Developing digital health interventions for falls prevention

An innovative user-centered design approach

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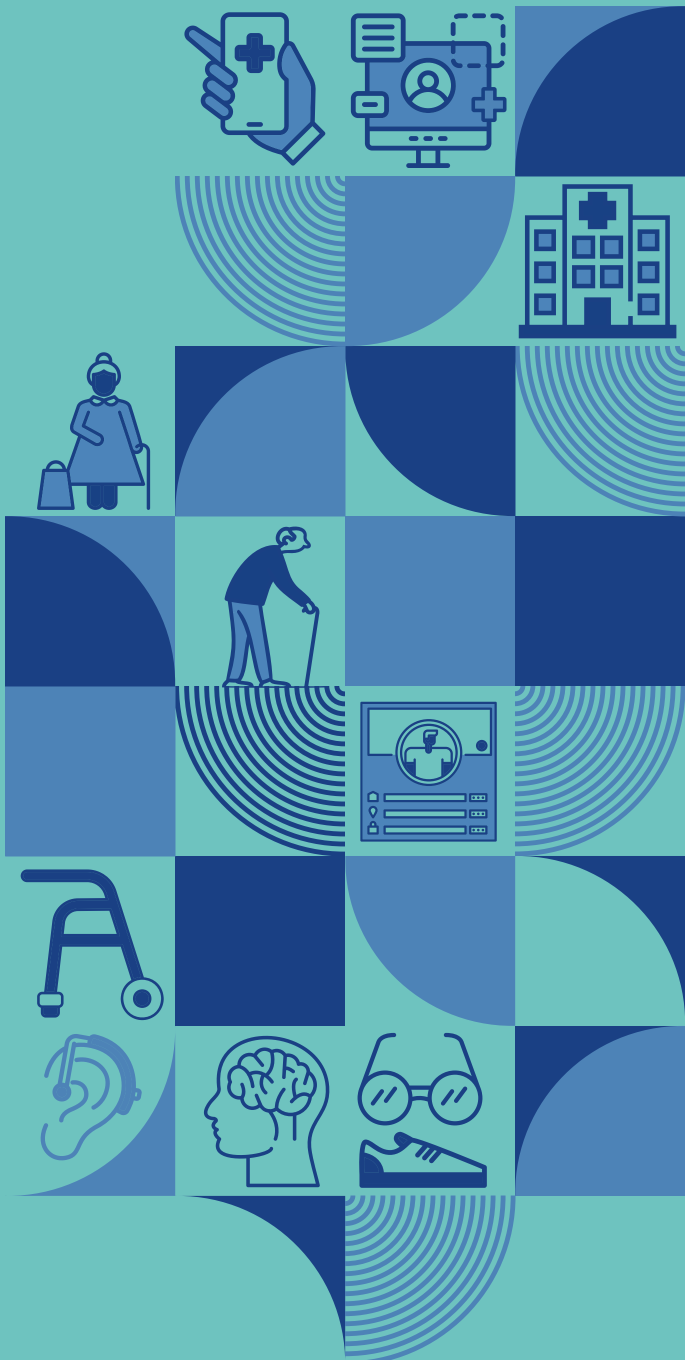
Chapter 7

