The intangible outcomes of an intergenerational hackathon for active aging

The intangible outcomes of an intergenerational hackathon for active aging: a case study

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ABSTRACT

Ensuring the design process aligns with active aging is as crucial as designing products for older adults promoting active aging. An emerging approach is to bring together OA with younger generations to collaborate on solutions for active aging via intergenerational hackathons. This study explored the intangible outcomes of an intergenerational hackathon aimed at promoting active aging. This hackathon was organized by an interdisciplinary team together with a senior center, and a mixed methods approach was applied to understand the experiences of participants during the hackathon and their reflections. The intangible outcomes were identified and mapped based on the scale of their effects on active aging, indicating intergenerational hackathons could be a lasting approach to foster active aging. Design implications for conducting this type of hackathon were formulated, and we position our findings as the starting point for researchers and practitioners exploring intergenerational hackathons as an approach to active aging.

CCS CONCEPTS

• **Human-centered computing**; • **Participatory design**;

KEYWORDS

Co-design, older adults, co-creation, societal change, education

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1 INTRODUCTION

The demographic change has been urging researchers and practitioners to rethink how to help older adults (OA) live independently, healthily, and happily. To support this initiative, the World Health Organization (WHO) outlined a policy framework that coined active aging as the process of "optimizing opportunities for health, participation, and security" to "enhance the quality of life as people age" [1]. To drive and sustain this societal change, on the one hand, a top-down approach, such as governmental policies and healthcare systems, is crucial to secure the resources allocated for active aging interventions. On the other hand, a bottom-up approach is equally important to understand the lived experience and needs of OA while developing a commitment to active aging at the citizen level. To facilitate the changes at the citizen level, researchers within the Human-Computer Interaction (HCI) domain have explored a range of persuasive technologies based on behavior change theories, such as exergames [27], activity trackers [25], social robots [26], communication tools [7], and community displays [15]. However, questions remain about the accessibility of these tools amid ongoing discussions regarding the dual role of information communication technology in societal change, serving as both an enabler and a potential source of challenges. End-users and stakeholders have been increasingly engaged in the design process of these technical interventions to minimize potential challenges that may arise. Given that well-being is a complex construct [47], we see active aging as one approach to help some OA live independent, healthy, and happy lives.

In addition to designing products for OA to support active aging, it is equally important to ensure the design process can support active aging. One emerging approach is conducting intergenerational hackathons to bring together **OA with younger generations** to collaborate on innovative solutions for active aging. The concept of hackathons originated in the technology sector, where they served as intense collaborative events aimed at solving complex problems in a short period in a multi-actor and interdisciplinary setting. Over time, hackathons have evolved to encompass various domains, such as social innovation and community development. Intergenerational hackathons provide a unique platform for knowledge sharing, skill development, and social interaction among participants, yet hackathons involving OA are scarce [11]. Moreover, previous research has mainly focused on the tangible outcomes of a hackathon, such as notes, sketches, developed concepts, actionable plans, functional software applications, or physical prototypes. The tangible outcomes are indeed important and can be further developed and implemented, while the intangible outcomes are equally, if not more important, and are understudied [31]. Intangible outcomes may include enhanced collaboration and teamwork skills, increased problem-solving abilities, improved communication and presentation skills, expanded networks and connections, and a sense of empowerment and satisfaction for the participants. Moreover, the cultivation of a diverse and inclusive environment during hackathons bolsters cultural understanding, empathy, and cross-disciplinary collaboration - outcomes that are difficult to quantify but undeniably influential in driving innovation and societal progress [41].

Investigating the intangible outcomes provides a deeper understanding of the educational and transformative aspects of the hackathon. It helps identify the skills, knowledge, and experiences gained by participants, shedding light on the personal and professional development opportunities offered by such collaborative events. This knowledge can inform future design and implementation of hackathons, facilitating their improvement and ensuring they continue to deliver valuable outcomes. Furthermore, the significance of intangible outcomes extends beyond individual projects, as it equips the next generation with essential skills, a pivotal factor for achieving lasting change. For instance, both technical and social skills are indispensable in developing interventions for active aging. The social skills encompass not only collaboration with OA and key stakeholders but also with peers from various disciplines; the intricate and multifaceted nature of contemporary societal challenges demand an interdisciplinary approach.

By emphasizing intangible outcomes and experiences, hackathons could align with the focus on democratic design, inclusivity, empowerment, and social engagement from Participatory Design (PD). Researchers and practitioners in PD have explored various aspects related to design processes, methods, and their societal impact. For instance, previous studies have explored similar themes in contexts such as workspace harassment [40], LGBT+ hate [13], ethnic marginalization [55], and maternal health [16]. Botero & Hyysalo reported strategies for co-designing with communities with special needs and limited resources by reflecting on the case of setting a communal alternative for growing old [4]. In the context of urban design, researchers also reflected that, in addition to the tangible design outcomes, a PD approach could build capacity within a community in terms of participation, organization, and collaboration [14].

Therefore, in this study, the main research question is: what are the intangible outcomes of an intergenerational hackathon for active aging that is designed with a participatory design approach?

We answer this question through the case study of an intergenerational hackathon organized by a consortium of three universities and a senior center in the Netherlands, during which students from four disciplines and OA were actively engaged to co-design together for an intervention supporting active aging.

The structure of the paper is as follows. In Section 2, we reflect on the state-of-the-art literature on PD with OA and the outcomes of hackathons. In Section 3, we provide the context in which the hackathon was conducted and describe the process of data collection and analysis. In Section 4, we present the intangible outcomes resulting from this hackathon. We then discuss our findings in relation to recent literature and reflect on the limitations of this study (Section 5), and finally conclude with indications for future work (Section 6).

2 RELATED WORK

2.1 Participatory design for active aging

The concept of "active aging" gained prominence in the 2000s, with the first paper on this subject in the field of HCI emerging in 2006 [35]. Moving away from the deficit model of aging, researchers and designers began to explore ways in which technology could empower OA to remain socially connected, physically active, and mentally engaged. The 2010s marked a period of increased focus on PD for active aging. Researchers recognized that involving OA in the design process was essential for creating democratic technologies that truly met the needs and aspirations of OA [23].

