AI-ThinkLets for Brainstorming

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Abstract

Digital Agents have the potential to be effective collaborators and significantly improve team collaboration practices. This study introduces the concept of AI-ThinkLets, which are repeatable collaboration activities involving Digital Agents. Using the Brainstorming process as an example, we demonstrate the applicability of AI-ThinkLets. We extend the existing OnePage ThinkLet with the Digital Agent by specifying its possible setup and functionality. This study provides insights for practitioners, orchestrators, and researchers. By integrating Digital Agents into established ThinkLets, we develop synergies that enhance the capabilities of human actors and enable new collaboration patterns.

Keywords: Collaboration Engineering, Digital Agents, AI-ThinkLets, Brainstorming

1. Introduction

Teaming up with Digital Agents (DA) can significantly boost collaboration efficiency and effectiveness (Seeber et al., 2020). Existing research, however, primarily concentrated on developing and implementing collaboration processes within human-only teams (Briggs & De Vreede, 2009). This study extends Collaboration Engineering (CE) by introducing the *AI-ThinkLet* concept. It integrates Digital Agents into structured collaboration activities.

A naive approach would treat a Digital Agent like a human agent. We could use the instructions provided by the human facilitator as a prompt for a Digital Agent built with generative artificial intelligence (GAI) (such as ChatGPT). But would the agent understand the instructions the (human) facilitator offers? Or does the Digital Agent need further instructions to function productively? Are there any tacit assumptions in the constructions of *ThinkLets* that need to be made explicit when instructing Digital Agents? What are the effects of such a Digital Agent on human participants? We address these questions when constructing an LLM-based Digital Agent that functions like a regular participant in a Brainstorming session with human actors. We collaborated with a leading provider of Group Support Systems to extend their Brainstorming tool to include an LLM-based Digital Agent as a team member.

Conceptually, this paper builds upon and contributes to CE. Collaboration engineering is a structured approach that designs and facilitates effective collaboration processes among individuals. It involves utilizing systematically designed group activities and procedures, using collaboration tools and techniques to improve communication and coordination within collaborative undertakings. Integrating a Digital Agent within collaboration systems goes beyond mere technological quality, delving into the art of efficiently organizing and managing the collaborative work process. This demands an in-depth understanding of the functioning collaboration system and the workflows of the involved stakeholders.

In this paper, we describe the setup and behavior of a Digital Agent as a part of an *AI-ThinkLet*. The described *AI-ThinkLet* offers insights for practitioners, collaboration orchestrators, and researchers, describing effective pattern and discussing emerging practice of effective human-DA collaboration.

2. Background

2.1 Digital Agents

The development of intelligent technologies and widespread high-speed Internet access have paved the way for the progress of autonomous intelligent solutions. Intelligent Information System (IS) artifacts can perform tasks independently and interact meaningfully with their environment, which allows to perceive them as Digital Agents (Brenner et al., 2012). Such agents are now able to perform some of the steps of a complex problem-solving process, i.e., identify a problem, determine root causes, propose and evaluate solutions, generate ideas, choose among options, make plans, act, communicate, or be part of debriefings. Integrating Digital Agents into traditional human collaboration pro-

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cesses may result in a more productive form of collaboration (Malone, 2018) in which the synergy of humans and AI may potentially exceed the capabilities of each individual intelligence (Lichtenthaler, 2018).

A Digital Agent may have a virtual character interacting with the user through visual, symbolic, and natural language communication (Dolata et al., 2019; Seeber et al., 2020; L. Yuan & Dennis, 2019). The virtual character can be explicit, i.e., have a name and a visual representation, or implicit, i.e., emerge through its actions . Furthermore, Digital Agents may also have a physical presence, like robots or similar devices with which humans can directly interact (Dolata et al., 2023). With the advent of new technologies, such as artificial intelligence (AI), Digital Agents find their application in many areas of human life and are ubiquitous in private and organizational contexts. Therefore, it is unsurprising that the impact of such agents on users has become an area of significant interest in IS research.

The design of a Digital Agent is challenging and goes far beyond the design of a simple conventional user interface. Each word, input, utterance, or atomic behavior of a Digital Agents can elicit an undesired response from the user (Gnewuch et al., 2017) and therefore requires careful consideration by the designer. So far, the research has primarily concentrated on technical feasibility. Developers often find themselves overburdened with this task and lack specific guidance on constructing a product that human users may perceive as a social entity (Seeber et al., 2020). Collaborating with Digital Agents requires understanding their perceived role within the larger context, shared goals, and norms. By recognizing the role of agents as part of a broader activity, we can work more meaningfully with them and align our efforts and communication styles for better collaboration. The complementary characteristics of humans and non-humans should be considered for Digital Agents solutions to be perceived as part of organizational and social structures. The need for high adaptability is a theme of the new IS discourse on machines as team members (Feine et al., 2019; Maedche et al., 2019; Nass et al., 1996; Seeber et al., 2020).