General discussion



Digital health interventions have the potential to improve the efficiency and quality of care delivery for health care professionals (HCPs) in real-life practice settings, provided these interventions are effectively designed to meet user needs (Gupta et al., 2022). In this dissertation, I applied an innovative User-Centered Design (UCD) approach to develop digital health interventions for falls prevention with three central aims. First, I aimed to set new standards for examining the needs of prospective users to inform the effective development of digital health interventions. To achieve this aim, I illustrated how constructing personas (i.e., descriptions of fictitious users) embedded in behavioral theory and a journey map (i.e., pathways visualizing user engagement) can facilitate a comprehensive understanding into the needs of prospective users, which can foster user-focused thinking when informing the design and implementation requirements for digital health interventions (**chapter 2** and **chapter 3**). Second, I aimed to improve the development and refinement efforts of digital health interventions. To accomplish this aim, I showcased how UCD developed digital health interventions can be developed with interdisciplinary expertise, specifically with regards to a medication-related clinical decision support system (CDSS) for falls prevention (i.e., the AD*F*ICE_IT CDSS; **chapter 4**). In addition, I demonstrated how the prioritization of identified usability problems for refinement efforts of UCD driven digital health interventions can be improved if the severity ratings of usability problems are based on the potential negative impact on the secondary (i.e. patient) rather than primary (i.e. HCP) user experience (**chapter 5**). Third, I aimed to investigate the effectiveness, user experience, and implementation of a UCD developed digital health intervention, namely a digital multifactorial falls risk assessment tool (i.e., Fall Analysis 2.0) and corresponding training for assessing risk factors for falling, in real-world practice settings. To realize this aim, I conducted a hybrid type 2 effectiveness-implementation study in Dutch primary care in which I found a positive influential effect of the Fall Analysis 2.0 on the falls risk management behavior of HCPs, in which the tool facilitated full completion of the multifactorial falls risk assessment in older adults (**chapter 6**). In this **chapter 7**, the implications of the findings of this dissertation for research, practice, and falls prevention are discussed followed by this dissertation's strengths and limitations, directions for future research, and final conclusions.

Discussion

Implications for theory and methods

UCD to adoption-centered design

In health care, diagnoses, treatment decisions, clinical support, care management and delivery can be augmented by digital health and UCD (Abernethy et al., 2022; Ferrucci et al., 2021; Gupta et al., 2022; Walden et al., 2020). However, even the most advanced UCD developed digital health interventions will have little impact on the aforementioned outcomes if they are not adopted (Chilana et al., 2015; Perski & Short, 2021). Therefore, UCD to adoption-centered design is complex, and requires a comprehensive understanding of who users of digital health interventions are and how they engage with these interventions in real-life practice settings. This dissertation showcased an improved approach to attaining a comprehensive understanding of user needs by constructing novel behavior theory driven personas (answering the who) and a visual journey map (answering the how), which was useful for optimizing the adoption of the digital health intervention. Specifically, this improved approach provided insight into the external user characteristics (i.e., context of use and usability-related needs), intrinsic user characteristics (i.e., behavioral determinants), and desired future state of the digital health intervention of prospective users (i.e., journey map), advancing UCD for the development of digital health interventions. The external user characteristics of personas were used to inform the design of the digital health intervention, ensuring that components of the user interface were in line with the identified needs of user. This enhanced adoption at the individual HCP level by increasing the user experience of the intervention for users, and reducing the threat of self-referential design decisions in the intervention by developers (i.e., the assumption that the needs of intervention developers reflect the needs of users; Graham et al., 2021). Traditional approaches to UCD are often focused on ensuring adoption at the individual level by matching design decisions to the needs of users for an enhanced user experience (Salinas et al., 2020). Other theoretical approaches to enhancing adoption at the individual level include the integration of the Technology Acceptance Model to ensure the perceived ease of use and usefulness of digital health interventions for users (Rahimi et al., 2018). However, focusing solely on adoption at the individual level can result in failure to adopt at the group and stakeholder level. Adoption at the group and stakeholder level relies on the effective implementation of the intervention into practice (Chilana et al., 2015; Perski & Short, 2021). Thus, not adapting implementation strategies to the needs of users could reduce the efficacy of UCD developed digital health interventions in practice. In this dissertation, the intrinsic user characteristics of personas were used to enhance adoption of the intervention at the HCP group level following a novel approach. Specifically, the use of tailored implementation strategies has been recognized as a core priority for the successful adoption of digital health interventions into practice (Alruwaili et al., 2023). Additionally, research suggests that interventions are more likely to be effective if they are tailored to influential determinants of behavior (Michie, 2008). In this dissertation, the Integrated Model of Behavioral Prediction (IMBP) framework was applied to uncover a wide range of possible behavioral determinants (i.e., intrinsic user characteristics) in personas that could pose a threat to adoption. These identified behavioral determinants in personas were matched with behavior change techniques using the taxonomy of behavior change methods (Bartholomew et al., 2011; Kok et al., 2016). These behavior change techniques were translated into tailored implementation strategies for the digital health intervention, which were integrated into the corresponding training. At the stakeholder level, the journey map depicting the desired future state of the intervention by HCPs was used to inform relevant stakeholders and policymakers, such as the Netherlands Expert Center on Injury Prevention (i.e., VeiligheidNL) and the Netherlands Ministry of Health, Welfare, and Sport, about the optimal configuration of the digital health intervention in practice. For example, prospective users emphasized the importance of establishing a connection between the intervention and existing communication platforms to facilitate the implementation of the intervention in a multidisciplinary care context.