Since then, various PD initiatives have been launched; for instance, design workshops were conducted to support OA to co-create with each other or with other generations ; design tools were developed to facilitate OA to create their personal Internet of Things [2] or produce digital content [56]. Light et al. (2015) found that keeping a social and cultural identity is as important as fitness or independence for OA [24]. Knowledge has been gained from both theoretical and applied work; for example, when developing a technology for OA, researchers should be alert if they have any common assumptions about aging [10], could apply factors for positive aging [34], and use strategies for co-designing with OA [46]. In recent years, PD for active aging has continued to evolve. The proliferation of mobile devices, wearable technologies, and smart environments has opened new possibilities for enhancing the lives of OA. Interdisciplinary collaboration has become increasingly important, with experts from HCI, gerontology, psychology, and other fields working together to tackle the complex challenges of designing for active aging.

2.2 Hackathons and their outcomes

A multidisciplinary literature review on hackathons has categorized the purpose of a hackathon into three main types, namely, innovation, learning, and collaboration [9]. Regarding **innovation**, Kopeć et al. have conducted hackathons involving OA as end-users to develop software supporting active aging [19]. This research group has also developed guidelines for better participation of OA in software development processes targeted at IT start-ups [20]. To the best of our knowledge, these two articles are the only studies explicitly reporting on involving OA in hackathons. The Massachusetts Institute of Technology (MIT) Hacking Medicine group is another example of conducting hackathons for innovation. This group aimed to energize the healthcare community and accelerate medical innovations by organizing hackathons [28]. The stakeholders of this type of hackathon usually come from different disciplines, sometimes a collaboration between academia and industry. For instance, in a hackathon for supporting patients with type 1 Diabetes, a team could consist of a Diabetes Nurse Specialist, a Ph.D. student in health psychology, a young adult living with Type 1 Diabetes, an IT consultant, and a start-up developer/biomedical engineer [17].

As for **learning**, some hackathons aim to provide an opportunity for students to work cross-discipline as part of their education. Moreover, through collaboration with end-users and stakeholders on real-world challenges, these hackathons help students from different disciplines prepare for their future roles in society. This type of hackathon also feeds into the pedagogy of challenge-based learning, where learning is achieved through participation in a real-world challenge while the learning process is inquiry-based and student-centric [8]. Hackathons of this kind usually take place in higher education, with the first widely regarded university hackathon being PennApps at the University of Pennsylvania in 2009 [39]. To evaluate the hackathon's outcomes on learning, pre-post surveys are commonly used to collect self-reported data from students on their confidence levels regarding the intended learning outcomes [6, 53].

Concerning **collaboration**, intergenerational collaboration has been applied as an approach toward active aging that improves the social and emotional well-being of OA [37, 52]. The rationale is that OA and younger generations are of value to each other in terms of their experiences, knowledge, and skills, and through collaboration, they will build empathy toward the other generations [20]. On one side, OA feel a sense of being connected with society and learn more about younger generations; on the other, as younger generations rethink their stereotypes about OA, it leads them to interact with OA in a more empathetic way in daily contexts, as predicted by intergroup contact theory [19]; yet this process is by no means without frictions and challenges, such as balancing the roles of facilitators and co-designers for students and the sense of ownership for OA [48].

According to Chau and Gerber, the outcomes of a hackathon usually depend on the purposes of the hackathon [9]. For a hackathon focusing on innovation, the tangible outcomes are the most important. For a hackathon focusing on learning, the outcomes are mainly intangible, and it is more common to evaluate the confidence of students regarding what they learned in the hackathon. For a hackathon focusing on collaboration, the outcomes are also mostly intangible and focus on the immediate experiences of participants.

Studies reporting the effect of hackathons on behavior change are starting to emerge. Along with global trends such as climate change, the aging population, and technological development, there is an increasing interest in understanding how to help people change their behavior toward an eco-friendly lifestyle, active lifestyle, and cyber-alert lifestyle, respectively. For instance, a recent study investigated whether a hackathon (termed "a short-term intervention") can impact students' understanding and motivation toward sustainability issues [49]. Previous work has proposed that short-term interventions might precipitate into lasting behavioral or value change due to the desire for integrity and individual value consistency [36]. Therefore, another intangible outcome of an intergenerational hackathon for active aging could be that OA intend to change behavior towards a more active lifestyle. To investigate these topics further, we formulated the sub-research questions below.

2.3 Sub-research questions

Based on the purposes and outcomes of hackathons introduced above, the scales of impact for hackathons with different purposes could vary (Figure 1). For collaboration, the impact is mainly immediate and only for the participants; for innovation, the impact is mainly mediated by the intervention developed, and the beneficiaries will also include users and stakeholders; for learning, the impact is mainly long-term and has more beneficiaries. This is because, by learning skills and knowledge during the hackathon, participants may become ambassadors or advocates for the issues addressed in the hackathon. This capacity building can have a cascading effect on a larger community over time. The effect of hackathons on behavior change could happen at any of the three scales. We postulate that an intergenerational hackathon for active aging could be designed to cover collaboration, innovation, and learning. This research aims to investigate the intangible outcomes generated by an intergenerational hackathon, specifically on its potential to promote active aging at different scales.

Starting from the main research question and based on the reviewed literature, we outlined the below sub-research questions to be answered by using our hackathon as a case study:

- Is there a change in the confidence level of students in developing interventions after the hackathon?
- Is there a change in the confidence level of students in working with OA after the hackathon?
- Does participating OA develop an intention for an active lifestyle after the hackathon?
- What are the other intangible outcomes of the hackathon for students and OA?

Sub-research question 3 emphasizes the *intention* of behavior change rather than behavior change itself because we cannot measure if OA changed his or her behavior for an active lifestyle immediately after the hackathon, while we are able to measure if OA developed an intention to do so. According to the transtheoretical model for behavior change, this intention is a critical step toward a complete behavior change [43]. The transtheoretical model posits that a person will go through six stages for a complete behavior change (Figure 2). At the pre-contemplation stage, the person has not considered changing the behavior; at the contemplation stage, the person starts to consider changing the behavior; at the preparation stage, the person prepares for behavior change; at the action stage, the person takes action to change behavior; at the maintenance stage, the person keeps practicing the behavior change; sometimes, the person will relapse and fall back to previous stages whether OA intend to change their behaviors toward a more active lifestyle after the hackathon links to the transition from the pre-contemplation to the contemplation stage of the transtheoretical model.

