [8, 64]. Therefore, it is recommended to use more rapid and flexible study designs, such as the Multiphase Optimization Strategy (MOST)[80], alongside shorter, iterative evaluation cycles, which can facilitate more efficient testing of proof-of-concept components in digital interventions, as also suggested in recent literature [3, 56, 64]. Nevertheless, involving end-users throughout the development process proved highly valuable in this project, as insights from the end-user advisory group could be quickly integrated into PF's design choices and intervention components. Future research should therefore consider combining PPI with more adaptive evaluation approaches. This would enable preliminary findings to inform subsequent development steps and thereby enhance the relevance, usability, and effectiveness of virtual coach interventions.

Overall, the results from **Chapters 3, 4, and 7** provide important insights into evaluating and incorporating (emerging) behavior change techniques into virtual coach interventions for smoking cessation and PA promotion, addressing **Research question 2**.

> **Insight 3: Virtual coach interventions can be feasible, acceptable, and effective in the short-term in real-world settings when combining theory-based content, personalization, and a dual-behavior focus.**

Virtual coach interventions for smoking cessation and PA promotion

The previous sections discussed PF's feasibility, acceptability, and two-month effectiveness, as well as key considerations, limitations, future directions, and initial implications for implementation, thereby addressing **Research question 3**. In short, the findings from **Chapters 6 and 7** indicated that the first functional prototype of PF was moderately feasible and acceptable, and showed promise as an accessible, multi-behavior virtual coach intervention. At two-month follow-up, PF achieved a promising smoking abstinence rate of approximately 35%, a conservative estimate based on the Russell Standard

(i.e., classifying participants with missing data as smoking)[81]. In addition, participants reported increased PA levels compared to baseline at the same time point. Findings also provided preliminary indications that PF could be used as a stand-alone intervention or alongside other support, such as smoking cessation medication. **Chapter 5** presented a comprehensive overview of PF, describing its components and features, their intended aims, and the supporting evidence. Together, Chapter 5 and the findings from Chapters 6 and 7 address the challenge of **'Limited reporting transparency and heterogeneous evidence on virtual coach interventions'** outlined in the General Introduction. Below, three key elements emerging from these findings are highlighted as particularly promising or important for informing the development of future virtual coach interventions.

First, grounding virtual coach interventions in relevant behavior change techniques and theoretical frameworks is crucial for increasing the likelihood of success and understanding mechanisms of behavior change [3, 5]. This approach was intentionally applied in PF. Qualitative feedback from **Chapter 7** reflected several evidence-based strategies embedded in PF, such as self-monitoring and problem-solving in high-risk situations, and linked these strategies to behavior changes. This suggests that these strategies contributed to the promising smoking abstinence and PA outcomes. By transparently reporting PF's content and theoretical foundations, employing a mixed-methods approach, and examining associations between individual factors and outcomes in **Chapters 5-7**, this dissertation provides insights into user experiences, potentially active intervention ingredients, and contextual influences on outcomes. In doing so, it contributes to the cumulative knowledge base on virtual coach interventions, while addressing the challenges **'Lack of evidence-based virtual coach interventions'** and **'Limited reporting transparency and heterogeneous evidence on virtual coach interventions'**. Finally, by making PF's intervention development [1], content [82], technical architecture [83], and source code [84] publicly available, we aimed to promote reusability, accessibility, and facilitate future research on virtual coach interventions.

Second, personalization is crucial for increasing the success of virtual coach interventions. **Chapter 6** revealed substantial variation in participants' experiences of PF's feasibility, acceptability, and appreciation of specific components, and qualitative feedback suggested that engagement was higher when the intervention felt personally relevant. These findings align with prior literature highlighting the importance of interactive and tailored interventions [56, 64, 85]. PF already incorporated several personalization strategies, such as allowing users to choose exercises or the duration of their preparation phase, which participants valued. However, feedback also identified opportunities for further personalization. For instance, the participants noted that the virtual coach was not always sufficiently adaptive to their input or personal situations, indicating the potential for greater content variation and responsiveness. Emerging technologies, such as large language

models, could enhance adaptability and personalization [5, 46, 50, 85, 86], though care is needed to maintain accuracy, consistency, and safety. Furthermore, as engagement can change over time [87], personalization based on dynamic user states (e.g., motivation, self-efficacy) may further support engagement and effectiveness in future virtual coach interventions [74, 88].