An extensive amount of research has applied UCD in the development of digital health interventions (Ghazali et al., 2014; Göttgens & Oertelt-Prigione, 2021; Ten Klooster et al., 2022). However, UCD is commonly relied upon in specific phases of the development process as opposed to continuously (Brunner et al., 2017; Chandran et al., 2020; Ghazali et al., 2014; Vial et al., 2022). This can lead to digital health interventions that do not adequately address the needs of prospective users, which could hinder adoption. Thus, in addition to a comprehensive understanding of user needs, UCD to adoption-centered design requires a rigorous UCD approach involving prospective users early and continuously through the development steps of the iterative cycle (i.e., understand needs, develop interventions, observe user interactions, and refine interventions). In this dissertation, both digital health interventions followed a rigorous UCD approach, effectively involving prospective users early and continuously through all steps of the iterative cycle (Witteman et al., 2015, 2021). Specifically, continuous feedback from prospective users was gathered by means of a survey study, semi-structured interview/focus group study, and one or more usability testing rounds. This made it possible to prevent pitfalls to adoption early on. For example, user needs that are developed from direct experiences, commonly referred to as tacit knowledge-related needs, can threaten the adoption of UCD developed interventions, as not all UCD methods are suitable to identify and operationalize such deepened needs in prospective users (Van Velsen et al., 2022) In this dissertation, using multiple and improved UCD methods in the first step of the iterative cycle made it possible to uncover tacit knowledge-related needs of users. Specifically, for both digital health interventions, the survey studies were highly useful in identifying specific user needs, such as the need to systematically guide HCPs through the assessment process. In turn, the semi-structured interview/focus group studies helped to operationalize this need into the consultation workflows of HCPs by uncovering their tacit knowledge-related needs with regards to performing multifactorial falls risk assessments (i.e., Fall Analysis 2.0) or medication reviews (i.e., AD*F*ICE_IT CDSS) in practice. Furthermore, for both digital health interventions, usability testing rounds in the second step of the iterative cycle revealed how certain requirements based on perceived needs did not fully align with the actual needs of prospective users. For example, regarding the AD*F*ICE_IT CDSS, a perceived need by HCPs was that the system used standardized medical terminology with regards to deprescribing medications in patients. However, during the usability testing round, HCPs perceived difficulties with the standardized medical terminology used in the system whereby terms such as “minimal effective dose” required further elaboration. Thus, in addition to preventing pitfalls to adoption early on in the development process, a rigorous UCD approach can help to uncover mismatched user needs in different steps of the iterative cycle, facilitating continuous improvements in digital health interventions to ensure their successful adoption in real-life practice settings.