2.4 Group gardening as a case for active aging

Active aging emphasizes maintaining physical, mental, and social engagement throughout the later stages of life, thereby enhancing

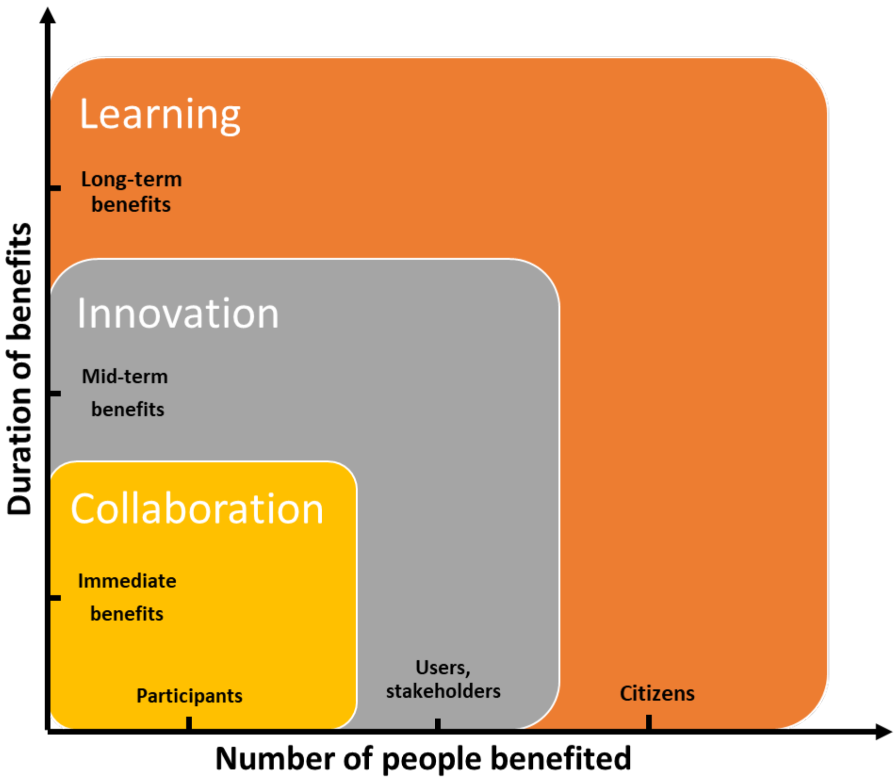

Figure 1: The scales of impact for hackathons focusing on collaboration, innovation, and learning

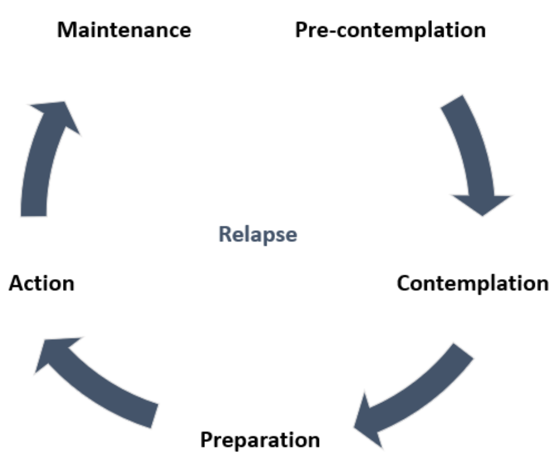

Figure 2: The transtheoretical model [43]

overall quality of life and independence [1]. Recent theories in Behavior Change pointed out that the social and physical environments are as important as personal factors for promoting behavior change [2]. In this synergy, group gardening emerges as a powerful vehicle for promoting active aging by fostering regular physical activity, cognitive stimulation, and social interaction. Engaging in gardening activities within a group setting not only encourages physical movement and exercise but also cultivates a sense of purpose and accomplishment [22, 33, 50]. This shared endeavor fosters social bonds, encourages knowledge exchange, and bolsters a collective commitment to healthy living [4].

Therefore, in this work, we investigate the intangible outcomes of an intergenerational hackathon that aims to develop an intervention promoting group gardening. Supported by the observations, interviews, and surveys, we aim to build on the body of work in HCI on Participatory Design and Behavior Change. Specifically, we explore how to actively connect OA with younger generations to design interventions for active aging and identify the potential intangible outcomes associated with this collaborative process.

3 METHODS

This study is a result of the interdisciplinary collaboration across three universities in the Netherlands. Together with the Senior Centre Ontmoet&Groet (O&G), a consortium was built to promote active aging in neighborhoods. The study protocol was approved by the Human Research Ethics Committee of XXX University. All participants (students and OA) filled in an informed consent form before the hackathon. As we aim to gain in-depth knowledge about the intangible outcomes of intergenerational hackathons on

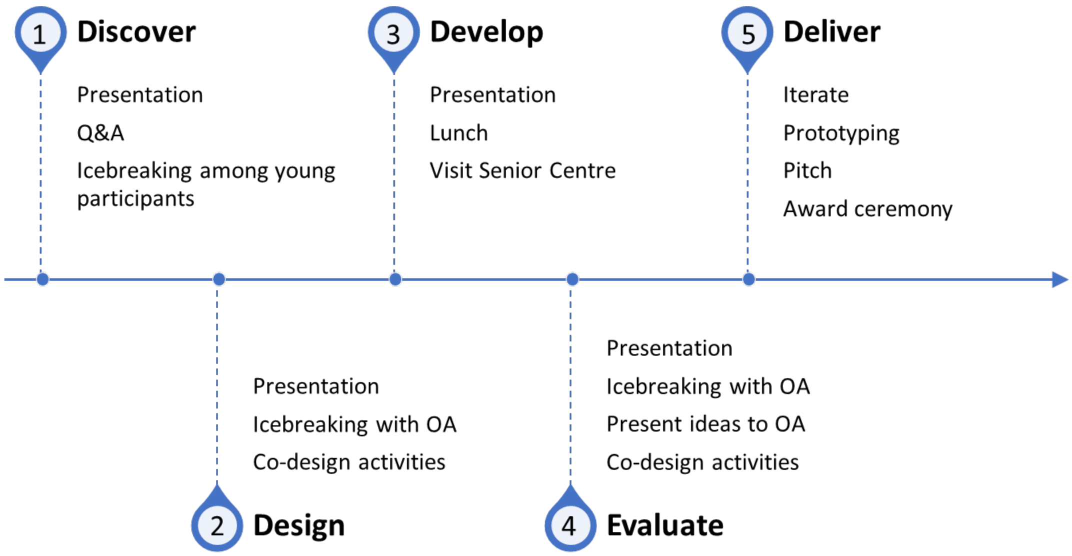

Figure 3: Hackathon agenda overview

active aging, we adopted a case study design and a mixed methods approach.

