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What If Artificial Intelligence Become Completely Ambient in Our Daily Lives? Exploring Future Human-AI Interaction through High Fidelity Illustrations

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ABSTRACT

As artificial intelligence (AI) has become prevalent in users' daily lives, it is becoming critical for HCI designers to envision and design future human-AI interactions. Recent studies have highlighted the importance of exploring user-centered future design directions before implementing a technology in users' lives. However, it is challenging for HCI designers to envision the societal impact of future technology that does not exist and understand potential users' perceptions. Therefore, to comprehensively envision future human-AI interactions and their impact and elicit potential users' perceptions of the future technologies, we created high-fidelity illustrations with designers and illustrators for immersive experience. Subsequently, through an online exhibition of these illustrations, we derived potential users' perceptions, expectations, and concerns about the future. Based on our findings, we explored user-centered considerations for implementing AI in users' daily lives through elaborately articulated human-AI interactions.

1. Introduction

Artificial intelligence (AI) is becoming increasingly prevalent in our surroundings. Furthermore, technological advancements, such as machine learning (ML) and ambient intelligence (AmI) (Amershi et al., 2019; Marenko, 2018), have diversified the forms and functions of human-AI interactions. With the rapid advancement of AI-related technologies, it is necessary to speculate on the changes new technologies will bring to human-AI interaction and how those changes may unfold in our daily lives. This is not only crucial for the human-computer interaction (HCI) research field but also for HCI design practitioner to design better user experiences (Cave et al., 2020; Luria et al., 2019, 2020; Marenko, 2018; Mucha et al., 2020; Torresen, 2018). Thus, HCI designers utilize their problem-solving skills in a user-centered approach, making it possible to design future interactions.

Even though HCI designers have become skilled at deriving future scenarios of user-centered human-AI interactions, previous studies revealed that HCI designers mainly struggle to envision and prototype AI systems (Dove et al., 2017; Gillies et al., 2016; Holmquist, 2017; Kuniavsky et al., 2017; van Allen, 2018; Yang et al., 2018, 2020). The first reason is that the definitions of the terms "AI" and "future" are familiar but ambiguous (Mucha et al., 2020). Therefore, comprehensively envisioning what future human-AI interactions may take place in what situations and impact of such interactions on society is not easy beyond fragmentary predictions of the moment at which users interact with the new technology. Second, although discussion and reflection on future technologies should be promoted based on future scenarios that everyone can understand (José et al., 2010), it is difficult to prototype and explain future concepts of AI to potential users (Yang et al., 2020). Accordingly, understanding potential user perceptions by indirectly experiencing a distant future is challenging.

To envision future AI applications and understand user perceptions, existing research has used diverse design methodologies; role-playing, scenarios-based storyboards, Wizard of OZ methodology (Lee et al., 2017; Luria et al., 2019; Riek, 2012; Stifelman et al., 2013). Particularly, among the various approaches, researchers have explored users' perceptions as a form of art representing future scenarios, such as movies, plays, and novels (Ambe et al., 2019; Bozic Yams & Aranda Muñoz, 2021; Kang & Jackson, 2018; Luria et al., 2020; Søndergaard & Hansen, 2018; Tomás, 2017). Based on the advantage of art, stakeholders can easily experience future scenarios then, previous studies have been able to derive various stakeholders' perceptions and critical perspectives on the future. Accordingly, future scenarios in the form of art made it possible for users to enhance the evaluation method for future AI applications (Duarte et al., 2019; Weiley & Edmonds, 2011).

Particularly, in the design research field, visual art has been used in design methodologies, such as storyboards and drawing studies, along with other forms of artwork because it is easy for various stakeholders to understand ideas intuitively by viewing it. Subsequently, future concepts can be evaluated by various users (Ambe et al., 2019; Kang et al., 2018; Luria et al., 2020; Parviainen & Søndergaard, 2020).

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Beyond the design research field, in the area of science-fiction movies, illustrations have been widely used to express the core concepts of movies beyond storyboards. An effective illustration makes it possible to evoke new directions of thinking with high-level visual detail. Therefore, movie directors have collaborated with illustrators in the early stages of film production (Harris & Scalzi, 2014; Mead et al., 2017; Peter-Hyams, 1943; Peter-Jackson, 2001) such as for *Star Trek* (Jeffrey-Jacob-Abrams, 2009) and *Blade Runner* (Ridley-Scott, 1982). Visual futurists such as Syd Mead have played an important role in predicting future trends based on core concepts conveyed in science-fiction movies (Mead et al., 2017). Referring to insights from science-fiction movies, we found that illustrations have been the basis of the core concepts in these movies, which have already inspired many HCI fields. In particular, our study focused on these characteristics of an illustration: (1) Visual details can specify the designer's idea, imply various moods, and draw out critical discourse through artistic connotations. (2) High-fidelity artwork can be more immersive and elicit deeper appreciation from the audience. (3) Illustrations are easy for various stakeholders to understand.

We aimed to envision what future human-AI interactions may take place in what context, how AI can blend into users' everyday lives, and explore how potential users perceive future scenarios and imagine future AI technologies. To achieve these goals, we conducted a collaborative workshop with HCI designers and illustrators grouped in pairs. Four pairs completed four illustrations over approximately one-and-a-half months through an iterative design process to complete high-fidelity artwork for exhibition. Then, we built an online exhibition site with four illustrations, allowing users to appreciate and experience future scenarios to identify their reactions and perceptions toward the future. The findings described features of future human-AI interactions and users' perceptions, expectations, and concerns regarding future human-AI interactions. Our contributions are (1) prototyping the users' daily lives in which AI coexists through comprehensive high-fidelity illustrations, (2) further understanding potential users' perceptions of implicit future AI applications by provoking critical perspectives, and (3) deriving insights and implications for designing future human-AI interactions.

2 Related works

2.1. Envisioning the future of artificial intelligence

Owing to the rapid development of AI-related technologies such as ML, the prediction of whether AI will have a positive or negative impact on society has been discussed in various research fields (Ambe et al., 2019; Cho et al., 2019; Clark et al., 2019; Huang et al., 2020; Lee et al., 2020; Nadikattu, 2016). Based on this background, speculating on how future AI technologies will change users and their lives has become important in the design research field as well. Therefore, designers have primarily applied two approaches to present future directions: (1) Discovering the current problem through traditional interaction design processes and suggesting future AI directions in which the problem is resolved (Cho et al., 2019; Park & Lim, 2020; Porcheron et al., 2018; Sciuto et al., 2018). (2) A speculative design approach focused on discovering new interaction design directions (Luria et al., 2019; Luria et al., 2020; Søndergaard & Hansen, 2018). Because the problem-solving approach tended to focus on solving the user's current issues, these studies suggested a design direction within the scope of the near future. On the other hand, research on a speculative design approach has mainly explored the relatively distant future by co-designing creative scenarios such as new functions and AI interactions. In this study, we focused on studies that explored future directions through a speculative design approach (Auger, 2013; Marenko, 2018).

José et al. emphasized that envisioning future technology cannot be seen as a simple prediction. They argued that discussion and reflection on future technologies should be promoted based on scenarios that can be understood by everyone (José et al., 2010). Based on this background, previous studies on envisioning the future, including design fiction, have explored future scenarios for various types of AI applications, including AmI and robots (Auger, 2013; Luria et al., 2019; Luria et al., 2020; Marenko, 2018; Søndergaard & Hansen, 2018), using diverse outcome formats, such as storyboards and novels. Augusto and McCullagh presented applicable examples to anticipate possible futures for AI by explaining systemic features of AI and importance of recognizing the changing paradigm before a technology becomes completely widespread. They introduced seven information-flow-oriented scenarios to better illustrate the idea of an application. These included a hospital room where a patient is monitored for health and security reasons, an underground station equipped with location sensors to track the location of each unit in real time, a school where students are monitored to balance their learning experience, and public surveillance (Augusto & McCullagh, 2007). Cambre et al. used story completion methodology to elicit participants' visions of possible futures. They asked 149 participants to complete a story individually based on a brief story stem set in 2050 in one of the following five contexts: home, doctor's office, school, workplace, and public transit. They found that the stories revealed functional limits and concerns about today's voice assistants and AI, such as replacing human jobs, eroding human organs, and causing damage owing to malfunctions. Then, they discussed how these speculative visions could inform and inspire the design of voice assistants and other AIs (Cambre et al., 2020).