Third, targeting both smoking cessation and PA promotion in a single multi-behavior intervention appears promising. Although no significant quantitative association was observed between smoking abstinence and self-reported PA levels, qualitative findings in **Chapters 6 and 7** showed that the combined focus of PF was positively received. Most participants indicated in the interviews that they valued the dual-behavior approach for several reasons. For instance, they described PA as a pleasant distraction from smoking, noted that PA felt easier as their fitness and energy improved after quitting, and experienced changing both behaviors as contributing to their broader health goal. These findings align with previous literature and reflect the assumed synergy between smoking cessation and PA promotion [52-55]. The addition of the smartwatch likely contributed to this, as participants found it motivating, allowing them to monitor progress and receive personalized feedback, which made PA more rewarding. At the same time, the smartwatch posed challenges. Frequent connection issues between the smartwatch and the virtual coach disrupted the intervention, were reported as a reason for early dropout, and likely reduced overall PF usage. Moreover, these issues led to a high percentage of missing objective PA data (approximately 57%). In addition, self-reported PA data were highly skewed, with extreme outliers. This limits the reliability of absolute values, although within-subject trends likely still provide useful information. These data limitations may have contributed to the lack of a significant quantitative association between smoking abstinence and self-reported PA levels. Had reliable smartwatch data been available, this could have offered richer insights into this association as well as into PA changes over time. Future studies could further investigate the dynamic interplay between smoking cessation and PA promotion in virtual coach interventions by integrating (smartwatch-based) Ecological Momentary Assessment methods for both smoking behavior [89] and PA [90]. Lessons learned regarding smartwatch implementation were reported in Chapter 6, providing guidance for future research.

Overall, the findings of this dissertation indicate that virtual coach interventions can be feasible and acceptable, and show potential for supporting short-term smoking cessation and PA, especially when combining theory-based content, personalization, and a dual-behavior focus (**Insight 3**). The findings lay important groundwork for follow-up research evaluating PF's long-term effectiveness at 6- and 12-month follow-up, which will provide insights into the potential to facilitate long-term behavior change and further inform the development of virtual coach interventions.

General conclusions

This dissertation focused on the content development and design (Part 1) and real-world evaluation (Part 2) of mHealth interventions with virtual coaches, thereby addressing key challenges identified in the literature.

To address the first challenge, **'Limited digital inclusion'**, this dissertation highlights the importance of interdisciplinary collaboration and PPI, and designing interventions and research procedures with broad accessibility in mind. A practical, step-by-step approach for meaningful PPI in eHealth research, including virtual coach interventions research, was shared. The studies in this dissertation resulted in the first main insight: virtual coach interventions for smoking cessation and PA promotion can be feasible, acceptable, and effective for lower-SEP and older individuals when developed in close collaboration with end-users.

Building on the second challenge**, 'Lack of evidence-based virtual coach interventions'**, and the third challenge, **'Insufficient relapse-prevention support in smoking cessation interventions'**, this dissertation highlights the importance of grounding virtual coach interventions in relevant behavior change techniques and theory. Insights were shared on their application in high-risk situations for smoking relapse, as well as on incorporating and evaluating emerging approaches, such as identity-related techniques. The findings resulted in the second main insight: mHealth interventions with virtual coaches can be suitable for supporting individuals in high-risk situations for smoking relapse by providing personalized and timely support.

Addressing the fourth challenge, **'Limited reporting transparency and heterogeneous evidence on virtual coach interventions'**, this dissertation contributes to transparent intervention reporting and real-world evaluation to improve understanding of active ingredients, behavior change mechanisms, and contextual factors, enhance reusability, and build a cumulative knowledge base. The real-world evaluation of PF's first functional prototype led to the third main insight: virtual coach interventions can be feasible, acceptable, and effective in the short term when combining theory-based content, personalization, and a dual-behavior focus.