3.1 Hackathon planning

The hackathon plan was developed through multiple meetings among all consortium members. A research protocol and toolkit were created (details see [author]). To ensure a sufficient number of participants, students from various disciplines and education levels (undergraduates to PhDs) were recruited from the three universities, and OA were recruited via the secretaries in O&G based on their interests in the hackathon. All participants were aware they would be developing an intervention promoting group gardening before they consented to participate. We did not ask about the age of OA during the recruitment because we align with Brandt et al. in that, in the context of aging-in-place, OA should not be defined by their age but by the kind of communities they are in [4]. Here, "community" refers to membership in a senior center where OA frequently go for social connection, help, or help others. The CEO of O&G played an important role in ensuring the hackathon suited the context of O&G and the capabilities of OA members. As a result, OA members were invited to the co-design sessions of the hackathon and to stay at the hackathon as long as they felt comfortable.

3.2 Hackathon

The hackathon was hosted on 4^{th} May 2022 from 9:00 to 18:00. Sixteen students registered for the hackathon from the disciplines of Industrial Design, Information Technology, Built Environment, and Medicine. The students were divided into four teams based on their disciplines to maximize interdisciplinary collaboration. Two co-design sessions were organized in the hackathon (10:30-12:00 and 14:00- 15:15). Four OA participated in the morning session, and each of them joined one team. Five OA participated in the afternoon session, each joining a different student team, while two OAs joined Team 2. The match was done by the CEO of O&G based on his personal acquittance of each OA and his observations of each team's dynamics. Additionally, four coaches, each representing one discipline, were enlisted to offer guidance during the event. The hackathon program was categorized into five stages, namely; discover, design, develop, evaluate, and deliver. An overview of the activities is shown in Figure 3, and the team compositions are shown in Table 1. Details of the hackathon program can be found in the Appendix.

3.3 Data collection

An overview of data collection methods in response to each sub-research question is shown in Table 2. The observations, group interviews, and individual interviews were conducted by several researchers for investigator triangulation. The data collected by observations, group interviews, and individual interviews are used for methodological triangulation for the sub-research question "What are the other intangible outcomes of the hackathon?".

While providing advice to teams, each coach also noted down their observations regarding the interaction styles and team dynamics. Some observations were done when the coaches were interacting with the teams and sometimes at a distance (when the coaches did not need to answer questions). Each coach was given an observation guide, which contained the most important aspects

Table 1: Team composition in the hackathon (The Arabic numbers indicate the number of participants; BS: Bachelor's students; MS: Master's students; M: morning; A: afternoon; *: non-native speaker)

	Team one	Team two	Team three	Team four
Industrial Design	1BSc	2BSc	1BSc	1BSc
Information Technology	1MSc	1PhD	1MSc	1MSc
Public Health (medicine)	1MSc	1MSc	1MSc	1MSc
Built Environment	1PhD*	0	1PhD*	1PhD*
Older adults	1M+1A	1M+2A	1M+1A	1M+1A

Table 2: Summary of data collection methods in response to the sub-research questions (OA: older adults)

Sub-research questions	Data collection methods
Is there a change in the confidence level of students in developing interventions after the hackathon?	Pre-post questionnaires
Is there a change in the confidence level of students in working with OA after the hackathon?	Pre-post questionnaires
Do participating OA develop an intention for an active lifestyle?	Questionnaire during the group interview with OA
What are the other intangible outcomes of the hackathon for students and OA?	Observations; group interviews with OA; individual interviews with students

to observe, including formal/informal language use, group atmosphere, and interaction frequency to evaluate the level of collaboration with students and OA. To avoid the interviewer effect, the participants were not briefed on the objective of the observation.

For the survey, pre-post questionnaires were introduced to the students (n=14). The pre-questionnaire collected qualitative data on their familiarity with behavior change and with working with OA. Baseline quantitative data on the confidence level of students in developing interventions for behavior change and in working with OA were also collected. Students completed the post-questionnaire after their pitches while waiting for the results from the judges. The post-questionnaire collected quantitative data regarding their confidence level in developing interventions for behavior change and in working with OA.

Immediately after the co-design sessions, two researchers (native Dutch speakers) conducted a series of group interviews with OA in Dutch (n=9). In the morning, each researcher interviewed a group of 2 OA, and in the afternoon, the division was one researcher interviewing a group of 2 OA, while the other engaged with 3 OA. The interviews consisted of open-ended questions that centered around the OA's experience in collaborating with students, their intentions regarding active aging, and their suggestions for enhancing future hackathons. Each OA also verbally filled in the stages-of-change questionnaire [29] on physical activities supported by the researchers. This questionnaire consists of four questions, and by answering "yes" or "no" to each question, a score was calculated that corresponds to the stages in the transtheoretical model. Specifically, the researchers read each question out to OA and noted down the answers given by OA to understand which stage of behavior change each OA is at.

After the hackathon, most of the students (n=12) participated in individual follow-up interviews. These interviews took place within a time range of 1 day to 2 weeks following the hackathon and were conducted by the four coaches. To minimize social desirability bias, each coach was responsible for interviewing students from a discipline that was different from his/her discipline. Importantly, while the coaches interacted with almost all students during the hackathon, there was no prior contact between the coaches and the students before the hackathon. An interview guide was provided for each coach, and it was ensured that all coaches were familiar with conducting interviews for qualitative data collection. The interviews employed open-ended questions that explored the students' experiences in collaborating with OA and with students from different disciplines, as well as what they have learned during the hackathon, if any. All interviews were audio-recorded and transcribed for analysis purposes.