To investigate complex future technologies in a human-centered way, Mucha et al. conducted a workshop called "A Workbook Sprint" with 45 participants to design future AI. The design workshop produced five speculative design concepts: the society, mobility, environment, health, and education (Mucha et al., 2020). To anticipate eliciting values and perspectives of 23 roboticists on future technologies, Cheon and Su introduced the "futuristic autobiographies" method, inspired by design fiction. Through an empirical and background approach, researchers posed several stories involving the participants as characters about a future with robots.

The stories involved technological expectations, broader societal tensions considering personal values, roles of robots in a future society, and popular public discourse. Based on these stories, this approach allowed participants to uncover new values and perspectives on future robots (Cheon & Su, 2018). In addition, Ambe et al. presented a co-design fiction that encouraged users to use their imaginations so that they would speculate not only on future technologies but also on a future life through co-created fictional works. Their stories showed a future that was neither dystopian nor utopian and the stories reflected an eagerness to maintain independence from technology in social and moral dilemmas. In addition, they revealed that writers never focused on the functionality of the technology itself but rather on its incidental influences on people's lives and relationships. This study provided the insight that artists could envision the future from a macroscopic perspective (Ambe et al., 2019). To explore possible future AI-related scenarios with social roles, Luria, Zheng, et al. generated a storyboard to prompt participants to reflect critically on the meaning of each future scenario. They explored how socially sophisticated agents can detect, judge, and navigate social roles and individuals in future scenarios. Based on their findings, they discussed the influence of future research and future agent behaviors (Luria et al., 2020).

Beyond simply specifying or visualizing future scenarios in writing, several researchers have studied co-designs with artists to discover new interactions to derive artwork as a design outcome that various stakeholders can intuitively understand and provoke critical discourse. To explore the design space of socially sophisticated future agents in social spaces such as homes, Luria et al. developed an immersive play called "Robotic Futures" using an iterative co-design process with designers and theater experts. Then, they performed it in front of an audience. The play demonstrated various unexplored AI applications utilized in various situations. They concluded with a proposal for design considerations for future agents. Based on the emerging research in this field, they focused on the characteristics of a privately owned agent (compared with a shared agent) and accounted for the roles and functions that each introduces when integrated into homes. As a result, authors revealed the three implications that may affect agent design: the agent's owners, type of the agent, and users present during the interaction (Luria et al., 2020). To gather insights on how people would interact with a voice assistant that can interact with whispering in different contexts, Parviainen and Søndergaard conducted a co-speculative workshop with an actress and designers. The participants' fictional short film raises critical questions about how much humanity an AI application should possess, how close users want to get along with AI technology, and whether users will become more dependent on this technology (Parviainen & Søndergaard, 2020).

Referring to existing studies, we assumed that collaborating with artists to represent future scenarios as artwork would be a meaningful approach to envisioning future AI scenarios. In particular, it is necessary to foresee the societal impact of AI technologies from a comprehensive perspective. It can also arouse critical views by conveying certain messages from designers and artists to future users.

2.2. Visual art for envisioning artificial intelligence

Among various art types, visual art have been used as a design methodology to generate user scenarios, such as storyboards (Fassl et al., 2021; Luria et al., 2020; To et al., 2021), or specify abstract concepts, such as users' mental models (Lee et al., 2019, 2020; Moraveji et al., 2007; Xu & Warschauer, 2020), because of the advantages of rapid iteration and articulating ambiguous concepts. In addition, within the field of science-fiction movies, when defining a concept of the future, concept artists and visual futurists express the future through illustrations (Burns & Haldeman, 2014; Mead, 1933). Mead et al. emphasized that illustrations are an appropriate form for presenting the core of future concepts beyond a simple storyboard (Mead et al., 2017). In this regard, we assume that illustrations are an appropriate form for exploring future scenarios for AI applications that do not yet exist, as well as for exploring how design requirements can be incorporated into our future. In addition, the high level of visual detail in illustrations can evoke new ways of thinking. Thus, many science-fiction filmmakers discuss core concepts with illustrators in the early stages of film planning (Burns & Haldeman, 2014; Mead et al., 2017). For example, when visual futurists, such as Syd Mead, draw illustrations to shape the core universe of a film, the illustrations express more than just how the future looks (Mead, 1933). Director Peter Hyams ultimately changed a script to incorporate such new ideas after collaborating with his illustrator (Peter-Hyams, 1943). By referring to insights from examples of science-fiction films, we found that illustrations are the basis of many core concepts of science-fiction films, which have already inspired many HCI fields.

Based on previous studies, we determined that illustrations can articulate a designer's idea through visual details and imply various moods and artist's intentions, which can draw out critical discourses. In addition, because illustrations can inspire various stakeholders, high-fidelity illustrations allow the audience to feel an immersive and deeper appreciation toward the artwork. Owing to these possibilities, we assumed that illustrations are an appropriate form of expressing future AI scenarios through collaboration. In particular, envisioning future AI through high fidelity illustration could express concepts related to what types of AI hardware will naturally communicate with users in various ways and what spaces can exist ubiquitously. Furthermore, illustrations could not only visualize designers' ideas but also could provide potential users with an immersive and indirect experience that can evoke a critical perspective and capture users' perceptions of future technologies.

3. Method

We aim to envision future human-AI interaction scenarios from interaction design perspectives and represent them as

Table 1. Pair composition, expertise, experience of participants (gender and age were excluded according to the participants' preference), and concept of future scenarios.

Pair	ID	Expertise	Experience	ID	Expertise	Experience	Concept of future scenario	Result
A	Illustrator 1	Cross-culture	10 years	HCI designer 1	Design fiction	8 years	The AI will be personalized for each user and always follow the user.	Illustration 1 (Figure 6)
B	Illustrator 2	Science fiction	8 years	HCI designer 2	AI for smart home	10 years	The AI will not only interact with the user, but also socially interact with other AIs.	Illustration 2 (Figure 7)
C	Illustrator 3	Social issues	8 years	HCI designer 3	User-centered interface design	8 years	The AI in as invisible form can accumulate the user's information without the user's permission.	Illustration 3 (Figure 8)
D	Illustrator 4	Metaphorical storytelling	11 years	HCI designer 4	Inclusive AI	6 years	The AI will support the user by changing its appearance according to the user's needs.	Illustration 4 (Figure 9)

high-fidelity artistic illustrations. We built a web-based exhibition site with high-fidelity illustrations to elicit user reactions and perceptions of future concepts. Because previous studies have revealed that artworks help users perceive the reality of immersive simulation beyond simple representation (Bidault-Waddington, 2017; Luria et al., 2020) and enrich the user evaluation method (Duarte et al., 2019; Weiley & Edmonds, 2011), we used an exhibition with illustrations as our research methodology. In this section, we explain how we created high-fidelity illustrations representing future scenarios and how we allowed the audience (i.e., potential users) to view future scenarios. Our study was approved by the institutional review board (IRB) at KAIST (KH2021-038).

3.1. Collaborative workshop to envision future human-AI interactions through illustration

3.1.1. Participants

We recruited HCI designers and illustrators to articulate future human–AI interaction scenarios from interaction design perspectives. Then, we advertised in the artist online community for illustrators and HCI community for designers. We intended to create collaborations between HCI designers, who have a user-centered perspective and expertise in designing AI interaction experiences, and illustrators, who have expertise in visualizing future concepts and expressing high levels of complete visual detail (see Table 1). Specifically, we intended to recruit HCI designers from various AI developers or HCI researchers because they not only have technical knowledge about AI but are also familiar with imagining future interactions via a storyboard or scenario. In addition, because all designers were familiar with using AI-embedded systems or devices, it was appropriate for them to play a role in the divergence of future AI design directions considering users' perspectives. The four HCI designers were based in South Korea. They had 6–10 years of experience, with an average of 7.62 years of experience ($SD = 1.79$). All HCI designers had previous experience in designing future human–AI interactions and wanted to collaborate with illustrators. For paired collaborations, we recruited four illustrators: two illustrators were based in the U.S. and the other two were based in South Korea. The illustrators had 8–11 years of work experience, with an average of 9.25 years of experience ($SD = 1.5$). We thought that a small group would be more effective in sharing opinions during the iterative process; therefore, we organized each pair as a team. Consequently, four HCI designers and four illustrators were grouped in pairs, creating a total of four pairs (see Table 1 for detailed fields of expertise). Because our study intended to use illustrations as stimuli to evoke new thoughts in the audience rather than generalizing the illustrations to a quantitative analysis, our small number of illustration samples was not a critical limitation. As the entire collaboration process took about a month and a half, the participants were rewarded with approximately U.S.$200. Furthermore, all participants were Korean; therefore, the entire process was conducted in Korean.