Overall, this dissertation represents a crucial step in developing and evaluating accessible virtual coach interventions to support smoking cessation and PA, demonstrating the potential of such multi-behavior interventions to benefit public health.

References

1. Versluis A, Penfornis KM, van der Burg SA, Scheltinga BL, van Vliet MHM, Albers N, et al. Targeting Key Risk Factors for Cardiovascular Disease in At-Risk Individuals: Developing a Digital, Personalized, and Real-Time Intervention to Facilitate Smoking Cessation and Physical Activity. JMIR cardio. 2024;8(1):e47730.
2. Keij B, Versluis A, Alblas EE, Keuper JJ, van Tuyl LHD, van der Vaart R. E-healthmonitor 2023: stand van zaken digitale zorg. [Internet]. Rijksinstituut voor Volksgezondheid en Milieu (RIVM); 2024 [cited 2025 March 21]. Available from: https://www.nivel.nl/nl/publicatie/e-healthmonitor-2023-stand-van-zaken-digitale-zorg.
3. van der Kleij RMJJ, Kasteleyn MJ, Meijer E, Bonten TN, Houwink IJF, Teichert M, et al. SERIES: eHealth in primary care. Part 1: Concepts, conditions and challenges. Eur J Gen Pract. 2019;25(4):179-89. https://doi.org/10.1080/13814788.2019.1658190.
4. Al-Dhahir I, Reijnders T, Faber JS, van den Berg-emons RJ, Janssen VR, Kraaijenhagen RA, et al. The Barriers and Facilitators of eHealth-Based Lifestyle Intervention Programs for People With a Low Socioeconomic Status: Scoping Review. J Med Internet Res. 2022;24(8). https://doi.org/10.2196/34229.
5. He L, Balaji D, Wiers RW, Antheunis ML, Krahmer E. Effectiveness and Acceptability of Conversational Agents for Smoking Cessation: A Systematic Review and Meta-analysis. Nicotine Tob Res. 2023;25(7):1241-50. https://doi.org/10.1093/ntr/ntac281.
6. Marcolino MS, Oliveira JAQ, D'Agostino M, Ribeiro AL, Alkmim MBM, Novillo-Ortiz D. The Impact of mHealth Interventions: Systematic Review of Systematic Reviews. Jmir Mhealth Uhealth. 2018;6(1). https://doi.org/10.2196/mhealth.8873.
7. Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. Bmj-Brit Med J. 2021;374. https://doi.org/10.1136/bmj.n2061.
8. Kip H, Beerlage-de Jong N, van Gemert-Pijnen L, Kelders SM. The CeHRes Roadmap 2.0: Update of a Holistic Framework for Development, Implementation, and Evaluation of eHealth Technologies. J Med Internet Res. 2025;27(1):e59601. https://doi.org/10.2196/59601.
9. Health Research Authority. Public involvement in research n.d. [Available from: https://www.hra.nhs.uk/planning-and-improving-research/best-practice/public-involvement/.
10. Harrison JD, Auerbach AD, Anderson W, Fagan M, Carnie M, Hanson C, et al. Patient stakeholder engagement in research: A narrative review to describe foundational principles and best practice activities. Health Expect. 2019;22(3):307-16. https://doi.org/10.1111/hex.12873.
11. Vanneste A, Wens I, Sinnaeve P, Louati C, Huys I, Ioannidis JPA, et al. Evolution of reported patient and public involvement over time in randomised controlled trials in major medical journals and in their protocols: meta-epidemiological evaluation. BMJ. 2025;389:e082697. https://doi.org/10.1136/bmj-2024-082697.
12. Hughes M, Duffy C. Public involvement in health and social sciences research: A concept analysis. Health Expect. 2018;21(6):1183-90. https://doi.org/10.1111/hex.12825.
13. Barnett G, Boduszek D, Willmott D. What works to change identity? A rapid evidence assessment of interventions. Journal of Applied Social Psychology. 2021(51):698-719. https://doi.org/10.1111/jasp.12776.
14. Burke PJ, Stets JE. Identity theory: Oxford University Press. New York, NY. 2009.
15. Notley C, West R, Soar K, Hastings J, Cox S. Toward an ontology of identity-related constructs in addiction, with examples from nicotine and tobacco research. Addiction. 2023;118(3):548-57. https://doi.org/10.1111/add.16079.