3.4 Data analysis

For the qualitative data, thematic analysis was conducted based on interview transcripts, observation notes, and surveys. Three researchers (GW, CV, and AK) independently coded all the interviews with OA and one-third of the interviews with students and then discussed the coding until reaching a consensus. GW thereafter coded the rest of the transcripts, observation notes, and surveys and organized them into a code book via the software Atlas.ti v9. For the quantitative data collected by the survey, after visualization, a two-sample t-test was conducted between the *before* and *after* samples for the confidence levels of both *developing interventions* and *co-designing with OA* using R. VanVoorhis and Morgan et al. suggest that for regression-based assessment, one should have a

Table 3: Summary of intangible outcomes from the hackathon for older adults and students (the corresponding sub-research question numbers are shown in the brackets)

Students	Older adults
Confidence in intervention development: increased (Q1)	The intention of behavior change: unclear (Q3)
Confidence in co-designing with OA: unclear (Q2)	Positive social experience (Q4)
Learned about behavior change (Q4)	Shared positive experience with other OA (Q4)
Expanded outlook (Q4)	
Professional growth (Q4)	

Table 4: T-statistics and p-values for the differences in confidence levels for developing interventions and for co-designing with OA before and after the hackathon (OA: older adults)

Confidence levels	T-statistic	P-value
Developing interventions	-3.38	0.005 (significant)
Co-designing with OA	-1.15	0.272 (not significant)

minimum of n = 7 participants [57]. We have n = 13 participants for the assessment; therefore, the t-test is a suitable approach for the analysis.

4 RESULTS

The intangible outcomes of the hackathon for students and OA will be reported below; see Table 3 for an overview. To facilitate reading, each participant is coded for reference later: the OA in the morning session are referred to as OA1_M to OA4_M based on the team they are in. In the afternoon session, two OA were allocated to team 2, while the other teams had one OA each; the OA in the afternoon session are referred to as OA1_A to OA4_A with OA in team 2 as OA2a_A and OA2b_A. The students are referred to by the team they are in and the discipline they are from. For example, S1_BE means the student from Built Environment from Team 1.

4.1 Students

For the survey results, seven of the 14 students indicated they had worked with OA before, and six indicated they had worked on health behavior interventions. In both pre-and post-surveys, participants were asked to indicate their confidence levels in developing health interventions and in working with OA on a 5-point Likert scale, ranging from "not confident" to "confident." Figure 4 provides an overview of the Likert scores given per confidence level (1 being not confident, 5 being confident). The y-axis indicates the number of answers given, and the x-axis denotes the confidence score. Each bar is subdivided into the education levels of the students (BSc, MSc, and PhD).

Figure 4 shows that the means of the confidence levels for both developing interventions and co-designing with OA have increased. To test whether the increase is statistically different, a two-sample t-test was carried out between the before and after samples. The t-statistics and p-values found are given in Table 4 below, where a t-value of > 2 and a p-value of < 0.05 indicate statistical significance.

As the null hypothesis is that the confidence level of students did not increase significantly after the hackathon, and the alternative hypothesis is that the confidence level of students increased significantly after the hackathon, a one-sided significance level of 0.05 was applied. From the t-tests performed and with a significance level of 2, it was found that the **confidence in designing interventions** amongst students was significant (p=0.005 and t=-3.38), thus proving the alternative hypothesis. However, regarding the **confidence in co-designing with OA**, the findings were not significant (p=0.272 and t=-1.15).

Interestingly, when comparing across education levels, the change in confidence levels on both developing interventions and on co-designing with OA are relatively smaller for PhD students than Bachelor and Master students. However, no significant difference was found in the change of confidence levels between education levels for both developing interventions and co-designing with OA (see Table 5).

Regarding the other intangible outcomes of the hackathon for the students, three themes were identified from the interviews. The first theme is **learning about behavior change**. More than half of the students have some prior knowledge about behavior change theories or interventions. These students are mainly from Industrial Design, Medicine, and Built Environment. For the students who have prior knowledge, what they learned from the hackathon are the other behavior change models and techniques they did not know before. Some students thought of some use cases for what they have learned: "I will use it, yeah, in the future as a doctor, I think, and I hope that I will be able to help some people and to use the behavioral change models as well [S2_M]"; "if, for example, someone, some patients come to me who want to stop with smoking, we need to know how far they are in their thinking process [S4_M]". For participants who do not have prior knowledge, what they learned are "what is an intervention for behavior change [S1_IT]" and "the process of design for behavior change [S2_IT]".

The second theme is **expanded outlook**. Many students reported that they learned about the other disciplines from the hackathon, which is quite different from what they are studying. A couple of students found it nice to learn how to interact with OA, even though it is not related to their current studies. Example quotes are: "I did the hackathon with the, like, an open mindset

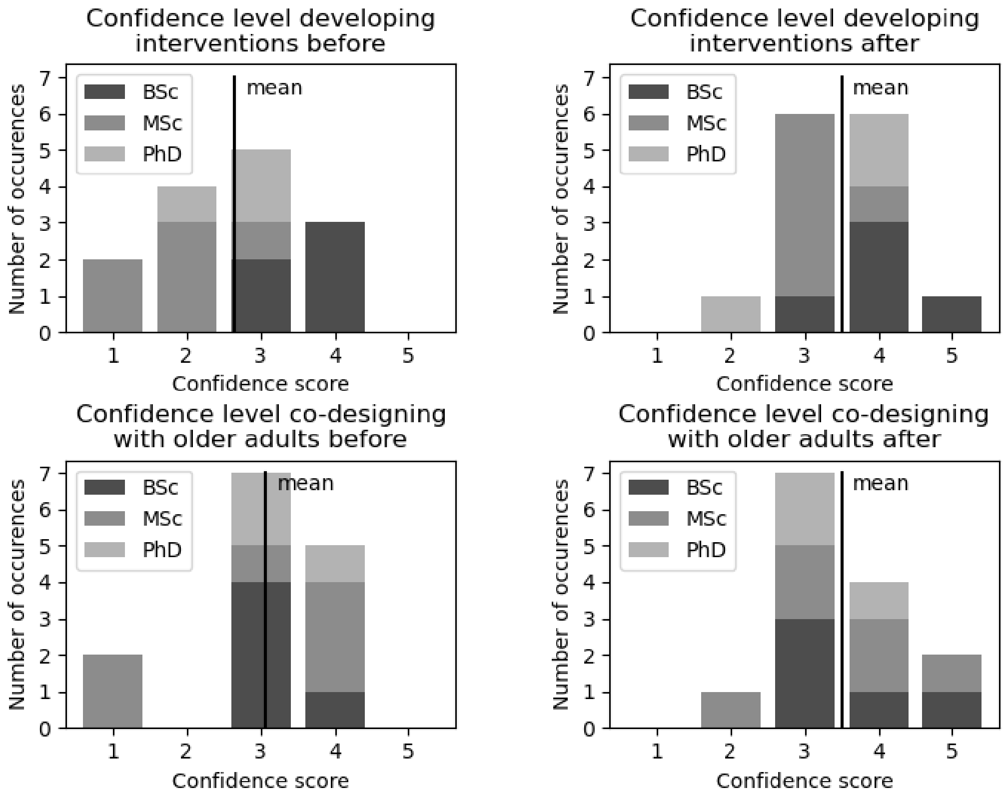

Figure 4: Distribution of confidence scores amongst students: developing interventions before (top left) and after (top right) the hackathon, and working with older adults before (bottom left) and after (bottom right) the hackathon