3.1.2. Procedure

The collaboration process comprised a 1-day design workshop, several weeks of interaction to develop ideas and complete illustrations until the concepts of the HCI designer and illustrator were merged, and debriefing interviews regarding the final illustrations (Figure 1). The entire process took approximately one and a half months. All procedures were conducted online because of COVID-19, with no significant limitations to the online experiments owing to effectively using online tools such as Zoom (2012), Google Hangouts (Google, 2013), and Miro (Participatory-Culture-Foundation, 2020).

3.1.2.1 Collaborative workshop. A collaborative workshop was conducted to envision how future interactions with AI could change users' daily lives. To determine the overall concept of future human–AI interactions and generate ideas for the first sketch, the author moderated a collaborative workshop. First, the moderator introduced everyone and shared design projects from designers and artwork from

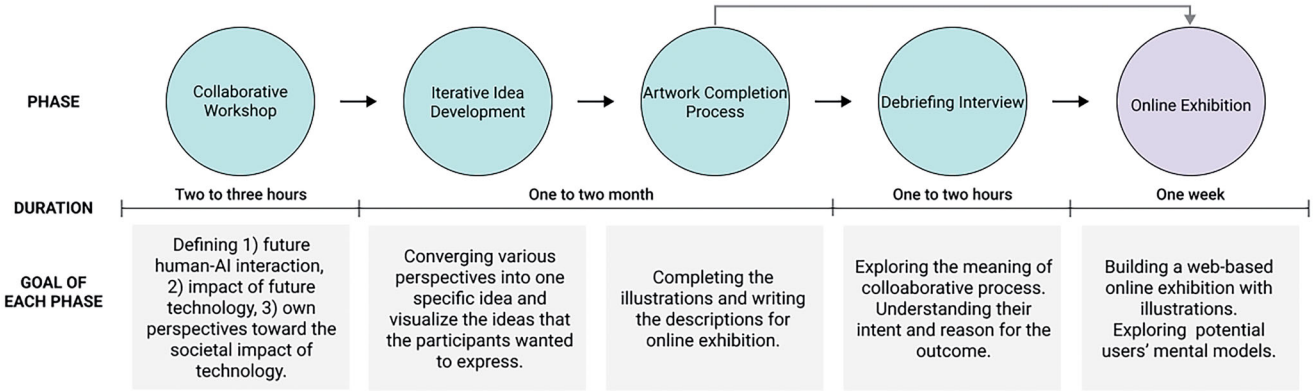


Figure 1. Entire procedure of the collaboration workshop and online exhibition.

illustrators. This helped the participants to understand each other's characteristics. After the introduction, movie clips related to future AI technologies, for example, *Iron Man* (Jon-Favreau, 2008), TV series *Years and Years* (Russell-T-Davies, 2019), and previous studies on the future of human–AI interactions were presented as stimuli to explain the collaborative topics. Our research team debated whether to present movie clips as stimuli because they could make participants have biased views. However, all the participants had already seen the movies and had knowledge of conceivable future uses of AI. These stimuli allowed the HCI designers and illustrators to generate their ideas without bias; the session lasted approximately 15 minutes. Then, each pair was asked to envision the ways and contexts in which users would interact with AI. They were asked to define terms such as "future" and "human-AI interaction" and determine the ideation process and way of expression according to their intended vision. In particular, we asked them to include four essential elements in the illustrations: (1) AI, (2) user or users, (3) interactions between AI technologies and users, and (4) environment or background. These four elements were not mandatory (which would limit ideas) but served as a guide for participants to express future human–AI interactions. Through guidance from these elements, we tried to avoid overly abstract or conceptual illustrations. After roughly setting the idea, we asked designers and illustrators to discuss and define their perspectives on future technology as well as the intentions that they wanted to convey to the audience through artistic connotations.

3.1.2.2. Iterative idea development and artwork completion process. After the collaborative workshop, the illustrators had one week to present their first sketches to HCI designers. The illustrators drew three to four versions of the sketch drafts based on ideas generated from their collaborations (Figure 2). The HCI designers and illustrators underwent an iterative process to combine multiple sketches into one specific idea and visualize the ideas that they wanted to express. During the iterative process of completing the illustrations and writing the descriptions, the illustrators and HCI designers interacted freely through the Messenger application and online meetings. The iterative design process lasted until they decided on a final idea and the illustration was completed. Figure 3 shows the development and change in ideas through an iterative process. During the process, the participants modified and added elements to complete collaboratively the ideas. As a result, they completed illustrations and descriptions over approximately one to two months. When visualizing the final idea, the illustrators were encouraged to promote their personal styles. By reflecting on their viewpoints, we attempted to capture their vision or viewpoint of future technologies. Through this approach, we intended to broaden the audiences' perspectives on

Figure 2. Examples of the first sketches based on the ideas exchanged between HCI designers and illustrators from the collaboration workshop.

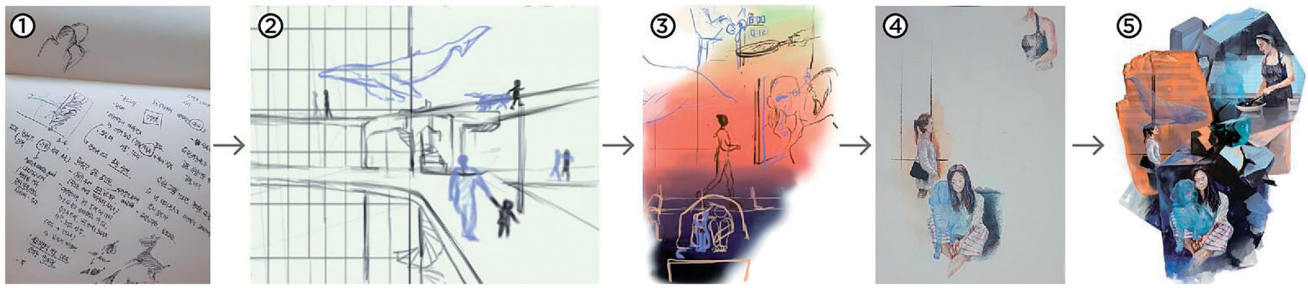


Figure 3. Changes over time for the concept converged by Pair D throughout the iterative process: ① Organizing ideas and drawing basics through collaborative workshops, ② the first draft of the visualized ideas from the collaborative workshop, ③ sketch reflecting modifications to emphasize the appearance and characteristics of each user, ④ sketch reflecting modifications to clarify user behavior, and ⑤ sketch reflecting modifications to specify where users communicate with AI.

future technologies from various viewpoints and deepen the imagination derived from the artwork.

3.1.2.3 Debriefing interview. After the collaborations, the HCI designers and illustrators sent their illustrations and descriptions to the moderator in a digital form. Then, we conducted an online debriefing interview that lasted approximately 90 min. HCI designers and illustrators were asked to explain the final result, and the moderator inquired about the future human–AI interactions expressed in the illustrations and messages they wanted to express in their artwork, as well as the perspective they wanted to convey to the audience. Regarding future human–AI interactions, we asked why they expressed the new interaction using their specific approach and how these new interactions affect users' daily lives.