UCD and interdisciplinary expertise

UCD is vital for enhancing the user experience of digital health interventions as it ensures that components of the intervention are tailored to the needs of users. As a result, UCD is expected to enhance the intervention's usefulness and usability for users in real-life practice settings (Gagnon et al., 2012). However, the involvement of interdisciplinary expertise has become increasingly important when developing complex digital health interventions, such as the interventions described in this dissertation that aim to support HCPs in treating and managing a complex condition (Smye & Frangi, 2021; Teo & Wang, 2024). Interdisciplinary expertise leverages knowledge and perspectives from several different disciplines to tackle complex societal problems (Witteman et al., 2013). While an iterative UCD cycle for leveraging interdisciplinary expertise for the development and evaluation of digital health interventions has been previously developed, it remains to be applied in practical research (Sucala et al., 2019). Specifically, the cycle by Sucala et al. (2019) includes five phases: (phases 1-2) (pre)define the needs of users; (phase 3) design the front- and back-end of the intervention; (phase 4) develop the intervention for testing; and (phase 5) deploy the intervention. This dissertation applies such a cycle in practical research showcasing how UCD developed digital health interventions can be enhanced with interdisciplinary expertise to further increase their usefulness and usability in real-life practice settings. For example, regarding the AD*F*ICE_IT CDSS, researchers from communication science, medical informatics, geriatrics, and epidemiology were involved to inform the effective development of the system in several core ways. First, shared decision-making has been shown to enhance medication-related knowledge and adherence in older adults (Van Weert et al., 2016). Thus, for (pre)defining user needs and designing the intervention (phases 1 through 3), knowledge from communication science was not only vital for UCD but also for ensuring the successful integration of a shared decision-making model in the system. This model can be used by HCPs during consultations to foster joint medication management and adherence in older adults. Second, for developing the intervention (phase 4), knowledge from epidemiology was critical for the development of the prediction model to enable the generation of a patient's personalized falls risk estimation in the system. This risk estimation supports HCPs in weighing treatment options for the deprescribing of falls risk increasing drugs (FRIDs) in older adults. Next, for deploying the intervention (phase 5), knowledge from geriatrics was integral for ensuring the completeness and accuracy of the guideline- and expert-based personalized deprescribing advice for HCPs in the system. This personalized deprescribing advice can support HCPs in deprescribing FRIDs optimally in older adults. Lastly, knowledge from medical informatics was pivotal for designing the back-end, developing the software, and deploying the system (i.e., phases 3 through 5) which included formalizing guidelines into clinical rules, ensuring the system's ability to generate personalized deprescribing advice for HCPs, and the successful integration of the prediction model in the system.

UCD and the secondary user experience

The inclusion of the patient experience is recognized as a core pillar for good quality health care (Doyle et al., 2013). In an attempt to enhance the patient experience in digital health interventions, UCD researchers are increasingly examining how to consider the secondary user experience during the development of these interventions. In health care, the secondary user experience refers to the experience of the patient during the interaction between the HCP and the digital health intervention (Alsos & Svanæs, 2011; Angell et al., 2016). The studies in this dissertation add to this literature by demonstrating how both the co-experience and direct experience of secondary users (i.e., patients) can be considered in digital health interventions. For example, the co-experience, which refers to the interaction between secondary and primary users, can be considered when developing provider-patient interaction components in interventions (Angell et al., 2016). Specifically, in both the AD*F*ICE_IT CDSS and Fall Analysis

2.0, the tailored treatment plan was available to HCPs in patient-friendly language to support provider-patient interactions during consultations. In the context of falls prevention, tailoring treatment information to the communication needs of older adults is recognized as an important component for enhancing provider-patient interactions (Brooks et al., 2017). This dissertation illustrated how the direct experience, which refers to the outcomes experienced by the secondary user as a result of the intervention, can be considered during usability evaluations to better prioritize usability problems for the refinement efforts of digital health interventions. Specifically, in this dissertation, an existing usability evaluation method, namely the Augmented Classification Scheme, was adapted in which the severity ratings of usability problems were based on the impact on the secondary, focusing on patient care outcomes, instead of primary user experience, focusing on clinical task outcomes (Khajouei et al., 2011). For example, the usability problem where users were uncertain about the use of functionalities to complete the multifactorial falls risk assessment was categorized as a usability catastrophe, even though it occurred in a small number of participants. In secondary user experience standards, not solving this usability problem could have resulted in a suboptimal assessment in older adults. This could threaten the wellbeing of older adults as not all risk factors for falling that make up a multifactorial falls risk assessment are assessed. However, in primary user experience standards, not solving this usability problem could have been considered as a minor disruption in the workflow of users, as users could simply skip the assessment of certain risk factors. By basing the severity rating on the impact on the secondary instead of primary user experience, digital health interventions can ensure that the most critical usability problems affecting patient care are tackled first, resulting in optimized refinement efforts of these interventions.