Table 5: F-statistics and p-values for differences between education levels in changes in confidence levels when comparing before and after the hackathon (OA: older adults)

Education levels	Developing interventions	Co-designing with OA
BSc	F = 2.20 p = 0.166	F = 0.07 p = 0.799
MSc	F = 4.13 p = 0.067	F = 0.08 p = 0.782
PhD	F = 0.33 p = 0.577	F = 0.00 p = 0.970

to learn about interdisciplinary working with other students from other fields [S2_ID]"; "I learned how to do the interviews and how to discuss with, the, uh, older adults and also discuss with team members [S3_BE]"; "There is a student in our time from medicines, and she was really good in communicating with older adults, which was really nice. So we learned something from her [S4_IT]".

The third theme is **professional growth**; many students mentioned that they learned how to work with other disciplines, which is valuable for their future careers. Two students explicitly commented that this hackathon aligns with their career development goals, among which one student would like to work in a multidisciplinary team as a designer, and the other student would like to work with OA in her medical training. Example quotes are: "...so I am a medicine student, and I prefer to work with older adults in the future. So yeah, it really matches my preference [S3_M]"; "I have that in my design vision or identity that I really like this sort of project management, so work with other disciplines really helps [S3_ID]".

4.2 Older adults

Regarding whether the hackathon caused **intention for behavior change** in OA, the outcome is inconclusive. Eight OA filled in the stages of change questionnaire with the help of the interviewers. Two OA are in the pre-contemplation stage, two OA are in the contemplation stage, and four OA are in the maintenance stage, respectively. For the OA in the pre-contemplation stage, they have not been doing enough physical activities, and they reported that their health is preventing them from doing more physical activities and that gardening will give them "dirty hands." For the OA in the maintenance stage, they are doing enough physical activities, and they replied they are busy enough. For the OA in the contemplation stage, they mentioned that they plan to do some gardening soon; OA2_M said, "I would like to be involved in some way, while I was not a gardener at all. Maybe I can do something outside with my scooter.", while OA2b_A expressed "I would like to be more active. . .but don't know how".

All OA indicated that they had a **positive social experience**. This is also evidenced by the observations during the hackathon. In general, all teams were attentive to the OA: they greeted the OA actively, leaned forward, and looked at the OA when they spoke, and one or more students took notes in each team. Teams 1, 3, and 4 included international students, so another student in these teams gave them regular updates in English. Hence, sometimes, there were two ongoing conversations in these teams. All teams tried to engage OA by asking questions and prompting further elaborations.

In the morning session, Team 3 had the highest level of collaboration. Specifically, OA3_M wrote and drew ideas together with the team, while the other OA mainly expressed their ideas verbally as consultants. Team 2 had no language barriers, and students also shared their experiences of gardening. Team 4 had a lively discussion and many waves of laughter with OA4_M. The language style in Team 1 was more formal than in other teams, and students only started to use Post-it notes when prompted by the coach. OA1_M also started to draw ideas later in the session when facilitated by the coach.

In the afternoon session, the focus of all teams was more on receiving feedback on their ideas; OA3_A was involved in writing and drawing while giving feedback, and OA in other teams gave feedback verbally. Since OA1_A speaks English, the burden of translation was removed, and all team members could engage in one conversation. In team 3, the team members switched roles so that different members did the translation in the morning and afternoon.

From the interviews, some OA mentioned the pleasure of intergenerational interaction, while others found that simply "interactions with others" made them feel happy. Example quotes are: "You were being listened to, and your idea was taken seriously [OA3_M]"; "It is a very motivated group, and they asked good questions; when you came up with an idea, they wanted to know what you exactly meant [OA2_M]"; "first of all, it is so pleasant to be busy together with young people [OA2a_A]".

We received a thank-you email from the CEO of O&G one day after the hackathon, in which the CEO mentioned the OA participants **shared their positive experiences** at the hackathon with other members and the management team of O&G.

5 DISCUSSION

In this section, we will first reflect on the identified outcomes of the hackathon, then relate to previous studies and introduce design implications for conducting this type of hackathon; we will end with the limitation of this study and future work.

5.1 Reflections of the intangible outcomes

An overview of the intangible outcomes identified from our hackathon is shown in Table 6, where inconclusive outcomes are marked with question marks. They are mapped based on the scales of their effects, as introduced in Figure 1. Since our data was collected during and immediately after the hackathon, we put "potential" for mid-term and long-term benefits that we think the intangible outcomes of this hackathon will lead to because we cannot evaluate them in this study.

First, the positive social experience of OA and the intention of behavior change that developed for some of them during the hackathon contributed to active aging immediately. Outcomes at the immediate level connect with the concept of reciprocal design in PD, which advocates that the participants should also benefit from the PD process and experience [18]. The positive social experience ends with the hackathon, and without further intervention, the intention of behavior change might diminish, and OA could not move from contemplation to the preparation stage according to the transtheoretical model [43].

Second, besides the tangible outcomes that directly relate to the innovation, the increased confidence of students in co-designing with OA and in developing interventions could also support the development of the innovation. In our case, the innovation is an intervention for group gardening; once the intervention is developed and implemented, it could play a positive role in promoting active aging. However, if there is no change in the societal perceptions and cultures about aging, its effect is likely to be limited and not lasting.