3.2. Online exhibition

To elicit potential users' reactions to future human-AI interactions, we built a web-based online exhibition with illustrations from a collaborative workshop (Figure 4). The exhibition was held online because of the COVID-19 pandemic. The web address of the exhibition was posted and promoted by the Korean online community. Through this online exhibition, audiences could view the exhibition freely, regardless of location and time, and we were able to collect responses from viewers of various age groups. We intended for potential users to appreciate high-fidelity immersive illustrations, including various perspectives, and imagine and think about the future critically. Audience members willing to view the exhibition on the future of AI were invited to respond to the questionnaire voluntarily. In particular, we targeted audience who are familiar with using AI-embedded devices were asked to respond to the survey. This is because people who are currently familiar with AI-related technologies are more likely to become potential users in the future, and it is necessary to understand the needs of everyday users. There was no specific standard for everyday users, but if the audiences themselves thought so, they responded to the questionnaire. Audiences who completed the responses were rewarded approximately U.S. $50 by a lottery. The online exhibition consisted of an overall introduction, exhibition guide for viewing the artwork (Figure 5), and individual description of the artwork. Before viewing the exhibition, the audience was asked to imagine each future situation through an indirect experience by placing themselves into the illustration. In the section explaining individual illustrations, the audience was allowed to view the exhibition freely without any description at first. Next, the audience can read detailed descriptions written by designers and illustrators. After viewing the online exhibition, the audience members were asked to voluntarily participate in the online survey. We provided a link to the survey along with the online exhibition. The survey consisted of four sections. First, the audience participants were asked to select their impressions of each illustration in a multiple-choice manner –positive, negative, neutral, and mixed (some aspects are positive and some aspects are negative)– and write the reasons for their answers in detail. Second, we asked open-ended questions about their thoughts on the future of AI after they experienced the various illustrative artworks. For the open-ended questions, the audience shared their concerns and expectations regarding future technologies. In the last section, we asked the audience whether any aspect of the exhibition made them think differently about AI, how the illustrations helped them experience the speculative future, and what aspects provoked critical discourses. Overall, 25 people viewed the exhibition and shared their impressions (females = 15, males = 9). Although the number of audience members who experienced the artworks was larger than this, the questionnaire was quite long and the dropout rate was high due to the lottery reward scheme.

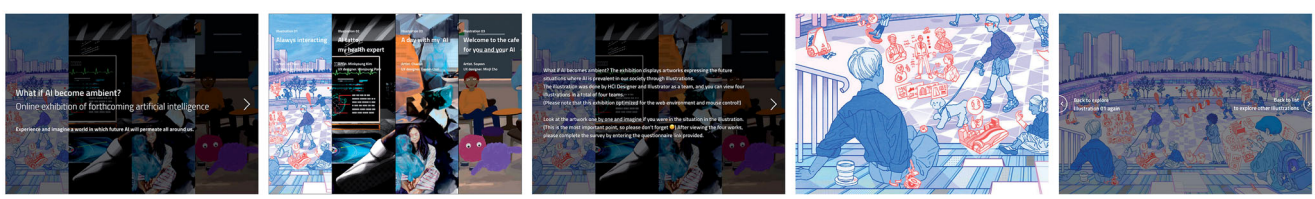
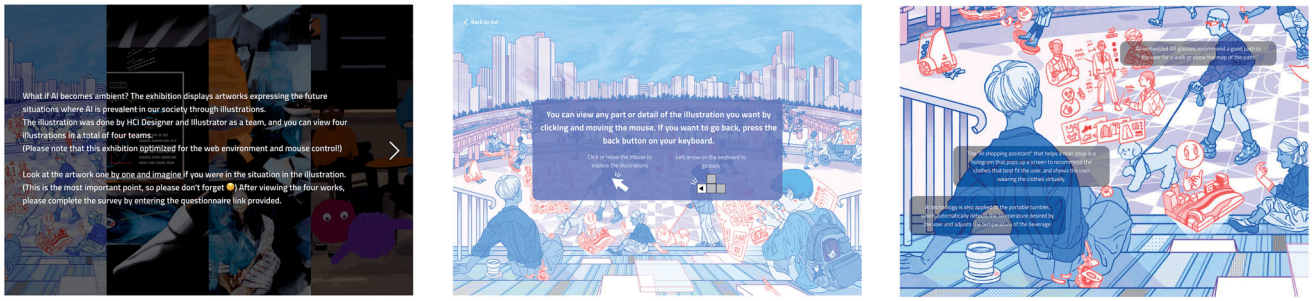


Figure 4. Example pages of web-based illustration exhibition



Please appreciate artwork one by one and imagine if you were in the situation in the illustration. (This is the most important point, so please don't forget 😉) After viewing the four works, please complete the survey by entering the questionnaire link provided.

You can view any part or detail of the illustration you want by clicking and moving the mouse. If you want to go back, press the back button (left arrow) on your keyboard.

When you click once more on the enlarged screen, an explanation about the details of the illustrations appears. After reading the description, double-click is for going back to full screen.

Figure 5. Examples of web-based illustration exhibition guides: an explanation of the exhibition guide included on the website screen

Consequently, 25 participants completed the survey, excluding incomplete responses. The responding audience members were between 23 and 63 years old (avg. = 32.6, $SD = 12.7$). Audiences from various age groups were able to respond because of the exhibition and survey's high accessibility and ease of use. Although the number of visitors was limited and small for an online exhibition, it was still possible to collect meaningful data because visitors of various ages viewed the exhibition and shared their in-depth thoughts. In addition, we did not find significant differences in responses with respect to age and gender. However, individual imagination and perception of AI had a greater influence on responses.

3.3. Data analysis

After the workshop and online exhibition, we obtained a design workshop video and communication content from outside the design workshop (texts and images from the messenger app and recorded data from the online meeting), final description of ideas, four illustrations, and user responses from the online exhibition. First, we analyzed the collaborative workshop data to investigate how detailed interaction elements were articulated in the illustrations. Then, by analyzing users' reactions to illustrations and linking the visual factors that users focused in the illustrations. In other words, we analyzed illustrations and exhibition results, then connected them to derive a human-AI interaction theme that transformed into potential lives of future users.

To analyze the workshop data, we transcribed all audio data and derived the initial theme by analyzing the entire transcription using the thematic coding method (Gibbs, 2007). Regarding the illustration result, thematic coding was conducted in the same way to reveal which factors were derived while labeling the visual elements in the illustration. To comprehensively analyze the workshop results, the first and second authors applied the labels to the initial theme, and then they conducted open coding. In the process of analyzing the workshop data and illustrations, two researchers repeated this process three times while cross-checking each other. We discussed these codes, refined, added, and merged them; then, deleted codes that were not included in the three times iterations. Through this process, 15 codes were excluded, and five themes were derived by affinity diagramming 122 codes (Beyer & Holtzblatt, 1997).

To explore the impact of these illustration stimuli on audience's perceptions, expectations, and concerns about future AI scenarios, the survey data were analyzed using a thematic coding approach. We discussed and refined codes to reach agreement ($K > 0.74$) and excluded data instances without agreement. After the coding process, a total of 119 codes were derived. We refined the themes through three iterative coding processes; then, 98 codes were analyzed and 13 final themes were derived by two authors through the affinity diagramming. Finally, the analyzed data of users' reactions were applied to themes derived from the illustration to identify the critical perspectives the users individually harbored toward future AI scenarios. Consequently, we categorized our results into five primary themes and 13 subthemes of potential users' mental models on factors future human-AI interactions.

4. Results

This section details the illustrations derived from collaborative workshops and describes the interactions between designers and illustrators to explain how these illustrations were expressed. At the end of this section, we will describe audience responses as well.

4.1. Illustrations from collaborative workshop

4.1.1. Illustration 1: Always interacting

Illustration 1 represents a societal change in which each user owns an AI system. This system communicates through various exteriors, functions, and interaction methods, based on each user's characteristics and situations.

Figure 6. Always interacting. AI will be personalized for each user and always follow the user (drawn by the Pair A): All details of the work were carefully expressed after three meetings and four revision processes throughout the workshop.

> Since we are living together in a space called society, it seems that we cannot exclude things like showing off or being shown to others. So, wouldn't people want to choose their own one from various options of AI exteriors? (Illustrator 1)

Particularly, Figure 6 ① shows an elderly hearing-impaired woman wearing smart gloves to communicate with a personal AI assistant using sign language. Her personal AI assistant also uses hands to interact and communicate in sign language. This AI that can use sign language has an exterior tailored to the user's communication ability and method, and the user's smart gloves act as a bridge for communicating with the personal AI. In addition, the child user carries her favorite stuffed animal, which has an embedded AI that provides location tracking, emotional comfort, and guidance (Figure 6 ②). Next to the child is her grandfather, who uses a smart cane to monitor and detect his health condition. The smart cane can send notifications and emergency alarms to family members and health care facilities if necessary (Figure 6(③)). Based on the personalized AI hardware, to maximize natural interactions, such as multitasking between humans and AI, Figure 6(④) depicts an AI embedded in a drone that informs the user about her running posture, heart rate, and distance while carrying the user's towel and water bottle. This allows the user to focus on running without the burden of carrying additional weight or objects. These conceptual multi-modal interfaces can enhance the natural and seamless interactions between users and AIs.