Implications for practice

Informing the development of interventions in multidisciplinary care

While the utility of UCD has been widely demonstrated for developing interventions in single-care contexts, this dissertation presented UCD driven intervention developed for both single-care and multidisciplinary care contexts (Göttgens & Oertelt-Prigione, 2021). Regarding the latter context, multidisciplinary care is increasingly becoming a standard approach for the management and treatment of complex conditions with multifactorial causes (Korylchuk et al., 2024; Teo & Wang, 2024). Multidisciplinary care inevitably requires the collaboration between HCPs from different disciplines and care settings, all with varying needs. Digital solutions can provide a fruitful avenue for facilitating multidisciplinary efforts in health care, if these solutions are designed appropriately for different users (Gupta et al., 2022; Teo & Wang, 2024). In this dissertation, primary care-based HCPs from more than five different disciplines were successfully involved throughout the entire development of the Fall Analysis 2.0 for use in a multidisciplinary falls prevention care context. This not only ensured the usability of the Fall Analysis 2.0 for multidisciplinary care teams, such as improving the sharing of patient information between HCPs, but also ensured that the intervention met the specific needs of HCPs from each discipline, such as optimizing the intervention's usability in different contexts of use (e.g., patient's home versus clinical practice). Therefore, the studies in this dissertation can serve as an example of how UCD can be applied to develop effective digital health interventions for HCPs in both single-care and multidisciplinary care contexts.

Informing the development of future digital health interventions

According to Van Velsen et al. (2022), input from prospective users during UCD should be made reusable to inform the development of similar, future digital health interventions. Therefore, the findings from this dissertation have several practical implications for developers looking to develop or improve existing digital health interventions. First, digital health interventions should reduce HCPs cognitive effort with regards to the requested clinical task. For CDSS, this includes, but is not limited to, reducing the amount of repeated and unnecessary alerts, clicks, and text-entry fields in these systems. In turn, for evidence-based health risk assessment tools, this means decreasing the manual calculation of scores for functional assessments. Second, digital health interventions should systematically guide HCPs in performing the requested clinical task. In both the AD*F*ICE_IT CDSS and Fall Analysis 2.0, vertical or horizontal menu bars as well as the incorporation of if-then rules were useful for guiding HCPs to the next clinical task step. Lastly, digital health interventions should provide HCPs with actionable recommendations for reducing risk in patients. For CDSS, this means integrating evidence-based and expert guidelines to foster treatment-related decision support in HCPs, which is in line with previous research examining the needs of medication-related CDSS users (Westerbeek et al., 2022). For online health risk assessment tools, this means using if-then rules to provide automated, actionable, and evidence-based (referral) advice based on the assessment results of detected risk factors.