Third, the policy framework on active aging by WHO explicitly states that aging takes place within the context of others [1]. Learning about the positive experiences of the hackathon from their peers may motivate other OA to participate in similar activities for active aging. The cultivation of cognitive stimulation, the reinforcement of social interaction, and the bolstering of self-efficacy from the hackathons could gradually change the deficit perception of aging that some OA might have. Furthermore, the intangible outcomes of students also have a key role to play in active aging. By learning about behavior change, expanding their outlook, and developing skills within their chosen profession, they are more likely to engage in future projects on active aging, change their perception of OA and aging, show their understanding toward OA, and encourage OA around them to live an active lifestyle. Increasing research has found that environmental factors are equally important for active aging as personal factors [12, 15, 21].

The three categories for the intangible outcomes are by no means definitive. Besides, their mapping to immediate, mid-term, and long-term effects on active aging is not fixed. These levels are interrelated in various ways. For example, "increased confidence in intervention development" could also be one aspect of "learned

Table 6: Summary of intangible outcomes (OA: Older Adult; S: Student)

	Collaboration - Immediate benefits for participants	Innovation – (Potential) mid-term benefits for users and stakeholders	Learning – (Potential) long-term benefits for citizens
Intangible outcomes	Positive social experience (OA) The intention of behavior change (OA)?	Increased confidence in co-design with OA (S)? Increased confidence in intervention development (S)	Shared their positive experience with other OA (OA) Learned about behavior change (S) Expanded outlook (S) Professional growth (S)

about behavior change," and this increase in confidence might manifest during the hackathon process and contribute to the positive social experience in OA. Recognizing and discussing these interconnections naturally results in making sense of the meaning each category intends to convey. This preliminary mapping helps us to convey that one emerging approach to fostering active aging could be through intergenerational hackathons.

Increasingly, more research on hackathons has started reflecting on their intangible outcomes, which echoes back to the current discourse on the impact of hackathons [16, 41, 54]. A different way of categorizing the intangible outcomes could be according to their impacts on i) participants, ii) the organizing parties, and iii) the society. For participants, hackathons can help them with professional development [38], networking [30, 41, 54], empowerment [16], and social interactions [3, 19, 41]; for organizing parties, hackathons can be beneficial for networking and increasing reputation [38]; regarding societal impact, hackathons can develop the future workforce [41], raise awareness and engagement [16, 30, 41, 54] as well as inspire entrepreneurship and confidence in the community [16, 30, 41, 54]. The intangible outcomes generated by our hackathon align with previous findings on professional development [38], empowerment [16], and social interactions [3, 19, 41]. Since we only collected data from participants, future research is needed to collect data at the organizational and societal levels to paint the whole picture of the impact of intergenerational hackathons on active aging.

Our study did not find a strong indication of the intention of behavior change among OA, and whether the students increased their confidence in working with OA is inconclusive. The findings regarding the intention of behavior change could possibly be due to recruitment criteria. As suggested by the CEO of O&G, we welcomed any OA who would like to participate rather than setting criteria on their health and physical activity levels. Some OA did not plan to take up group gardening because they were already active enough, and some OA thought they were not healthy enough to do group gardening. Previous research postulates that exposure to hackathons may cause behavior change at the individual level over time [49]. In our case, another explanation is that the hackathon is too short for participants to digest the knowledge introduced to them. We also acknowledge that not all OA will be interested in the same activities. To investigate the confidence of students further, empirical studies with larger samples (e.g., a series of hackathons of the same design, a larger hackathon) that control for various procedural and contextual factors are needed.

5.2 Organize an intergenerational hackathon with a PD approach

As mentioned in the introduction, a PD approach pays special attention to inclusivity, power dynamics, and empowerment, which we will reflect on in this section, specifically on what could be improved for the future. Regarding inclusivity, we translated "hackathon" to "ideas day" for OA during the recruitment. This is because most OA are not familiar with the concept of a "hackathon", and "ideas day" makes it easier for them to expect what will happen on the day and hence engages OA to participate. On the contrary, the term "hackathon" is more motivating for the students. Reflecting on the process of the hackathon, no participant engaged in using laptops or coding; most of them did rapid prototyping, such as foam mock-ups. Previous studies also reported that when non-technical participants were involved in hackathons, coding activities became limited while "the spirit of rapid prototyping lived on in other mediums" [41]. Some students from the Information Technology background indicated that they felt they did not contribute much to the teams in comparison to traditional hackathons; while based on triangulation with observations and interviews from other students, students from Information Technology have contributed to the teams and particularly given good advice on what is technically feasible.

Compared with traditional hackathons, our hackathon has adopted a PD approach emphasizing not only technical skills but also the non-technical skills and lived experiences of OA. By placing less focus on technology, the power distribution among participants was more balanced. Specifically, OA felt they were being heard and that they had a bigger influence on the decision-making of the design process, while students with non-technical backgrounds also contributed greatly to the teams. In contrast, participants with technical skills are more dominant in traditional hackathons. Achieving a balance between the inclusivity of end-users and the creativity of technical participants (e.g., Information Technology students) in hackathons is worth further investigation. For future events, if the end product would be a working prototype, the technical participants could feel more involved. From a conceptual level, the term "hackathon" has been reported to be problematic since it is no longer representative of the breadth of activity undertaken in the event [54]. The emerging term "makathon" might be more descriptive of what activities people are expected to do; however, most participants will only understand this term if they are familiar with the concept of "hackathon". Embedding in ongoing living labs or collaborating with municipalities, councils, and other related organizations could allow these terms to gain more exposure and gradually improve citizens' understanding.

Involving more stakeholders introduces additional power dynamics in the hackathon, which needs to be managed carefully. To facilitate this, recent work by von Busch and Palmas has outlined a few propositions on coping with political and social conflicts in PD settings [5]. Even though carefully managed, there are some power dynamics in our case that cannot be ignored. First, the CEO acted as the gatekeeper for participant recruitment, and the idea of focusing on group gardening was drafted by researchers and the CEO before the researchers had the chance to talk to participants. Therefore, the CEO and researchers are more powerful regarding decision-making in the design process. This dilemma is commonly echoed by PD researchers [32, 51]. During the hackathon, since students are from different educational levels, disciplines, and cultural backgrounds, plus some students relied on other students to translate the conversation, another layer of complexity is added to the power dynamics. Moreover, OA were regarded as experts in their lived experiences during PD, so students did not question the opinions of OA critically. On the other hand, some OA were awed to be able to work with university students; this could also lead them to question the decisions made by the students less. Previous research on intergenerational co-design workshops also indicated that the sense of ownership regarding the designed outcomes is relatively low for OA [3]. More research is needed to navigate the complex power dynamics during this kind of multi-stakeholder hackathon.