> I want AI to become very diverse. I try to express many different AIs as possible in the future for different cultures and different age groups. (Designer 1)

This future concept of AI tailored for each user was derived from the synergy between the designer's intention to consider various target users and illustrator's macroscopic view of a society in which various people coexist. The designer focused on the relationship between users and AI, as well as the interaction experiences of various users; while the illustrator focused on the societal changes that could occur if advanced AI got developed, rather than individual user–AI interactions. Sometimes, when an illustrator thinks too macroscopically, the designer can help the artist see the detailed interaction elements. On the other hand, when the designer focuses only on the one-on-one interaction between the user and AI, the illustrator can encourage the designer to think about the societal impact. This process attempts balance the perspectives of the designer and illustrator based on different ways of thinking in the ideation process.

4.1.2. Illustration 2: Welcome to the café, AIs and people

Illustration 2 depicts a café that users and AIs in the form of pets can visit together. This café is a space for social

Figure 7. Welcome to the cafe for AIs and people. The AI will not only interact with the user, but also socially interact with other AIs (drawn by the Pair B): This concept was completed through four meetings and six revisions throughout the workshop.

interaction between people and AIs who follow their owners. Accordingly, AIs can freely interact with other AIs. Pair B envisioned that if each person has an individualized AI in the future, then social interactions between AIs should also naturally follow. Additionally, Pair B expressed AI as pet-like entities to depict a situation in which AIs will become more integrated in users' lives. The appearance of AI was similar in shape, with only the color and shape of the hair being different for each user. Designer 2 explained the reason for the AI's appearance:

> Appearance of AI would not be very unique. If it's too noticeable, users may be reluctant to talk outside. For example, even though the designs of smartphones are slightly different, the exterior design does not get out of the broad category of smartphones, so future AI will only have slightly different details for each user within a similar category. (Designer 2)

During the collaboration process, Illustrator 2 imagined that AIs could engage in social activities, such as gathering with other AIs in a café (Figure 7 ①). The designer thought that the illustrator's unexpected imagination of social interaction between AIs was interesting; in previous studies, communication among multiple AIs was used to perform a function seamlessly. However, it has never been considered as a social activity for AIs.

> It will be an interesting situation when users meet friends at the café. When AIs follow their owners, they can eat something and hang out with other AIs as their owners do. Through this situation, we can show that in the future, our lives and those of AIs will become closer. (Illustrator 2)

Based on the illustrator's idea, the designer tried to design a new function for AIs' social activities. The designer stated that, even though the illustrator's idea was unexpected and unfamiliar, the concept was easy to understand because the illustrator communicated the unfamiliar concept through visualization. Moreover, it was possible to envision the future from a new perspective. Through this collaborative process, designers and illustrators have shared inspiration for new AI features. Furthermore, designers and illustrators have expressed concerns about people becoming dependent on AI with whom they may form closer relationships than with other people. Accordingly, the designer attempted to clearly define the vertical relationship between AIs and humans. As shown in Figure 7 ②, the poster on the wall, which shows that AIs are not allowed to sit on users' seats, implies that AIs and humans are in a vertical relationship rather than an equal relationship. As a result, Pair B's illustration underlines the roles of AIs as subservient to people such as pets or secretaries. The illustration expresses the possibilities of various social interaction types in the future:

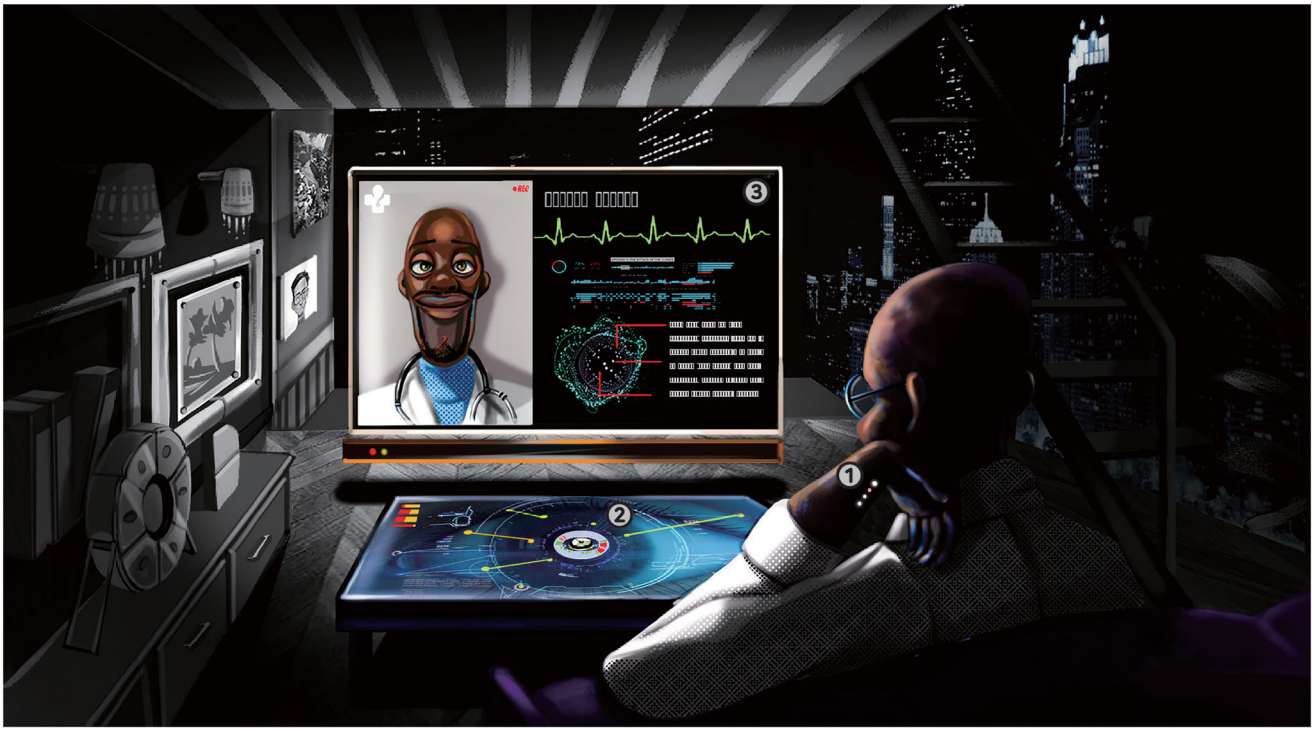


Figure 8. Tattoo AI, My Health Expert. AI with an invisible form can accumulate the user's information without the user's input (illustrated by pair C): This work was expressed in detail through four times of meetings and five or more revision after the workshop.

not only user–user and user–AI but also AI–AI (Figure 7 ④, ③, ①).

4.1.3. Illustration 3: Tattoo AI, My health expert

Illustration 3 shows a user communicating with a doctor based on the user's biometric information accumulated via a biometric tattoo and badge AI at home. When the user in the illustration separates the smart badge from its bespoke location, the badge stops collecting data. Subsequently, the collected data are analyzed on a smart table and transmitted to the doctor. Based on the data, the doctor checks the user's health status every evening and informs him of important issues (Figure 8 ③).

> When I imagine the AI of the future, I always expect to have a completely personal AI. Because AI already knows everything about the owner, if AI is going to use all of my personal information, it would be nice for it to be a completely personalized AI assistant. (Designer 3)

During the initial stages of ideation, the designer expected that, although current devices require users to give permission to an assistant for collecting data from their smart devices, future AIs would more easily accumulate user data without bothering users. Based on this initial idea, Pair C thought that an AI in the form of an unobtrusive tattoo (Figure 8 ①) or badge (Figure 8 ②) would naturally collect health information continuously, rather than asking the user's consent for collecting information. Moreover, users would not repeatedly need to wear and remove the AI similar to current wearable devices. Future unobtrusive AI applications could accumulate user information without requiring user attention or any spatial restrictions, even in public places.