16. Oyserman D, Elmore K, Smith G. Self, self-concept, and identity. Handbook of self and identity, 2nd ed. New York: The Guilford Press; 2012. p. 69-104.
17. Penfornis KM, van Vliet MHM, von Haeseler EF, Gebhardt WA, Meijer E. Conceptualisation, operationalisation and role of identity in physical activity and smoking in individuals aged 45 and over: a systematic scoping review. BMJ Open. 2025;15(7):e097232. https://doi.org/10.1136/bmjopen-2024-097232.
18. Rhodes RE, Kaushal N, Quinlan A. Is physical activity a part of who I am? A review and meta-analysis of identity, schema and physical activity. Health Psychol Rev. 2016;10(2):204-25. https://doi.org/10.1080/17437199.2016.1143334.
19. Markus H, Nurius P. Possible Selves. Am Psychol. 1986;41(9):954-69. https://doi.org/10.1037/0003-066x.41.9.954.
20. Barreto ML, Frazier LD. Coping With Life Events Through Possible Selves. Journal of Applied Social Psychology. 2012;42(7):1785-810. https://doi.org/10.1111/j.1559-1816.2012.00918.x.
21. Ouellette JA, Hessling R, Gibbons FX, Reis-Bergan M, Gerrard M. Using images to increase exercise behavior: Prototypes versus possible selves. Pers Soc Psychol B. 2005;31(5):610-20. https://doi.org/10.1177/0146167204271589.
22. Strachan SM, Marcotte MME, Giller TMT, Brunet J, Schellenberg BJI. An online intervention to increase physical activity: Self-regulatory possible selves and the moderating role of task self-efficacy. Psychol Sport Exerc. 2017;31:158-65. https://doi.org/10.1016/j.psychsport.2016.05.001.
23. Penfornis KM, Gebhardt WA, Rippe RCA, van Laar C, van den Putte B, Meijer E. My future-self has (not) quit smoking: An experimental study into the effect of a future-self intervention on smoking-related self-identity constructs. Soc Sci Med. 2023;320:115667. https://doi.org/10.1016/j.socscimed.2023.115667.
24. Meijer E, Gebhardt WA, van Laar C, van den Putte B, Evers AWM. Strengthening quitter self-identity: An experimental study. Psychol Health. 2018;33(10):1229-50. https://doi.org/10.1080/08870446.2018.1478976.
25. Chan CKY, Cameron LD. Promoting physical activity with goal-oriented mental imagery: a randomized controlled trial. J Behav Med. 2012;35(3):347-63. https://doi.org/10.1007/s10865-011-9360-6.
26. Meslot C, Gauchet A, Allenet B, Francois O, Hagger MS. Theory-Based Interventions Combining Mental Simulation and Planning Techniques to Improve Physical Activity: Null Results from Two Randomized Controlled Trials. Front Psychol. 2016;7. https://doi.org/10.3389/fpsyg.2016.01789.
27. Murru EC, Ginis KAM. Imagining the Possibilities: The Effects of a Possible Selves Intervention on Self-Regulatory Efficacy and Exercise Behavior. J Sport Exercise Psy. 2010;32(4):537-54. https://doi.org/10.1123/jsep.32.4.537.
28. Perras MGM, Strachan SM, Fortier MS, Dufault B. Impact of a randomized possible selves experiment on new retirees' physical activity and identity. Eur Rev Aging Phys A. 2016;13. https://doi.org/10.1186/s11556-016-0167-x.
29. Priebe CS, Beauchamp M, Wunderlich K, Faulkner G. "I'm a runner not a smoker": Changes in identity as predictors of smoking cessation and physical activity. Psychol Sport Exerc. 2020;49. https://doi.org/10.1016/j.psychsport.2020.101702.
30. Cooke LM, Duncan LR, Deck SJ, Hall CR, Rodgers WM. An examination of changes in exercise identity during a mental imagery intervention for female exercise initiates. Int J Sport Exerc Ps. 2020;18(4):534-50. https://doi.org/10.1080/1612197x.2019.1593216.

