Making AI Understandable by Making it Tangible: Exploring the Design Space with Ten Concept Cards

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The embodiment of Artificial Intelligence (AI) in everyday use products is raising challenges and opportunities for HCI and design research, such as human understandings of AI's functions and states, passing back and forth of control, AI ethics, and user experience, among others. There has been progress in those areas, such as works on explainable AI (XAI); fairness, accountability, and transparency (FAccT); human-centered AI; and the development of guidelines for Human-AI interaction design. Similarly, the interest in studying interaction modalities and their contributions to understandable and transparent AI has been also growing. However, the tangible and embodied modality of interaction and more broadly studies of the forms of such everyday use products are relatively underexplored. This paper builds upon a larger project on designing *graspable AI* and it introduces a series of concept cards that aim to aid design researchers' creative exploration of tangible and understandable AI. We conducted a user study in two parts of online sessions and semi-structured interviews and found out that to envision physicality and tangible interaction with AI felt challenging and "too abstract". Even so, the act of creative exploration of that space not only supported our participants to gain new design perspectives of AI, but also supported them to go beyond anthropomorphic forms of AI.

CCS CONCEPTS • Human-centered computing~Interaction design; Interaction design process and methods

Additional Keywords and Phrases: Human-AI Interaction, Creativity Support Tools, Explainable AI, Product Design.

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1 INTRODUCTION

Establishing the connection between tangibility and the understandability of AI is the goal of Graspable AI (GAI) [23, 25]. Graspable AI research asks questions such as the following: can physical and sensory attributes and tangible interaction of AI products, support an understanding that humans can find in natural and artificial

non-humans, such as everyday use objects (affordances, feedback, etc.) and plants (growth, dynamic forms, change in colors, etc.)? Can the physicality and tangibility of interaction contributes to AI's fairness, accountability and transparency [20, 39]? Can those issues become more visible and by that making AI more open for criticism?

To help advance graspable AI, we developed creativity tools that would support design researcher's creativity in the graspable AI space. We took inspiration from card-based creativity tools such as Hornecker's The Brainstorming Cards game. That game is designed based on the Tangible Interaction Framework [10] and "transforms its abstract concepts into provocative questions for a brainstorming exercise with a 'game' format" [28]. It includes main themes, theories, questions, and visuals to aid the creative exploration. Following a similar approach, we defined three themes and designed ten cards, to explore the creative space of Human-AI tangible and understandable interaction. We then ran three online sessions with 11 participants and conducted semi-structured interviews with 10 participants, to answer our two main research questions:

1. How did the cards support exploration of creative space in the context of tangible and understandable AI? Did they support critical discussion as well?
2. How did the cards shed light on forms and form-giving practices in service of graspable AI?

During the sessions, we attended to participants' experiences and interactions with the cards and then followed up with them by semi-structured interviews to explore our research questions. The present study introduces the cards and the results of a user study. Its main research contribution is a series of design research insights on forms and form giving practice for tangible and understandable AI space. It also contributes insights about the impact of creativity support tools on creative and critical explorations of tangible and understandable AI as a relatively underexplored space.

2 KEY CONCEPTS

2.1 Forms and Understandability in AI

As AI systems are embodied in everyday use products and into everyday life of people, HCI and AI researchers are increasingly concerned about trust, control, transparency, and explainability [13, 31, 33]. Explainable AI (XAI) seeks to explain intelligent systems' inner-workings or outputs to support human understanding [37]. However, historically, designers, artists, and design researchers often focused on forms (visual, tactile, sonic, etc.) to explain things to the world [3, 38]. In design literature, forms often refer to how something in the world is organized in such a way to fit into the irregularities of the context [4, 22]: the branches of a river, the plant's shape to maximize its exposure to the light, the fin of a fish, the hollow bones of a bird, the enlarged nostrils of the cheetah. In the context of design, forms convey meaning, values, and specific cultural contexts. Forms communicate objects' function, as well as how they can be used through their perceived affordances [18, 30, 32, 34]. For instance, a bike handlebar's form communicates how it is intended be gripped. The form also shows the specific style of biking (e.g., road bikes have drop bars, while mountain bikes have wide bars) [18]. The perception and appreciation of form in art is one of the traditional roles of aesthetic criticism [7]; for example, in formalist criticism, a work's form is viewed as its unifying principle (sometimes known as "significant form" after Clive Bell [9]) or as a whole that is complete with meaning within its use and cultural context [30].