While generating concepts, the illustrator, who usually had a negative perception of AI technology, imagined the negative aspects of the invisible exterior that could cause ethical problems. In particular, the illustrator thought that AI accumulating information without the user's permission is convenient for the user but, at the same time, could invoke the feeling of being constantly surveilled by the AI. This negative perception of technology was indirectly expressed in a dark painting style. Based on these concerns, the illustrator emphasized that no matter how much AI provides user convenience, a private space without surveillance is always needed. Based on this, the designer added a badge as miniaturized AI such that the user could stop the AI tracking by detaching the badge.

> This badge can be removed and charged, and when the user comes home, they are in a private space. Here, the user can separate the AI from themselves so that it does not interfere with them, and then they can easily communicate with a health expert AI in various ways. (Designer 3)

4.1.4. Illustration 4: A day with an AI

Illustration 4 expresses a day in a user's life in one scene. The hologram AI changes its shape and role according to the user's situation, including transforming into a pet that provides emotional comfort, a giant whale going home with the user, and a chef that helps the user cook. This shape-shifting AI application provides three functions and interaction methods for various purposes and user needs. Figure 9 shows that the appearance of a single user's AI can differ depending on the time and place. In the morning, the AI, shown in Figure 9 ① helps the user cook like a roommate or family member helping to prepare breakfast together.

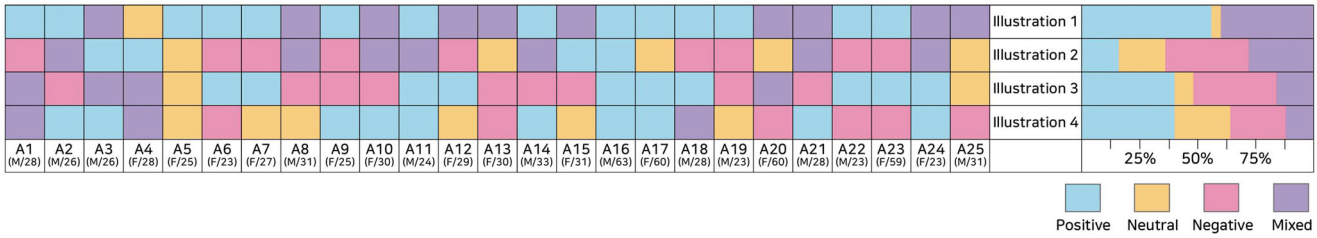
Figure 9. A Day with an AI. The AI will support the user by changing its appearance according to the user's needs (drawn by Pair D): All details were expressed through four meetings and five or more rework throughout the workshop.

When the user returns home from work, the AI appears as a giant whale (Figure 9 ②), so the user will be protected and not be lonely. At night, the personal AI appears as a pet (Figure 9 ③) to provide emotional comfort. For this concept, Pair D attempted to express that future AIs could change their appearances depending on the user's context, beyond simply providing customized functions. They also intended to express the concept of providing various modalities for each situation. They envisioned that future AI would be more useful than current AI and will always accompany the user.

> I think AI will become a very indispensable entity someday in the future. I think I will be able to interact personally in public spaces, and AI will solve my problems conveniently, just like carrying a smartphone all the time. (Designer 4)

During the collaboration process, Illustrator and Designer 4 thought that if AIs became ambient, it would be inefficient to spend the day with an AI of the same function and shape. Accordingly, they believed that it would be more useful to interact with an AI that changes its function and appearance according to the user's contextual needs. Starting with this concept, the designer was aware of the importance of the trust relationship between users and AIs. Thus, the designer thought that a single personal AI would be better for establishing trust than interacting with multiple AIs. In the process of visualizing this concept, Illustrator 4 wanted to convey an AI that could change its appearance as if by magic. However, Designer 4 questioned whether real-time physical shape-shifting was feasible and suggested a shape-changing holographic AI instead. As a result, this concept

Table 2. Each participant's reaction and overall reaction to illustrations



was derived through the process of combining the illustrator's new perspectives with the HCI designer's feasibility.

4.2. Overview of audience response

This section provides an overview of the audience responses to each concept expressed in the illustrations and their impressions of the online exhibition (we refer to individual audience members using the letter "A" followed by a numeric identifier). Table 2 shows the categorized reactions of the audience to each concept. Of course, the mood and painting style of each illustration influences the evaluations. To mitigate this effect, we asked audience members to explain the reason for the evaluation in detail. This helped us determine which factors influenced the audience's evaluation aside from the style of painting. In addition, the purpose of our study was to elicit potential users' reactions and perceptions of future scenarios involving AI. Therefore, illustrations from various perspectives provided more opportunities for audiences to imagine a future with diverse possibilities. The audience members' detailed perceptions of the four illustrations are described in the findings section.

Illustration 1 (positive = 14, negative = 0, mixed = 10, neutral = 1) was evaluated most positively because it showed that AI could functionally support people or enhance their capabilities as they overcome difficulties (A9 and A14). For example, AI can support diverse users, including people with disabilities, elderly, and children, to help them communicate or perform specific functions (A10 and A12). Furthermore, most audiences have focused on the various appearances of AI depicted in Figure 6. In addition, audiences preferred these exteriors because they were not overly personified as uncanny humanoid robots but had a convincing look based on their functions. With an exterior that makes users intuitively understand the use of the function, the audience thought that anyone could promote interaction without feeling excluded (A3, A8, and A14). On the other hand, some of the audience members perceived the situation negatively because there was no human interaction at all. A public square is meant to be a space that connects people. However, at the public square depicted in Illustration 1, people interact only with their AI. In this regard, a relatively large number of audiences rated it as "mixed" owing to the lack of human interaction or users' over-dependence on AI in a possible future scenario.

In *Illustration 2* (positive = 4, negative = 9, mixed = 7, neutral = 5), the audience expressed both positive and negative perceptions about the relationship between the user and AI being hierarchical. It was positive in that humans can take control of technology rather than becoming dependent on it (A2, A3, A10, and A14), but negative in that it discriminates against another species if future societies were to admit AI as a coexisting species (A7 and A11). In addition, although most of the audience preferred the cute fluffy form, they believed that social communication between AIs should be excluded because they might share each user's private data. Therefore, some audiences who rated it negatively thought that AI's social activity was an unnecessary feature in supporting the users.

Illustration 3 (positive = 10, negative = 9, mixed = 4, neutral = 2) received a relatively high number of negative reactions along with Illustration 2. Although the dark mood of the illustration influenced this result, the primary cause was the small and unobtrusive device. Because an AI tattoo is invisible and inseparable, the user cannot know how to stop the AI from monitoring them. In particular, the audience described concerns about privacy issues such as data misuse, fatal medical accidents, and wrong decision of data owners using a large amount of accumulated data (A8–10). On the other hand, because timing is important for health care, audiences thought that an AI tattoo could be useful in an emergency healthcare context (A16 and A25). Accordingly, some audiences expected that this AI would reduce current anxiety about health caused by uncertain information obtained from online searches (A3, A16, and A18).

Participants perceived that the *Illustration 4*, in which one agent-based AI changed into various agents depending on the context and function, was very useful in terms of expanding usability (positive = 10, negative = 6, mixed = 3, neutral = 6). In addition, intimate and one-on-one communication between human-AI and comfortable mood of the painting style eased audiences' concerns about privacy issues compared with the scenario presented in Illustration 3. In addition, they realized that AI could present possibilities regarding emotional support (A2, A3, A4, and A6). However, audiences expressed a negative impression because being with AI 24 h a day is similar to constant surveillance. They also felt reluctant to interact with AI that had the specific appearance of a person or living creature because these appearances could provoke user discomfort owing to the uncanny valley effect (A1 and A15). Via the illustrations and online exhibitions, audience members were evoked from various perspectives because of the four different concepts

and painting styles. Moreover, the implicit element of the artwork allowed the audience to imagine the next scene of the illustration and picture what might happen to them in the future by substituting themselves into these scenarios. In addition, the audience commonly thought that the illustrations had deepened their thoughts by following the meaning of the artwork more immersively via the online exhibition that gave them a high degree of autonomy.

5. Findings

Through analyzing the final illustrations and subsequent audience reactions, we describe three features of future human-AI interaction that were envisioned from a common point of view shared by the designers and illustrators and were perceived as critical discourse evoked by audiences.