31. Husband CJ, Wharf-Higgins J, Rhodes RE. A feasibility randomized trial of an identity-based physical activity intervention among university students. Health Psychol Behav. 2019;7(1):128-46. https://doi.org/10.1080/21642850.2019.1600407.
32. Morris KL, Goldenberg JL, Arndt J, McCabe S. The enduring influence of death on health: insights from the terror management health model. Self Identity. 2019;18(4):378-404. https://doi.org/10.1080/15298868.2018.1458644.
33. Hollman H, Sui WY, Rhodes RE. A feasibility randomized controlled trial of a multi-process action control web-based intervention that targets physical activity in mothers. Women Health. 2022;62(5):384-401. https://doi.org/10.1080/03630242.2022.2072050.
34. Fox J, Bailenson JN. Virtual Self-Modeling: The Effects of Vicarious Reinforcement and Identification on Exercise Behaviors. Media Psychol. 2009;12(1):1-25. https://doi.org/10.1080/15213260802669474.
35. Kastenmüller A, Greitemeyer T, Fairclough S, Waite D, Fischer P. Playing Exergames and Sporting Activity The Impact of Identification with One's Game Character. Soc Psychol-Germany. 2013;44(4):264-70. https://doi.org/10.1027/1864-9335/a000111.
36. Song H, Kim J, Kwon RJ, Jung Y. Anti-smoking educational game using avatars as visualized possible selves. Comput Hum Behav. 2013;29(5):2029-36. https://doi.org/10.1016/j.chb.2013.04.008.
37. Helweg-Larsen M, Pyakuryal M, Pisinger C. Reminders of a Stigmatized Status Might Help Smokers Quit. Stigma Health. 2020;5(3):273-83. https://doi.org/10.1037/sah0000197.
38. Strachan SM, Brawley LR. Reactions to a perceived challenge to identity - A focus on exercise and healthy eating. J Health Psychol. 2008;13(5):575-88. https://doi.org/10.1177/1359105308090930.
39. Ferrer-Garcia M, Garcia-Rodriguez O, Pericot-Valverde I, Yoon JH, Secades-Villa R, Gutierrez-Maldonado J. Predictors of Smoking Craving During Virtual Reality Exposure. Presence-Teleop Virt. 2012;21(4):423-34. https://doi.org/10.1162/PRES_a_00125.
40. Selby P, Zawertailo L. Tobacco addiction. New England Journal of Medicine. 2022;387(4):345-54.
41. Kock L, Brown J, Hiscock R, Tartan-Birch H, Smith C, Shahab L. Individual-level behavioural smoking cessation interventions tailored for disadvantaged socioeconomic position: a systematic review and meta-regression. Lancet Public Health. 2019;4(12):E628-E44. https://doi.org/10.1016/S2468-2667(19)30220-8.
42. Reid JL, Hammond D, Boudreau C, Fong GT, Siahpush M, Collaboration I. Socioeconomic disparities in quit intentions, quit attempts, and smoking abstinence among smokers in four western countries: Findings from the International Tobacco Control Four Country Survey. Nicotine Tob Res. 2010;12:S20-S33. https://doi.org/10.1093/ntr/ntq051.
43. Shadel WG, Cervone D. Evaluating social-cognitive mechanisms that regulate self-efficacy in response to provocative smoking cues: An experimental investigation. Psychol Addict Behav. 2006;20(1):91-6. https://doi.org/10.1037/0893-164x.20.1.91.
44. Naughton F. Delivering "Just-In-Time" Smoking Cessation Support Via Mobile Phones: Current Knowledge and Future Directions. Nicotine Tob Res. 2017;19(3):379-83. https://doi.org/10.1093/ntr/ntw143.
45. Pericot-Valverde I, Germeroth LJ, Tiffany ST. The Use of Virtual Reality in the Production of Cue-Specific Craving for Cigarettes: A Meta-Analysis. Nicotine Tob Res. 2016;18(5):538-46. https://doi.org/10.1093/ntr/ntv216.