Today, AI is introducing new functionalities and interaction paradigms [5, 10]. Many of Human-AI interaction design principles and guidelines includes strategies to make the AI system understandable and explainable [5]; make task goals and constraints explicit and provide effective data representations [19], and to use interactivity and promote rich interactions [10, 15]. The aforementioned guidelines, paradigms and principles seek to emphasize the key concerns of human-AI interaction design, that of transparency, understandability, goals of AI, rich interactions, and user experience, among others. We adopted these key concerns from HCI, blended them with form studies and what forms can communicate, then designed our concept cards as creativity support tool to support a creative exploration of tangible and understandable AI space (introduced in section 2).

2.2 Creativity Support Tools

Creativity has been studied in design, engineering, humanities, and psychology [16]. However, although diversely theorized, creativity still has some common characteristics across domains, including *agency*, *support and scaffolds* and *artifacts* [6]. Tools that support creativity [35], either digital [15, 34] or analogue [26] have been the subject of numerous studies in HCI and interaction design. For instance, Kim et al. researched how Creativity Support Tools (CST) can be used by novice designers to create opportunities to growth by providing a safe space to experiment and to fail [29], Cherry and Latulipe developed the Creativity Support Index to measure the effectiveness of creativity tools [14]. Frich et al. call for an interdisciplinary and collaborative effort between creativity research in HCI on the one hand and creativity in psychology on the other [21]. Researchers also investigated factors that affect the creative process. For instance, Halskov and Dalsgaard designed Inspiration Workshops, which use physical cards inspired by both Domain Cards and Technology Cards [26], the former to help creatives to develop the concept and the latter for understanding of how and which technology can be used. Biskjaer et al. researched time constraints in CST creative writings [11], Warr and O'Neil researched the use of boundary objects as externalizations in the Environment and Discovery Collaboratory (EDC) [41]. The design of CST spanning from tangible tools (e.g. SonAmi [8]) to digital platforms and a mix of both (e.g., [12]) has seen a growing interest among HCI and design researchers. While the community has developed guidelines on human-AI interactions [5] less explored is how AI's key concerns (e.g., transparency, intelligence, goals) might manifest in the creative exploration of tangible and understandable AI space.

3 METHODOLOGY

The point of departure of this research was the question of how we can support a creative and critical exploration of the emerging paradigm of Human-AI tangible interaction design, with a focus on forms of AI along with some of the key concerns of AI such as intelligence, goals, transparency and predictability. We used design principles and guidelines of human-AI interaction to identify key concerns of AI (e.g., *G1: Make clear what the system can do. Help the user understand what the AI system is capable of doing*, and, *G11: Make clear why the system did what it did. Enable the user to access an explanation of why the AI system behaved as it did* [5]; *P1: Explainability* and *P2: Correctability* [31]). Furthermore, based on our experience in an international workshop [23]–where we used tangible interaction brainstorming cards [28]– we realized that there is an opportunity to include the AI key concerns in creativity support tools.

3.1 Concept cards

We represented key AI concerns (e.g., intelligence, goals, transparency) in ten visual cards. The cards emphasize three themes, which were chosen because they reflect basic concepts in HCI and design research related to form [4, 18, 30]: forms themselves (i.e., traditional product affordances and semantics); forms over time (i.e., interactions, task flows, and so forth); and finally forms in the world (i.e., experience, AI in the wild, contextual AI, etc.) [23–25]. Each theme includes 2 subthemes, for which we designed one or two cards. Each card includes a question, and it asks to take an action (Table 1).

Table 1. Ideation cards' themes, subthemes, questions, and actions.