Inclusivity, power dynamics, and empowerment are tightly connected. In the hackathon, we regularly acknowledged the contributions of participants and provided coaches to mentor the teams not only on technical skills but also non-technical ones, such as team dynamics (e.g., involving OA to write and draw). We also designed the activities and assigned participants to teams beforehand to ensure the flow of the hackathon was smooth and structured. This, indeed, gives the researchers more power than the participants. Since lack of structure and forming teams on the spot have been found to negatively affect the experiences of OA during the hackathon, we decided to prioritize the experiences of OA, which is a key ingredient for empowerment. Critics have raised concerns about hackathons, suggesting that their time and resource constraints may limit participants' creativity, resulting in similar ideas but not truly innovative [44]. However, we aim to position hackathons as one activity within the design process, emphasizing that intangible outcomes can be equally, if not more, valuable than tangible outcomes. For instance, the hackathon fosters understanding and bonding between students and OA, empowers students to produce more desirable designs, and arranges evaluation sessions with OA independently after the hackathon. Likewise, OA were empowered to be creative and express their ideas when working with students.

5.3 Limitations and future work

This study has three main limitations. First, our study focuses on a specific intergenerational hackathon conducted in the Netherlands, which limits the generalizability of the findings to other contexts. The outcomes and experiences may differ in different cultural, social, and geographical settings. Second, our study primarily relies on self-reported measures such as interviews, surveys, and questionnaires to collect data on the outcomes and experiences of the hackathon. Self-reporting may be subject to response biases and inaccuracies, potentially affecting the reliability of the findings. To mitigate self-reporting biases, we also conducted observations during the hackathon. After triangulating with observations, only students who were enthusiastic about the hackathon attended the interviews. Thirdly, the data were collected immediately after or a few weeks after the hackathon. More evidence is needed to validate the postulated long-term benefits of hackathons. Moreover, future hackathons could explore involving other stakeholders such as hackathon organizers, policymakers, healthcare professionals, and community members. This would provide a more holistic understanding of the outcomes and potential challenges associated with intergenerational hackathons for active aging, while more care needs to be paid to managing the power dynamics. To enhance the generalizability of the findings, future research could replicate the study in different countries or cultural contexts. Conducting longitudinal studies that follow participants over an extended period would provide insights into the long-term effects and sustainability of the outcomes generated by intergenerational hackathons. This would enable researchers to assess behavior change and the continued impact on active aging.

6 CONCLUSION

In conclusion, this study organized an intergenerational hackathon promoting active aging with a PD approach and explored the intangible outcomes it created. By engaging both OA and younger generations in collaborative design processes, this hackathon was found to offer opportunities for personal and professional growth, mutual understanding, and social connection. Whether this hackathon can increase the confidence of students in co-designing with OA and whether this hackathon can initiate the intention for behavior change among OA remain inconclusive. The study contributes to the existing literature on hackathons by specifically focusing on their intangible outcomes in the context of active aging and contributes to the field of PD by reflecting on its roles in organizing the hackathon and what could be improved. In the next step, we plan to develop an intervention for promoting group gardening based on the outcomes of the hackathon, evaluate it in the collaborating senior center, and follow up on the experiences of participants. We encourage researchers to further investigate the long-term effects of intergenerational hackathons on behavior change and active aging while reflecting on the roles of PD in organizing these hackathons.

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APPENDIX

A HACKATHON PROGRAM

The hackathon program consists of five stages, namely, Discover, Design, Develop, Evaluate, Deliver. The key activities in each stage will be explained in detail below; while speakers of each presentation are mentioned within the brackets.

In the Discover stage, guided by the name cards, students sat with their team members as soon as they arrived. After being welcomed by the organisers with a presentation about the purpose of the hackathon (AK), the context of O&G (CEO of O&G), and advice and tips on co-design (GW), an ice-breaking activity was carried out to let students express their assumptions about the disciplines in which their teammates are, and their interpretations of the key concepts of this hackathon (e.g., "co-design", "behaviour change"). Then students from each team discussed what knowledge and skills they can bring to the team and listed them in a table.

In the Design stage, the co-design session started with a presentation in Dutch (CV) when all the OA arrived. The presentation helped OA to recap the goal of the session, facilitated ice-breaking and introduced a fictional character Anne, an OA who likes gardening but is experiencing physical challenges and living alone. In the morning session, the first activity was created to let OA tell students if they would like to add more information about Anne. This activity was followed by a series of questions to provoke discussion within the teams. The questions were printed on A3 papers and participants were encouraged to draw and write on post-its and stick them on the papers. The questions were distributed to the teams in the sequence below: "What should we take into account?", "Possibilities, concepts, and ideas?", "What are your favourite ideas?", "What can motivate participants to stay engaged?". This is the stage where their preliminary idea originated.

In the Develop stage, after OA participants left, the students were introduced to the toolkit for supporting their design process via a presentation (GW) and visited the O&G under the guidance of the CEO of O&G during the lunch break.

In the Evaluate stage, a new group of OA participants joined, and the same presentation and icebreaking were carried out as in the morning (by CV in Dutch). After ice-breaking, students presented the idea selected in the morning (Design stage) to OA participants. A template was created for the students to pitch their ideas to OA participants in a structured way. Then some questions printed on A3 papers were distributed to the teams to provoke discussion in the co-design activities (e.g., "What do you like about this idea?", "What do you think could be done better?").

In the Deliver stage, when the OA left, the students had 1.5 hours to iterate and prototype their ideas. At the end of the hackathon, each team pitched their concept for five minutes, and eight judges were invited to ask questions and rate the concepts against the assessment rubric. Seven of the judges work in local organisations on promoting active ageing and one judge had researched how to design for promoting active ageing during her PhD. The team that received the highest score (from all the judges combined) was awarded the best team.

During the hackathon, to motivate OA participants and address their concerns about lacking technical knowledge, we explained to them that technical skills were less important than their willingness to share their personal insights and experience. For both co-design sessions, there was a wrap-up presentation (CV) to let OA know they have achieved the goal of the workshop and each of them received a pot of flowers as a thank-you gift. We also reiterated that participants could resign at any time and that we would provide them with transportation and any help that they may require as stated in the informed consent forms.