46. Oh YJ, Zhang J, Fang ML, Fukuoka Y. A systematic review of artificial intelligence chatbots for promoting physical activity, healthy diet, and weight loss. Int J Behav Nutr Phys Act. 2021;18(1):160. https://doi.org/10.1186/s12966-021-01224-6.
47. Milne-Ives M, de Cock C, Lim E, Shehadeh MH, de Pennington N, Mole G, et al. The Effectiveness of Artificial Intelligence Conversational Agents in Health Care: Systematic Review. J Med Internet Res. 2020;22(10). https://doi.org/10.2196/20346.
48. Perski O, Crane D, Beard E, Brown J. Does the addition of a supportive chatbot promote user engagement with a smoking cessation app? An experimental study. Digit Health. 2019;5. https://doi.org/10.1177/2055207619880676.
49. Santarossa S, Kane D, Senn CY, Woodruff SJ. Exploring the Role of In-Person Components for Online Health Behavior Change Interventions: Can a Digital Person-to-Person Component Suffice? J Med Internet Res. 2018;20(4). https://doi.org/10.2196/jmir.8480.
50. Bendotti H, Lawler S, Chan GCK, Gartner C, Ireland D, Marshall HM. Conversational artificial intelligence interventions to support smoking cessation: A systematic review and meta-analysis. Digit Health. 2023;9. https://doi.org/10.1177/20552076231211634.
51. Duan YP, Shang BR, Liang W, Du GH, Yang M, Rhodes RE. Effects of eHealth-based multiple health behavior change interventions on physical activity, healthy diet, and weight in people with noncommunicable diseases: systematic review and meta-analysis. J Med Internet Res. 2021;23(2). https://doi.org/10.2196/23786.
52. Prochaska JJ, Prochaska JO. A Review of Multiple Health Behavior Change Interventions for Primary Prevention. Am J Lifestyle Med. 2011;5(3):208-21. https://doi.org/10.1177/1559827610391883.
53. Kunicki ZJ, Hallgren M, Uebelacker LA, Brown RA, Price LH, Abrantes AM. Examining the effect of exercise on the relationship between affect and cravings among smokers engaged in cessation treatment. Addict Behav. 2022;125. https://doi.org/10.1016/j.addbeh.2021.107156.
54. Zhou YH, Feng WX, Guo YG, Wu JH. Effect of exercise intervention on smoking cessation: a meta-analysis. Front Physiol. 2023;14. https://doi.org/10.3389/fphys.2023.1221898.
55. Berkovitch A, Kivity S, Klempfner R, Segev S, Milwidsky A, Goldenberg I, et al. Time-dependent relation between smoking cessation and improved exercise tolerance in apparently healthy middle-age men and women. Eur J Prev Cardiol. 2015;22(6):807-14. https://doi.org/10.1177/2047487314535116.
56. Riley WT. Theoretical models to inform technology-based health behavior interventions. LA, Marsch, SE, Lord, J Dallery,(Eds), Behavioral health care and technology: Using science-based innovations to transform practice. 2014:13-26.
57. Michie S, Hyder N, Walia A, West R. Development of a taxonomy of behaviour change techniques used in individual behavioural support for smoking cessation. Addict Behav. 2011;36(4):315-9. https://doi.org/10.1016/j.addbeh.2010.11.016.
58. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. Psychol Health. 2011;26(11):1479-98. https://doi.org/10.1080/08870446.2010.540664.
59. West R, Brown J. Theory of Addiction. 2nd ed. Hoboken, New Jersey: Wiley-Blackwell; 2013.
60. Marlatt GA, Donovan DM. Relapse prevention: Maintenance strategies in the treatment of addictive behaviors. New York, NY: Guilford press; 2007 Dec 26.
61. Parks GA, Anderson BK, Marlatt GA. Relapse prevention therapy. The essential handbook of treatment and prevention of alcohol problems. 2004:87.