Themes	Subthemes	Questions	Actions
Forms themselves	Intelligence	1. How is this specific AI intelligent?	*Diagram* the intelligence for this AI.
		2. Does it need to be intelligent?	--
	Goals	3. What are the main goals of this specific AI?	*Describe* the AI's goals and subgoals, put them in priority order.
		4. Are the AI's goals clear to humans?	*Discuss* tangible forms that convey the goals.
Forms over time	Statelessness	5. How can the ML process be shown to be iterative?	*Show* the iterative process and time.
		6. What does an AI activity mean? (e.g., sensing, listening, etc.)	*Get inspired* by metaphors of biological growth and related visual forms (e.g., plants <3).
	Predictability	7. How can AI be more predictable if data were tangible?	*Imagine* AI as predictable as an everyday use object (e.g., vacuum cleaner).
Forms in the world	Socio-cultural context	8. How can AI be designed for a specific social and cultural context?	*Contextualize* AI for a specific geographical or cultural situation.
		9. How can the process of personalization be made more understandable?	*Synthesize* the personalization process into tangibles.
	Transparency	10. How can tangibles, expose AI's ethical concerns?	*Conceptualize* things that can be understandable, and things that cannot.

The visual and communication design of the cards are not the primary focus of this paper; therefore, we do not explain them in detail here. But we highlight that in designing the visuals we considered a mix of non-human subjects, such as abstract shapes, natural forms, and everyday use products. The reason behind that choice was that we wanted participants to consider the diversity of physical forms that can be found in products, plants, and abstract shapes. We were inspired by Krippendorff's product semantics [30] and Alexander's structure preserving transformations [4] and how they link to the artifacts' forms.

The visual nature of the cards has two key benefits for design researchers [40]: first the visuality helps to translate abstract problems (e.g., intelligence of AI, goals of AI) into the language of products (forms, affordances, product semantics, etc.) without giving hints on how those forms might look like. We made this decision because AI forms are yet to be explored, and we tried to avoid any visualization of concrete AI products (e.g., Google Nest). Second, the visuals also support theme and variation-style reasoning [40]. By including visual of a concrete example of a familiar product, the intention is to frame and give examples that AI can learn from (e.g., in the card no.7, "predictability" we used vacuum cleaner as an example).

3.2 User study: online sessions and interviews

We invited 11 participants (6 female and 5 male – Table 2), including graduate students and faculty members from Malmö University, Sweden in online sessions featuring Zoom and Miro, 2 hours each. We wanted to attend to their experiences of using the cards and to observe how the cards would support the creative exploration of tangible and understandable AI. Further, we conducted 10 follow up semi-structured interviews from the same pool of participants who used the cards in the online sessions. Participants were split into three heterogeneous groups consisting of both interaction design and computer science faculty members and graduate students who have had experience in AI and UX design research.

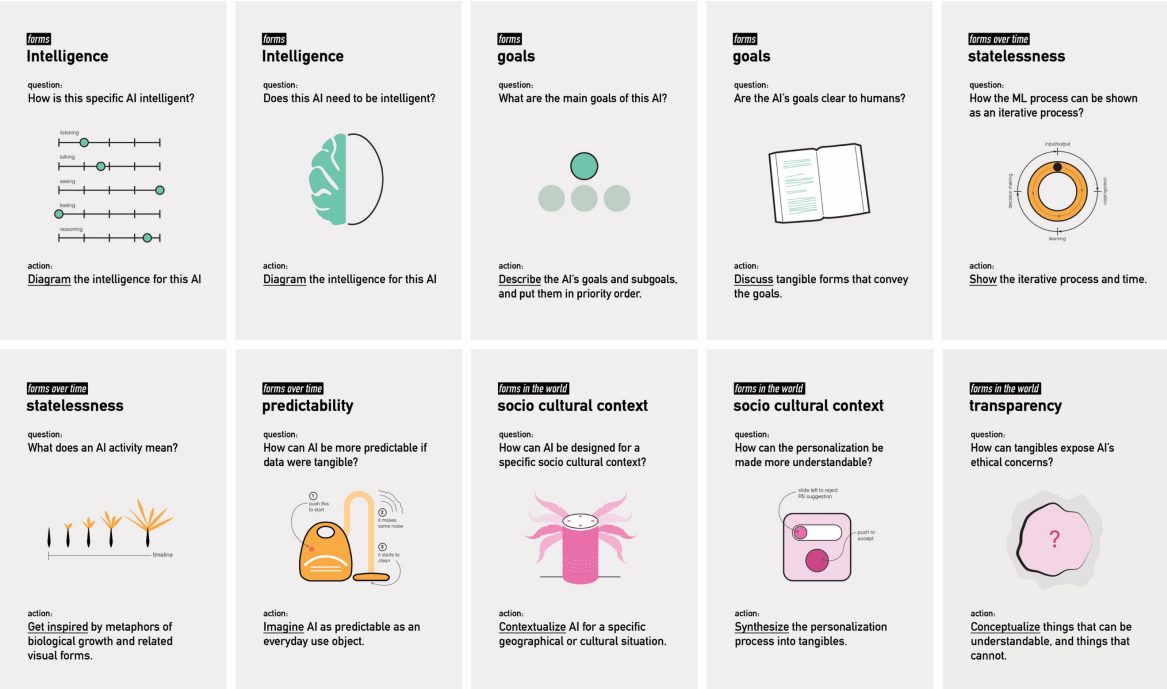

Figure 1: Three themes and ten concept cards (see Table 1 for descriptions).