5.1. Personally-owned AI with tailored exterior

The results show that when all users individually owned AIs that had a tailored exterior based on each user's needs, users interacted with them while noticing or facing physical entities. We found that an appearance tailored according to functions and user characteristics could be implemented in the future. Although the AI devices' exteriors in each illustration were drawn as diverse and changing (Illustrations 1 and 4) or all the same (Illustration 2), the physical entities of AIs were customized according to the user needs and context. For example, a hearing-impaired user can use a pair of smart gloves to communicate with their personal AI using sign language, the child could use favorite stuffed animals for emotional comfort as a friend, and elderly user might use a smart cane indoors and outdoors to measure their health information, such as heart rate (Figure 6). As Figure 9 depicts, holographic AI can change its appearance according to the users' context.

After experiencing the four illustrations, all audiences focused on the tailored exterior of personally owned AI itself. Most audience members mentioned that if both the appearance and function of the AI device are personalized and coexist in their daily lives, as presented in the illustration, they would be able to accept the future technology positively. Particularly, audience members preferred the different appearances of AI for each function or user because each user may have different needs regarding the function and exterior of a device.

> It is impressive that the appearance differs depending on the role, and I gained a lot of insight. It seems natural, and in a situation where artificial intelligence and us all coexist, I think we should use an AI that suits the user's preference. (A1)

> From a very emotional AI exterior to a functional AI exterior as the AI exterior changed, it was definitely influenced by how we perceived its role. Expectations for the tailored exterior of AI increased, and it made a positive impression. (A25)

On the other hand, seven audiences thought that if the exteriors were unlikable to them, such as provoking the uncanny valley effect, they would not use a device even though it may have advanced features. Therefore, potential users believed that an unprecedented new appearance only for AI would be necessary by connecting the appearance to function because an appearance that imitates an existing living thing may cause ethical issues or evoke negative emotions. In addition, other six audience members addressed their concerns that the appearance of AI, which differs from user to user, could create a new gap between the rich and poor or other discrimination. Therefore, they emphasized the need for an inclusive approach that considers societal effects.

> It would be nice to have a personalized AI, but it's not okay to too much imitate the shape of specific lifeforms because there will be resistance to anthropomorphism. (A3)

> If the AI has an appearance that does not reflect the user's intention (for example, the user's skin color is reflected in the AI), there is a possibility that it may lead to negative results, so we need to be careful. (A7)

Based on the audience members' reactions, we determined that AI's appearance was linked to users' first impressions of AI, which played an important role in building the initial mental model through which users could decide whether to continue using the technology. Consequently, it is necessary to comprehensively personalize the exterior, interaction methods, and functions rather than focusing only on personalized functions. In addition, we found that when diversifying and tailoring the AI exterior, it would be necessary to consider the function that the user expected in-depth and try to connect it with the desired function and exterior carefully.

5.2. Fluid multi-modal interaction with AI

All illustrations depicted that AI provides diverse interaction methods that combine various modalities according to the user's context, allowing users to communicate more naturally with AIs in the public space without caring about others. For example, the combination of multi-modal interaction methods, based on the situation, would allow users in the illustrations to request additional information or express additional non-verbal behaviors while performing main tasks, such as exercise and study (Figure 6). The illustration also expressed the concept of providing fluid combinations of modalities for each situation, anticipating that future AIs would be more useful owing to providing different combinations of modalities according to the user's situation than now. Illustration 4 (see Figure 9) shows how an AI can interact with the user according to their needs and environment via three different AI appearances. When a user needs assistance on a task, the AI communicates and guides via conversation. In addition, the user can be comforted by a pet through physical interactions such as gestures and touch.

The illustrations depicting people's natural interaction with AI made audiences think that the current society would transform into a society where human-AI interactions become prevalent. Through these envisioned futures, audiences expressed two positive aspects of fluid multi-modal interaction depending on the situation. First, fifteen

audience members thought that the fluid interaction method based on the situation would reduce their reluctance to communicate with AI anytime and anywhere. Therefore, they mentioned that it would not be awkward to communicate with AI in the public in the future. As a result, they thought positively that the fluid interaction method would make it easier to receive AI support anytime and anywhere. Second, nine audience members expected that the task and mental load they had to learn to interact with a new device would be reduced because of the interaction method tailored to users' individual characteristics. Consequently, they thought that fluid multi-modal interaction would allow various people to enjoy the benefits of technology equally, such as the elderly, people with disabilities, and children.

> It seems to be the hardship of people living in the modern society that we have to learn how to use technology whenever new technology comes out. Also, it's very difficult to explain how to use new technology for parents. If we interact with AI just like people interacting with each other, I think all people in the world would be easy to interact with AI naturally. (A20)

> Natural communication seems to reduce the load of learning new technologies, and this is likely to be the way for as many people as possible to enjoy the technology. (A5)

However, most audience members expressed concerns while acknowledging the positive aspects of fluid multi-modal interactions. This is because they are concerned that diverse interaction methods mean that AI will collect more types of user behavior data, which will amplify the concerns regarding privacy issues. They also believed that if multi-modal interaction became too similar to human communication, the boundary between user interaction with AI and human interaction could be blurred. They anticipated that finally, some users might rely too much on AI or feel creepy.

> Inevitably, various user behavioral data will be input to AI, and if it is exposed as it is, it may be used for fraud or privacy issues. Therefore, it is desirable to commercialize the natural interaction method when the data handling method is thoroughly developed. (A9)

> Communication using the appropriate modalities depending on the situation seems convenient (sometimes verbally, sometimes by touch). However, if the way AI uses the five senses to communicate is aimed at being like humans, it would be appalling. (A12)

Based on these insights, we determined that it is necessary to develop an inclusive interaction method that allows various people can enjoy the benefits of technology without discrimination, rather than making the uniform interaction method with AI unconditionally. Furthermore, we found that if AI collects more information and communicates with users in more diverse manners, it would be necessary to implement appropriate privacy policies or standards.

5.3. Ubiquitous AI in users' daily lives

Our study utilized high-fidelity illustrations to explore not only possible interactions but also a future society in which AI is prevalent from a macroscopic perspective. Illustrations depicted that the users' daily routine (e.g., community settings, cafes, home) could change owing to the prevalence of AIs. This holistic view of intelligent environments allowed the audience to imagine an abstract future life as a plausible future life that they would experience and evoke new discourses that they had never thought of. Furthermore, the daily lives expressed in the illustrations created a more immersive experience for the audience. Through this, we could better understand what the audience expected and what they were concerned about.

Regarding the positive aspects of daily life coexisting with AI, the audience expects that AI will improve their routine because it can further enhance human capability or possess abilities that people do not have. In addition, ten audience members who positively evaluated the emotional exchanges with AI expected AI to coexist in everyday life as new friends, as depicted in Illustrations 2 and 4. Based on potential users' reactions, we discovered that, high-fidelity illustrations triggered the audience members to think about the positive aspects of the coexistence of AI and people.

> Because it [illustration] is the future that must come someday, I feel like I have glimpsed the future where AI will help people and improve the quality of life through illustrations. (A4)

> I thought coexisting with AI positively. Because, things that people cannot normally do, due to space, time, and human limitations, will become possible through coexistence with AI. (A9)

However, after seeing the exhibition, most audience members also stated ethical issues caused by technology that could affect them negatively. For example, they realized that using AI-embedded mobile phones and living in an AI-embedded society would be completely different because using AI-embedded mobile phones does not significantly affect people's lives. However, they thought that no matter how ethical issues were raised, the future in which AI will be prevalent would come unconditionally and living in an AI-immersed society would greatly influence them, as depicted in the illustrations. Therefore, they pointed out that society with AI should be carefully assessed from a critical perspective rather than unconditionally applying new technologies to society. We determined that this was because audience members could easily compare the society they live in to a possible future society owing to detailed expressions of illustrations.

> I think the role of AI needs to be defined more specifically. The future of coexistence seems to come naturally at some point, but I thought that if the role was not well defined, we could lose our control in our daily lives completely. (A15)

> Acceptance of AI as a completely new member of society must be accompanied by a sense of ethics and social consensus. (A21)

> AI contains the nature of unpredictability, and there are some risks that users cannot completely control. Therefore, rather than forcing AI to be applied in various fields, a guide to avoiding the risks of the technology should be established and then gradually applied to society. (A12)

Based on the responses of potential users, we discovered that future human-AI inter-actions that illustrated a holistic society view could evoke both positive or negative reactions

from the audience members, as well as the possible problems they will face. Because AI's positive or negative effects must be discussed before applying the technology to our surroundings, we determined the importance of provoking discussions by asking what society in which AI is prevalent would look like. Therefore, perspectives that predict the overall impact on society rather than simple fragmentary interaction are necessary for designers, developers, and users when commercializing AI technologies because of their context-dependent and ubiquitous characteristics.