Implications for falls prevention

This dissertation showcased the effective UCD driven development of clinical tools for improving falls prevention in both single-care and multidisciplinary care contexts, providing important implications for falls prevention. First, studies suggest that the incorporation of clinical guidelines for falls prevention into routine practice is suboptimal (McConville & Hooven, 2021). This was also observed among HCPs providing usual care in the effectiveness-implementation study of this dissertation, whereby the multifactorial falls risk assessments performed in older adults were not per the recommended international and national guidelines for falls prevention (Federatie Medisch Specialisten, n.d.; Montero-Odasso et al., 2022). The findings of this dissertation suggest that the implementation of clinical guidelines regarding falls prevention can be improved through digital health interventions accompanied by trainings that are developed following UCD. This could be particularly valuable for stakeholders and policymakers involved with the Dutch national multidomain falls prevention program whereby the Fall Analysis 2.0 and corresponding training could improve the carrying out of multifactorial falls risk assessments in primary care. Specifically, the Fall Analysis 2.0 facilitated significantly more fully completed multifactorial falls risk assessments in older adults compared to usual care as the tool helped streamline the guideline-based assessment process for HCPs. This enhanced efficiency can, in turn, increase the quality of falls prevention for older patients at high risk of falling, as their risk factors for falling are better assessed by HCPs, which could result in better targeted and thus more effective multidomain interventions in these patients. Although the effectiveness of the AD*F*ICE_IT CDSS is currently being tested in a large, multicenter cluster randomized controlled trial across several hospitals in the Netherlands, I expect this CDSS to streamline the guideline-based deprescribing of FRIDs for HCPs as both the AD*F*ICE_IT and Fall Analysis 2.0 interventions followed similar UCD approaches (De Wildt et al., 2023).

Systematic reviews suggest that the adoption of digital health interventions for falls prevention are hindered by a number of barriers, such as difficulty of use, incompatibility with the workflow and contexts of use, poor communication and coordination, lack of knowledge and skill, and unclear role distribution (Vandervelde et al., 2024; Westerbeek et al., 2021). The studies in this dissertation highlight the need for policymakers to look beyond the clinical usefulness of digital health interventions for falls prevention and start prioritizing their usability for HCPs and implementation in real-life practice settings. Regarding usability, the incorporation of time-saving functionalities has been recognized as an important facilitating factor for adopting clinical tools for falls prevention in practice (Casey et al., 2016; Shubert et al., 2014; Vandervelde et al., 2024; Vincenzo et al., 2021; Westerbeek et al., 2021). This dissertation showcased how these functionalities can be operationalized together with HCPs and integrated into clinical tools. For the Fall Analysis 2.0, important time-saving functionalities for an enhanced user experience by HCPs included auto-fill score and advice forms, auto-saving of results, one-click actions, and risk assessment automation (i.e., automated scoring of assessment results and providing automated advice for identified risk factors based on these results). In turn, for the AD*F*ICE_IT CDSS, important time-saving functionalities for HCPs included a connection between the electronic health record and the system, automated treatment options based on FRIDs, and summary of the consultation that can be copied into the patient's EHR. Regarding implementation, stakeholders and policymakers should consider the implementation of corresponding trainings to increase HCPs knowledge and skills for assessing and treating risk factors for falling. In this dissertation, the corresponding training of the Fall Analysis 2.0 was viewed by HCPs as a facilitator for successful implementation into practice.

Additionally, the findings of this dissertation suggest that stakeholders and policymakers should consider the role of other primary care-based HCPs (beyond the general practitioner) in conducting multifactorial falls risk assessments in older adults at high risk of falling. For the national multidomain falls prevention program, HCPs that could have a central role in conducting these assessments using the Fall Analysis 2.0 are physical therapists, occupational therapists, nurse practitioners, and district nurses. While the Fall Analysis 2.0 is currently being implemented as a standalone product in primary care, the findings of this dissertation suggest that the sustainable implementation of the tool relies on its integration into existing electronic health records. The feasibility of an interoperable system should be explored by the Ministry of Health, Welfare, and Sport, and VeiligheidNL.