Table 2: Participants and groups compositions

Groups	Participants	Field of study/research
Group 01	P1, P4	Computer Science
	P2, P3	Interaction Design
Group 02	P5	Computer Science
	P6, P7, P8	Interaction Design
Group 03	P9, P10	Computer Science
	P11	Interaction Design

Each session started with a 5-minute moderator presentation, followed by a group activity in four steps (Table 3). In the first part, participants were invited to discuss and to choose an AI system that they know and use, then to discuss it around two questions of, (a) what does that AI system explain to them? and (b) what they

want to be explained by AI? The questions had an analytical purpose and were based on guidelines for human-AI interaction [5], in particular *G1: Make clear what the system can do. Help the user understand what the AI system is capable of doing,* and *G11: Make clear why the system did what it did. Enable the user to access an explanation of why the AI system behaved as it did.* In the second part of the sessions, the participants were presented with ten concept cards, clustered under three themes (Table 1, Figure 1).

10 out of 11 participants agreed to participate in a follow-up semi-structured interview. We asked two main questions with several follow up questions on whether the cards supported creative and critical discussions around key concerns of AI and tangible and understandable AI.

Table 3. Sessions' setting, sections, and objectives.

	Group activities	Duration	Objective
(1)	Choose an everyday use AI system	10 minutes	Familiarization and icebreaking
(2)	Discuss themes' questions and actions	60 minutes	Reflection on some key concepts of AI
(3)	Visualize discussions and ideas	20 mins/theme	Externalization of thoughts and ideas
(4)	Give feedback on cards	10 minutes	Reflection on usefulness of cards

4 RESULTS

We transcribed and analyzed the participants' discussions during the online sessions and the interviews using a coding method [2]. We identified broad categories of AI education, the meaning of AI, AI understandability, user experience, etc. and specific themes, which are presented below (human qualities and non-humans' intelligence; ambivalent relations between intelligence and (un)predictability; physical, metaphoric and symbolic forms of AI). These were to respond to our initial research questions: How did the cards support exploration of creative space in the context of tangible and understand-able AI? Did they support critical discussion as well? How did the cards shed light on forms and form-giving practices in service of graspable AI?

4.1 Human qualities and non-humans' intelligence

The term "intelligence" was ubiquitous from the beginning to the enduring final discussions, sketching and even at the beginning, during picking existing AI products. Notably, the cards did not define central concepts, such as "intelligence." As a result, participants used the "intelligence" cards to argue about what is AI: P4 for example stated that [...] *AI is actually about mimicking human intelligence, so a robot is not an AI. But when we want to consider the wider context of intelligence systems… adaptability and learning, then this [AI] is not different than any other software....* The question of intelligence was also discussed in relation to the trustworthiness and fakeness. For example, *P9* argued that *AI needs to fake something to look like intelligent. Developers of Siri for example need to prepare it for questions like "do you love me"… there needs to be some fakeness to make the AI system trustworthy.*

Other themes came up. P9 and *P10* claimed that products need to be intelligent to be truly personalize-able, and for that, humans and AI need to form a close relationship. *P9* asked *[…] YouTube, needs to be intelligent? Maybe because it needs to gain more users? P10: yes, maybe then intelligence means tailoring a service to user needs.* Participants also used the cards to reflect upon the nature of intelligence and the difference between human and AI qualities of intelligence. *P1* said: *AI is not intelligent in ways that we see or define intelligence […] I was thinking about robot [vacuum cleaner] and if it would talk [she referred to "talking" as one of the properties of intelligence], it is fun! If you are sitting on the sofa and it cleans and occasionally talks, it would*

sound pretty intelligent. Collectively, these quotes suggest that the ill-defined nature of AI's "intelligence" supported generative reflections. These reflections, as we have just documented, illustrate how heterogeneous participants' understanding of "intelligence" is, and how simply grappling with it as a concept, that is, concretizing and exemplifying it, was a prelude to designing with it. The participants did not seem to be seriously interested in philosophical questions about what constitutes "intelligence"; rather, they played with different concepts and definitions as a tactic to think through the creative space of possibility. In so doing, they considered different formulations of the relationship between human and machine "intelligence."