62. Versluis A, van Luenen S, Meijer E, Honkoop PJ, Pinnock H, Mohr DC, et al. SERIES: eHealth in primary care. Part 4: Addressing the challenges of implementation. Eur J Gen Pract. 2020;26(1):140-5. https://doi.org/10.1080/13814788.2020.1826431.
63. Suijkerbuijk A, de Bruijn A, Stok M, Jansen M. Zorginnovaties. Een checklist voor succesvolle implementatie [Internet]. Rijksinstituut voor Volksgezondheid en Milieu; 2022 [cited 2025 March 31]. Available from: https://www.rivm.nl/documenten/zorginnovaties-checklist-voor-succesvolle-implementatie.
64. Domin A, Spruijt-Metz D, Theisen D, Ouzzahra Y, Vögele C. Smartphone-Based Interventions for Physical Activity Promotion: Scoping Review of the Evidence Over the Last 10 Years. Jmir Mhealth Uhealth. 2021;9(7). https://doi.org/10.2196/24308.
65. Gold N, Yau A, Rigby B, Dyke C, Remfry EA, Chadborn T. Effectiveness of Digital Interventions for Reducing Behavioral Risks of Cardiovascular Disease in Nonclinical Adult Populations: Systematic Review of Reviews. J Med Internet Res. 2021;23(5):e19688. https://doi.org/10.2196/19688.
66. Staniszewska S, Brett J, Simera I, Seers K, Mockford C, Goodlad S, et al. GRIPP2 reporting checklists: tools to improve reporting of patient and public involvement in research. Res Involv Engagem. 2017;3:13. https://doi.org/10.1186/s40900-017-0062-2.
67. Baum F, MacDougall C, Smith D. Participatory action research. J Epidemiol Community Health. 2006;60(10):854-7. https://doi.org/10.1136/jech.2004.028662.
68. Collins SE, Clifasefi SL, Stanton J, Straits KJE, Gil-Kashiwabara E, Espinosa PR, et al. Community-Based Participatory Research (CBPR): Towards Equitable Involvement of Community in Psychology Research. Am Psychol. 2018;73(7):884-98. https://doi.org/10.1037/amp0000167.
69. Lowlands. Lowlands Science n.d. [cited 2025 October 15]. Available from: https://lowlands.nl/ll-science/.
70. Weekend van de Wetenschap. Weekend van de Wetenschap 2025 [cited 2025 October 15]. Available from: https://weekendvandewetenschap.nl/.
71. Wildevuur S, Dorrestijn S, Jukema J, Remmers G, Wolkorte R, van Wijk RM, et al. Veldboek burgerwetenschap voor gezondheid: Praktijkervaringen in regio Twente. Enschede: DesignLab, Universiteit Twente; 2023.
72. Van Gestel ECE, Nagelhout GE, Mogendorff KG, Mogana M, Rougour M, Remmers G, et al. De Kracht van Burgerwetenschap in het Gezondheidsdomein. Enschede, Breda, Amsterdam: Universiteit Twente, Avans Hogeschool, Mijn Data | Onze Gezondheid; 2025.
73. MacFarlane A, Papya A, Guha S, Phelan H. Time to sing? The use of music and singing as participatory methods to facilitate co-production in implementation science [Conference session]. European Implementation Collaborative (EIC); 2025 [cited 2025 October 15]. Available from: https://implementation.eu/wp-content/uploads/2025/09/Agenda_EIC-General-Assembly_23102025.pdf.
74. Albers N, Melo FS, Neerincx MA, Kudina O, Brinkman WP. Psychological, economic, and ethical factors in human feedback for a chatbot-based smoking cessation intervention. Npj Digit Med. 2025;8(1). https://doi.org/10.1038/s41746-025-01701-3.
75. Castro O, Mair JL, Zheng SL, Tan SYX, Jabir AI, Yan XX, et al. The LvL UP trial: Protocol for a sequential, multiple assignment, randomised controlled trial to assess the effectiveness of a blended mobile lifestyle intervention. Contemp Clin Trials. 2025;150. https://doi.org/10.1016/j.cct.2025.107833.
76. Schaap MM, Kunst AE. Monitoring of socio-economic inequalities in smoking: Learning from the experiences of recent scientific studies. Public Health. 2009;123(2):103-9. https://doi.org/10.1016/j.puhe.2008.10.015.