Strengths and limitations

The findings presented in this dissertation should be evaluated with regards to some strengths and limitations. A key strength of this dissertation was the comprehensive needs assessment which included the embedding of behavioral theory, specifically the IMBP framework, in personas-construction and the inclusion of journey mapping. Similarly, another key strength was employing a rigorous UCD approach to development. This can ensure that digital health interventions are adopted at both the individual, group, and stakeholder level, which is vital for realizing their effectiveness in health care. Additionally, this dissertation demonstrated the usefulness of UCD for developing digital health interventions that better align with the multidisciplinary care needs of a group of HCPs using insights from physical therapists, occupational therapists, district nurses, general practitioners (GPs), nurse practitioners, podiatrists, exercise therapists, and pharmacists. However, a limitation is that participation rates between these disciplines varied in these studies, leading to an unequal representation of HCPs from certain disciplines, most notably among GPs. The successful recruitment of GPs is a well-established challenge among researchers, also regarding falls prevention-related research (Parkinson et al., 2015; Pit et al., 2014; Tan et al., 2019; VanGeest et al., 2007). In line with previous research, the recruitment of GPs for the studies described in this dissertation was difficult due to reasons related to lack of time, lack of motivation, and not feeling responsible for the conducting of multifactorial falls risk assessments in older adults. While the latter reason is reflective of falls prevention in Dutch GP practices, in which these assessments are often distributed to nurse practitioners, the low participation rates of GPs presents limitations to the generalizability of the findings to this user group. As a consequence, the needs of GPs may not be sufficiently addressed in the tool, which could reduce the usefulness and usability of the Fall Analysis 2.0 for this user group.

Another strength of this dissertation is that it showcased how interdisciplinary research expertise can enhance the usefulness and usability of UCD developed digital health interventions. Nevertheless, certain lessons were learnt during the development of the digital health interventions described in this dissertation, which can serve useful for researchers looking to develop similar interventions. First, there is often a mismatch between what the user wants in clinical practice and what can be feasibly developed for use in clinical practice, which results in another lesson learnt: the need for effective problem mitigation early on in the development process. In the context of this dissertation, for instance, it was not feasible to incorporate functionalities that facilitated the collaboration between HCPs in the Fall Analysis 2.0 due to time and monetary constraints. Thus, in an attempt to mitigate this problem, much of the focus was placed on streamlining the assessment and referral process for users through the incorporation of time saving functionalities, such as an automatically generated PDF with the assessment results. The findings from the effectiveness study suggest that the lack of functionalities fostering collaboration did not hinder the user experience of the Fall Analysis 2.0 for users in practice. This implies that functionalities that may be perceived as useful by users, may not be the most effective in practice. Similarly, regarding the AD*F*ICE_IT CDSS, it was not feasible to integrate the system into the electronic health record of certain hospitals due to technical constraints, which led to the development of a standalone system. Third, effective translation of the needs of users to other members is crucial in an interdisciplinary team. Specifically, since members within an interdisciplinary team each have their own set of expertise, one should not assume prior knowledge of one's expertise by other members.

Thus, effective translation of user needs means avoiding jargon, which can prevent misunderstandings during the development of digital health interventions between team members.

Directions for future research

Future research is needed to further enhance and understand the added value of UCD for the development of digital health interventions. This dissertation proposes specific directions for future research in an attempt to broaden current understandings of how UCD methods and their application can be improved for the development of digital health interventions. The studies in this dissertation illustrated how two secondary user experiences (i.e., co-experience and direct experience) can be successfully taken into account during the development of digital health interventions. However, Angell et al. (2016) also highlight a third secondary user experience, namely transferred experience from the primary user. In other words, negative user experiences experienced by primary users, such as frustrations with the usability of an online clinical tool, can transfer to secondary users, thereby negatively affecting the secondary user experience (e.g., decreasing provider-patient interaction). Therefore, when considering the secondary user experience in digital health interventions, it is vital not to neglect the needs of primary users and vice versa (Alsos & Svanæs, 2011; Angell et al., 2016). Future research could examine how to limit the effects of a negative transferred experience when developing digital interventions in which prospective users are HCPs. For example, future research could explore the added value of directly involving secondary users, such as patients, in the development of digital health interventions. Although the AD*F*ICE_IT intervention involved older patients in the development of the intervention to enhance provider-patient interactions by means of CDSS and patient portal, secondary user involvement was limited to informing the components of the patient portal only. Thus, increased involvement by secondary users could be useful for informing certain components of digital health interventions. For example, secondary users could be involved in the development and communication of treatment plans to facilitate better provider-patient interactions. Future research could develop guidelines that aid evaluators of digital health interventions to critically reflect on the