In our research questions we asked whether the cards supported critical and creative explorations. This result confirms that they did, although the explorations were more in service of imagination than of developing philosophically rigorous definitions. We also wanted to know whether participants' engagements revealed anything about form giving to the concept of graspable AI, and participants ruminations about "intelligence" did not directly address tangibility or understandability; instead, thinking about AI tended to be along the lines of disembodied information processing, rather than a feature of a body-in-the-world.

4.2 Ambivalent relations between intelligence and (un)predictability

Another insight was that the themes were not islands, but highly interconnected to each other and especially to the "Intelligence" cards. For example, *P3* said: *it's really hard to choose one card, because it's a process and they are connected* –referring to the cards as all are parts of the same issue. *P1,* agreed: *I think both transparency and predictability [are important in tangible and understandable AI]. But they go hand in hand as I see them even if they are not the same. What is important for the user I think is to start to use the artifact for the transparency, so they know what is going on [then] the user wants to know that the system is predictable so they can trust them.* "Predictability" and "Intelligence" were used interchangeably or closely linked together. For instance, *P4 said: but robot cleaner is predictable most of the time…. P1 continued: hmmm, but sometimes it does stupid things, but yes when it is intelligent, it is predictable.*

Themes such as predictability, transparency, and control were seen as qualities that users and designers contradictorily both expect and do not expect from AI systems [27]. Participants stressed that they do not always want predictability from AI. P10 believes that unpredictability might be desired for some AI systems: *A vacuum cleaner is predictable, but it does not need to be an AI. I think to make AI, is to make things sometimes less predictable* [1, 27] – r*ecommendations [from Recommender Systems (RS)] would be nice to surprise you. So, in YouTube predictability is not the most valuable feature…[while] in self-driving cars we need predictability*. P7 said: the element of surprise in music RS is actually wanted and P11 mentioned: *hmmm, I was researching trust and IoT and lots of people wanted to know exactly what will happen if they press the button! So that is really important for the users, but in AI for example in Instagram or FaceBook, maybe that's a bit different, sometimes I want to be surprised*.

This result confirmed the importance of predictability in AI systems for specific applications, where privacy, safety and accuracy are crucial. Hence, predictability was desired as a contextual quality rather than a universal one. Also, the predictability seemed to be linked to the participants' perceptions of system's intelligence.

4.3 Physical, metaphoric, and symbolic forms of AI

Participants discussed semantic connections between familiar forms and tangible and understandable AI. They were troubled to imagine physical shapes of specific AI systems, and giving form to tangible and understandable AI, labeling it as something *quite difficult* (*P1*) or *confusing* (*P5*). However, they showed a curiosity to explore the semantic connections and sketched some ideas. For instance, *P3* offered an abstract definition of the formal character of AI as something that does not have a perfectly balanced or symmetric shape: *if I want to give it a form would not give it a form that is perfect or finished. I would give it a form that is sketchy or inclined towards a specific direction [asymmetric shapes], or a broken form… [because] AI can´t be perfect.*

P7 and *P4* were inspired by existing everyday use products. For example, *P7* made associations between physical music players and music Recommender Systems: *[…] before digital music streaming services was probably hi-fi systems with knobs you would turn and with buttons you would press or skip [songs] etc*. *P4* discusses using symbolic shape of fairness and justice for AI: *Maybe a scale could be an interesting form to add. For example, face recognition works better on white rather than indigenous people, so there could be a scale that can show the degree of bias … a scale weights or tends towards specific direction… it can be a feature for any AI system: the AI scale.* Similarly, *P8,* who was interested to design forms that show the transparency, and trust issues of AI, used the metaphor of layered form: *I have an image of a black box that has different layers like Matryoshka doll, that has different layers and layers that never end. I think that is important for the user to understand that there are always some parts of the system that they can never know, because it can never be explained or exposed completely… I guess.*