77. Wetter DW, Cofta-Gunn L, Irvin JE, Fouladi RT, Wright K, Daza P, et al. What accounts for the association of education and smoking cessation? Prev Med. 2005;40(4):452-60. https://doi.org/10.1016/j.ypmed.2004.07.001.
78. DeLaughter KL, Sadasivam RS, Kamberi A, English TM, Seward GL, Chan SW, et al. Crave-Out: A Distraction/Motivation Mobile Game to Assist in Smoking Cessation. Jmir Serious Games. 2016;4(1):E3-U59. https://doi.org/10.2196/games.4566.
79. Schlam TR, Baker TB. Playing Around with Quitting Smoking: A Randomized Pilot Trial of Mobile Games as a Craving Response Strategy. Games Health J. 2020;9(1):64-70. https://doi.org/10.1089/g4h.2019.0030.
80. Collins LM, Murphy SA, Strecher V. The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART): new methods for more potent eHealth interventions. Am J Prev Med. 2007;32(5 Suppl):S112-8. https://doi.org/10.1016/j.amepre.2007.01.022.
81. West R, Hajek P, Stead L, Stapleton J. Outcome criteria in smoking cessation trials: proposal for a common standard. Addiction. 2005;100(3):299-303. https://doi.org/10.1111/j.1360-0443.2004.00995.x.
82. Versluis A, Penfornis KM, van Vliet MHM, Albers N, Scheltinga BL, van der Burg SA, et al. Perfect Fit virtual coaching intervention for smoking cessation and physical activity: Dialogs and exercises: Open Science Framework (OSF); 2024 [cited 2025 October 30]. Available from: https://osf.io/ngaje/overview.
83. Baccinelli W, Van Der Burg S, Richardson R, Smits D, Geng C, Ridder L, et al., editors. Reusable virtual coach for smoking cessation and physical activity coaching. Proceedings of the 22nd ACM International Conference on Intelligent Virtual Agents; 2022.
84. van der Burg S, Baccinelli W, Richardson R, Scheltinga B, Albers N, Smits D, et al. Perfect-Fit (v.1.0.0) [Software]. Zenodo; 2024 [cited 2024 April 17]. Available from: https://doi.org/10.5281/zenodo.10837093.
85. Ng YJX, Cheong SHR, Ang WW, Lau Y, Lau ST. Types, functions, and mechanisms of machine learning for personalizing smoking cessation interventions: A systematic scoping review. Artif Intell Med. 2025;170. https://doi.org/10.1016/j.artmed.2025.103274.
86. Almusharraf F, Rose J, Selby P. Engaging Unmotivated Smokers to Move Toward Quitting: Design of Motivational Interviewing-Based Chatbot Through Iterative Interactions. J Med Internet Res. 2020;22(11). https://doi.org/10.2196/20251.
87. He L, Braggaar A, Basar E, Krahmer E, Antheunis M, Wiers R, editors. Exploring user engagement through an interaction lens: what textual cues can tell us about human-chatbot interactions. Proceedings of the 6th ACM Conference on Conversational User Interfaces; 2024.
88. He LW, Basar E, Wiers RW, Antheunis ML, Krahmer E. Chatting your way to quitting: A longitudinal exploration of smokers' interaction with a cessation chatbot. Internet Interv. 2025;39. https://doi.org/10.1016/j.invent.2025.100806.
89. Elling JM, de Vries H, Candel MJJM, Crutzen R. Contextual Factors Associated With Temptations and Lapses Among Smokers Trying to Quit An Ecological Momentary Assessment Study. Z Psychol. 2023;231(4):278-90. https://doi.org/10.1027/2151-2604/a000536.
90. To QG, Green C, Vandelanotte C. Feasibility, Usability, and Effectiveness of a Machine Learning-Based Physical Activity Chatbot: Quasi-Experimental Study. Jmir Mhealth Uhealth. 2021;9(11). https://doi.org/10.2196/28577.