the transferred experience during the prioritization of usability problems to further optimize refinement efforts of digital health interventions. Furthermore, an extensive amount of research has leveraged journey mapping to understand and improve health care services from the patient's perspective (Davies et al., 2023; Joseph et al., 2020). Therefore, future research could also explore whether the UCD outcome of journey mapping is useful for understanding and improving the transferred experience of secondary users in digital health interventions. Additionally, future research could explore the utility of a holistic personas-construction approach whereby the intrinsic user characteristics of personas represent the influential determinants of secondary users. This could help inform provider-patient communication strategies during consultations.

Regarding the holistic personas-construction approach described in this dissertation, future research could examine the utility of leveraging several theories to elicit a diverse range of intrinsic user characteristics in personas. Specifically, in this dissertation, measures from the IMBP were used to elicit intrinsic user characteristics in personas. However, several other determinants can influence the implementation of falls prevention interventions into clinical practice (Vandervelde et al., 2024). This can ensure better targeting of behavioral determinants during the implementation of digital health interventions, as implementation strategies are tailored to several relevant behavioral determinants. In addition to examining the usefulness of other behavioral theories in personas-construction, future research could broaden personas-construction beyond prospective users of digital health interventions. Specifically, rather than constructing holistic personas representing different types of intervention users as described in this dissertation, future research could use the Diffusion of Innovation Model to construct holistic personas representing different types of intervention adopters (i.e., innovators, early adopters, early majority, late majority, and laggards; Rogers, 1981). The intrinsic user characteristics of such personas can be used to optimize the implementation efforts of digital health interventions over a period of time, thereby enhancing the likelihood for successful long-term adoption of interventions by users. Beyond personas-construction, future research could explore the added value of combining behavioral theory with other UCD methods. Regarding journey mapping, the integration of behavioral theory, such as the Transtheoretical Model, could provide valuable insight into the influential determinants that drive the journey to behavior change in prospective users of digital health interventions as they move through a series of stages of change (i.e., precontemplation, contemplation, preparation, action, and maintenance; Prochaska & Velicer, 1997). Such an approach to journey mapping could help optimize the use of behavior change techniques in digital health interventions, as it showcases when such a technique is most influential at driving a change in behavior during prospective users interactions with the intervention.

Future research could conduct a randomized controlled trial to examine the effectiveness of the Fall Analysis 2.0 on risk of falling and actual falls in primary care to more confidently conclude the value of UCD for the development of digital health interventions. Additionally, future research could explore the integration of a question prompt list in the Fall Analysis 2.0 for older patients in an attempt to improve adherence to falls prevention advice in the long run, which was not feasible in this dissertation. The effectiveness of the AD*F*ICE_IT intervention is currently being tested in a large, cluster randomized controlled trial across several hospitals in the Netherlands (De Wildt et al., 2023). The insights from this trial will be useful for determining the effectiveness and cost-effectiveness of the UCD developed CDSS in secondary falls prevention care.

Conclusion

This dissertation improved current UCD practices, and demonstrated their usefulness by developing two digital health interventions for use in falls prevention care (i.e., the Fall Analysis 2.0 and AD*F*ICE_IT CDSS). A comprehensive needs assessment embedded with behavioral theory, continuous user involvement, and interdisciplinary expertise are vital for realizing the promising effects of UCD developed digital health interventions in clinical practice, such as improving the efficiency and, in turn, delivery of multifactorial falls risk assessments in Dutch primary care. Furthermore, this dissertation highlighted the added value of accounting for the secondary user experience (i.e., the experience of patients) in digital health interventions, particularly when prioritizing usability problems for refining interventions. Together, the findings from this dissertation set new standards for the development of UCD digital health interventions intended for use by HCPs both within and outside of a falls prevention context.