P7 also discussed the rivers' dynamic shape as a possible metaphor for the growth and expansion of AI using Machine Learning: *[she shows a picture of a riverbed], I am thinking of these riverbeds that over time they break into smaller branches and they have loops, so they develop from a straight line of water moving from point A to point B, then they gradually become more branched. So, an algorithm becomes trained over time and like the river they develop branches…details and specifications, maybe also adaptations and fitting to the context, and the user can see and grasp how the system is actually trained […]. P11* pointed out to the neutral forms of current AI products (e.g., Google Home, Alexa, etc.) as they seem to lack a certain level of personalization themselves but provide the opportunities for the users to personalize them according to their desires: *[…] people may not want to have alien sitting in their home, so they add stickers or decorate them to customize them.* Participants felt stuck at times and were not able to envision new shapes of AI as direct responses to the questions on the cards. But they were nonetheless engaged with a kind of organic creative explorations, by shifting their focus from the questions to the actions and to the visuals on the cards and vice-versa. This finding responds to one of our research questions, confirming that the concept cards supported ways forward to the form-giving process of graspable AI [23, 25].

5 DISCUSSION

Building on key concepts in HCI and design research, the cards featured three themes related to the forms of AI – *forms themselves*, *forms over time*, and *forms in the world*. Each raised key concerns of AI – e.g., intelligence, goals, transparency – and supported creative and critical explorations among participants. Conversations around AI ethics, bias and racism were abundant; hence, the cards supported some levels of critical discussion. We found out that some of the cards were more impactful than the others. For example "intelligence"

and “predictability” were both heavily discussed, but participants felt that each theme and related cards nonetheless supported each other in an organic way.

We observed that the cards supported participants reflecting upon ontological questions such as what AI is, what the form and physical shapes of AI can represent, and what intelligence can mean in a specific socio-cultural context. Further we observed that no formal reference to human or animal body shapes were made, while the references to shapes of plants, trees and rivers were more abundant. We saw references to strange and non-familiar forms such as asymmetric and unfinished shapes, layered and mysterious dolls, but also familiar and universal forms, such as the shape of a scale. What intelligence *means* and *does* led also to the question of relations between forms and the content and meaning. Whether a music Recommender System (RS) can be “informed” enough – or as well as a friend [P10[1]] – to recommend meaningful music, was more the question of human experience and the meaning rather than the efficiency of the categorization and pattern recognition in an RS.

Deciding on which forms designers can give to an AI product remains difficult. The difficulty does not originate from the complexity of the system, design or its affordances and functionalities, but from the authenticity that the forms required to represent –as both a well-crafted designed object but also as an ethical practice of form giving. It was about deciding between accommodating users’ desires on what AI *could be*, or to inform them about what AI *is* with all its imperfections and shortcoming through the forms. Some participants believed that *alien* and neutral forms (e.g., Google Nest) are maybe most suitable for AI, because they do not have any cultural connotations that increase the risk of being perceived as biased or inappropriate. Neutral shapes may be a synthesis of well-crafted designed object and an ethical form giving practice. However, it feels like an easy fix to an ill-defined problem, which suggest avoiding taking any risk in design of AI products that have serious impacts (positive and negative) in our lives.

6 CONCLUSION

We presented a series of concept cards as creativity tools to aid design researchers’ creative explorations in the context of tangible and understandable AI. We conducted a user study in two parts of online sessions and semi-structured interviews. Generally, the cards seemed to help participants to analyze the existing AI products and to be engaged in critical discussions and creative explorations of tangible and understandable AI space. Hence, the cards supported the further developments of graspable AI design space by encouraging the participants to use both verbal and visual language and to think about forms that are the synthesis of well-crafted designed object and a transparent, authentic form giving process. However, we also found out that to envision physicality and tangible interaction with AI felt challenging and “too abstract”. This result implies that form-giving to tangible and understandable AI remains a wide-open problem—so wide open, in fact, that participants were often confused, and had to retreat to basic definitions and formulations. Further, participants expressed a general anxiety regarding the term “intelligence”, which suggests that the cards stipulate some working definitions, possibly as an outcome of future studies that seek to develop such definitions.

[1] “They [AI] do not have as much information as friends have for example for recommending a movie or music. I believe AI cannot replace human [friends] recommendations.”

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