6. Discussions and design implications

In this study, HCI designers and illustrators articulated where and how future human-AI interactions would take place. Based on the envisioned future through an iterative process, potential users perceive three features as important: (1) a tailored exterior connected with the personalized function of AI, (2) fluid multi-modal interactions in which anyone can interact with AI naturally anywhere, and (3) their entire daily lives that will be changed by AI technology. We present design implications that could lead future AI to better coexist with users.

The first is to consider the user-centered exterior of the AI system aligned with its personalized function. In our findings based on high-fidelity illustrations, various AI appearances were expressed in various ways according to users' situations, needs, and characteristics. Based on the interaction with the tailored exterior AI, we discovered that users consider the appearance of the AI to be as important factor as the personalized function because it affects their first impression of the AI. In addition, potential users positively perceived the association between personalized functions and tailored exterior, as shown in the illustration. Previous research provides precedent that AI can personalize the user's experience by learning from their actions over time for better human-AI interaction (Amershi et al., 2019). In addition, in studies that have analyzed the current AI use experience, current users expected that AI technologies should be personal and a personalized agent should provide customized information (Cho et al., 2019; Lee et al., 2020). Moreover, in the industry, Google Assistant provides personalized information through voice-detection (Google-Assistant, 2022). These types of AIs are embedded in multiple devices at households with consistent functions as personal assistants (Apple, 2011; Goggle-Assistant, 2016). Our results go beyond these: the personally owned AI's exterior needs to be tailored considering the personalized functions. Currently, HCI designers and developers have rarely considered the appearance of AI when envisioning future interactions. However, as our findings suggest, they should consider not only personalized functions but also personalized exteriors suitable for the functions and users.

The second is to provide fluid multi-modal interactions depending on users' contexts, needs, and characteristics. In our study, potential users perceived that combining various and fluid multi-modal interactions articulated through illustrations would become a driving force to more naturally incorporate AI into their daily lives. Furthermore, they expected that fluid multi-modal interactions could present an opportunity for more people to enjoy the benefits of technology. Previous researchers have focused on emphasizing and developing natural multi-modal interactions (Cook et al., 2009; Maity et al., 2020; Noroozi et al., 2018; Oliveira et al., 2022). Currently, in the smart home industry, which is the initial step of implementing an intelligent environment, attempts have been made to combine multiple modalities for natural interactions (Cook et al., 2003; Weiser & Brown, 1997). However, few studies have provided fluid combinations of multiple modalities according to the user context. In addition, commercially available AI devices that currently provide multi-modal interaction, for example, the Nest hub from Google Home (Google, 2018), provide a fixed type of multi-modality that combines conversation, touch, and gestures for all users. One step further from current attempts, more fluid and inclusive interaction between the users and AI needs to be considered by combining modalities according to usage time, user age, and environment. For example, a combination of voice, gestures, and tangible interactions can be implemented for visually impaired people, a combination of gestures, mouth motion, and eye-tracking for hard-of-hearing people (Abascal, 2004; Casas et al., 2008; Emiliani & Stephanidis, 2005); and haptic and voice interaction for children and the elderly. As future AI systems become more ambient and personalized, AI will blend into users' lives more naturally and recommend appropriate combinations of multi-modal interaction methods depending on the individual.

The third is to apply AI technology to users' daily lives, considering the societal impact of technology to better coexist with AI and humans. Our study explores not only moments of interaction, but also a future society in which AI is prevalent from a macroscopic perspective through high-fidelity illustrations. This holistic view of intelligent environments allowed the audience to shape abstract future life to their future life that they will face and evoke critical discourses, including positive and negative perspectives toward coexistence with AI. Through this, we discovered the critical perspective of potential users that AI technologies should be applied in society after carefully considering the societal influence of the technology, rather than applying it unconditionally, just because the technology develops. However, in previous studies, the design direction of AI was often limited to a smart home environment (Cook et al., 2003; Luria et al., 2020; Porcheron et al., 2018; Sciuto et al., 2018), then interactions in public spaces or society have been less explored. Alternatively, future human-AI interactions are often predicted only at the fragmentary moment of interaction, and the design direction was derived based on this. For example, AI directions have been explored focusing on limited space or specific target users such as families, children, and people with disabilities. Therefore, previous studies have less explored the future from a comprehensive and high-fidelity perspective, in which AI is incorporated into users' daily lives. Our study showed that envisioning the comprehensive impact of new technologies could induce

new discourses in potential users. This aligns with the previous study that a vision for future technology cannot be seen as a simple prediction and that discussion and reflection on future technology should be promoted based on scenarios that can be understood by everyone (José et al., 2010). Through this, we discovered the implications of envisioning societal impact and used it as a probe to understand the perception of potential users. As a result, our study suggests that designers need to consider expanded and boundless spaces beyond the home when designing future human–AI interactions, even if users interact with personal AI that manages their private information. In addition, it will be necessary to have a comprehensive perspective to investigate the continuous interaction integrated everywhere in users' everyday lives.

7. Limitations and future work

To envision future human-AI interactions, we conducted a collaborative study with HCI designers and illustrators. In the collaborative workshop, we intended to recruit HCI designers to imagine future design directions from a user-centered perspective. Therefore, stakeholders, such as AI developers or everyday users, were excluded, which may have limitations in reflecting users' key needs and advanced AI-related technical knowledge. To alleviate these limitations, our study recruited HCI designers who had knowledge of AI and could design human-AI interactions from a user-centered perspective. However, to speculate on the future technologies, including various perspectives, further collaborative workshops involving various stakeholders are needed.

In addition, because these findings were obtained from a small sample of HCI designers and illustrators, this may have affected our interpretation of the audience members' thoughts and limited the generalization and extension of the results. Moreover, future AI features in illustrations could be easily influenced by the personal characteristics of participants. To mitigate these limitations, HCI designers and illustrators envisioned the future through in-depth discussion integrating academic and practical knowledge and creativity through several iteration processes. Furthermore, because our study intended to use illustrations as a medium to stimulate new thoughts in the audience rather than statistically represent the results of illustrations, we could not determine the critical limitations owing to the limited number of samples. However, future work would need to explore more cases of possible future and expand our findings.

It should also be noted that, despite the online exhibition, only 25 audience members completed their responses owing to the task load of the survey and lottery reward system. This limitation could be mitigated by eliciting in-depth thoughts of potential users from various perspectives through intuitive illustration stimuli. However, to expand and strengthen the findings, it will be necessary to attempt future research by inviting more audiences through modifying the method approach. For example, analyzing the reactions depending on the characteristics of everyday users or generalizing design directions.

Regarding the specific mood or style of illustration, in our study, we intentionally allowed designers and illustrators to express the message they wanted to convey through a specific mood or style of painting; the painting style tended to influence the audience's reaction rather than the concept of the scenario. However, we were able to compensate for this limitation by asking the audience to explain the reasons for their evaluation in detail. Furthermore, illustrations helped the audience evoke critical views and imaginations by providing various perspectives on future technologies as artwork. In addition, because the exhibition was held online, some audience members expressed that immersive offline exhibitions were necessary as well. However, we conducted an online exhibition and survey to explore immediate reactions because of the pandemic. Accordingly, online exhibitions help the audience reduce spatial and temporal constraints in imagining future technologies. Although exploring potential users' reactions was enough to elicit critical perspectives, it is possible that future studies with offline exhibitions and interviews might provide deeper insights into future human-AI interactions.

8. Conclusion

In this study, we conducted a collaborative workshop between HCI designers and illustrators for envisioning future human-AI interactions and potential users' perceptions of them. To envision future users' daily lives coexisting with AI, we conducted a collaborative study with four HCI designers and four illustrators, grouped in pairs. Four pairs completed four illustrations over approximately eight weeks through an iterative design process. To explore users' reactions and perceptions of future human-AI interactions, we built a web-based online exhibition using the four illustrations. Our findings include features of future human-AI interactions and users' perceptions of these features. Our findings led us to discuss the implications for designing future human-AI interactions. We hope that deliberating users' mental models and design implications will allow AI-related stakeholders to design future coexisting humans and AI more human-centered way.

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