The role and impact of Digital Agents, the emerging work configurations and decision-making processes, and how the division of labor and the task delegation to and from Digital Agent work have recently become the subject of IS research (Baird & Maruping, 2021). The ability of Digital Agents to interact meaningfully with their environment transforms the existing paradigm of one-way human agency into a two-way relationship between humans and IS artifacts (Dolata et al., 2023). As Digital Agents become increasingly intelligent through AI development, new work configurations may emerge. This, in turn, has the potential to transform the organizational context. As a result, IS has recently begun to explore the future of work and the distribution of capabilities between humans and AI (Dellermann et al., 2019; Dolata et al., 2019, 2022; Feuerriegel et al., 2020; Maedche et al., 2019; Seeber et al., 2020; vom Brocke et al., 2018). A better understanding of the division of labor mechanisms could contribute to a better understanding of human-AI collaboration regarding social impact, explainability, and performance.

Recent advancements in the development of Large Language Models (LLM), such as Generative Pretrained Transformers (GPT), particularly the GPT-3 and GPT-4 models, have significantly enhanced the capabilities of Digital Agents in understanding natural language and context. These models excel in processing and generating human-like text, making them highly effective in various applications (Katsiuba et al., 2023). GPT's ability to comprehend nuanced language and provide contextually relevant responses has led to its widespread adoption as a personal assistant. Beyond this, LLM models may act as Digital Agents within collaboration teams. As a member of a collaboration system, LLM-driven Digital Agents may facilitate communication, manage workflow, and support the ideation process. As a result, new collaboration practices emerge, which promise to improve team dynamics, stimulate innovative problem-solving, and demonstrate the transformative impact of advanced AI technologies in collaborative practices. One important example is including Digital Agents in Brainstorming. Prior work indicates that ideas generated by GAI are as creative as human contributions (Haase & Hanel, 2023; Joosten et al., 2024; Stevenson et al., 2022). The quality of the ideas depends on the prompt engineering technique (Memmert et al., 2024). The participants in a brainstorming session supported by their personal GPT4-based Digital Agents engage in a more extensive exploration of topics (Memmert & Bittner, 2024). While the Digital Agents stimulated them, they also lured them into free-riding (Memmert & Tavanapour, 2023). Researchers found that brainstorming participants supported by a personal GAI agent are more productive and creative than nominal groups and computer-supported interactive groups without GAI (Bouschery et al., 2024).

In the 1990s, there was already evidence of significant increases in productivity through the computerization of brainstorming, with higher efficiency and idea generation compared to traditional methods (Dennis & Valacich, 1993). However, there has been no research into developing a GAI-based brainstorming participant. Furthermore, current studies on GAI-based brainstorming lack a foundation in collaborative engineering, highlighting a gap that needs to be addressed to fully realize the potential of GAI in collaborative environments.

2.2 Collaboration Engineering

Collaboration Engineering (CE) is an approach to designing collaborative work practices for high-value recurring tasks (Briggs et al., 2006). The underlying motive for collaborative engineering research was to address the challenge posed by the shortage of collaboration experts (De Vreede & Briggs, 2019). CE aims to bundle facilitation skills so that reusable and predictable work methods can be designed, which then can be applied to recurring, critical work situations (De Vreede & Briggs, 2019).

A key advantage is that CE research is built on the philosophy that design decisions must be made at multiple levels, including people, processes, information, technology, and leadership (De Vreede, 2014). Briggs et al. (2015) translated this philosophy into the six-level model of collaboration. This idea helps collaboration engineers design repeatable work practices to make the necessary design choices layer-by-layer, improving the overall performance (Randrup & Briggs, 2015).

The value of collaborative technologies can only be realized in the larger context of a collaboration system, which R. Briggs (2009) defines as a combination of actors (incl. team members and facilitators), tools (incl. hardware, software), and procedural knowledge to facilitate groups in achieving their goals, effectively and efficiently. Procedural knowledge is defined and described in *ThinkLets*, i.e., scripted facilitation techniques that trigger predictable effects and group dynamics among team members working toward a common goal (Briggs et al., 2003). A *ThinkLet* consists of three main components: *tools*, *setup*, and *script* (Briggs & De Vreede, 2009). The *tools* refer to the physical resources or software used for collaboration and encompass a wide range of possibilities, from digital platforms such as project management software to tangible tools such as sticky notes. The *setup* includes the specific arrangements and parameters of the tool in the context of collaboration. The *script* outlines the sequence of actions participants perform when using the tool within the defined *setup* and provides guidance, prompts, and instructions for navigating the collaborative activity. The *script* assists participants in effectively managing their roles and contributions, thereby ensuring consistency and coherence in the collaborative process. During the collaboration process, team members engage in a sequence of basic thinking patterns (generate, reduce, organize, clarify, evaluate, or build consensus) (Briggs et al., 2006). Such reusable and predictable work practices can be given to practitioners to perform independently without constant support from a collaboration expert (De Vreede et al., 2009). As a result, practitioners can be easily trained in these recurring work practices without having to become experts (Briggs et al., 2003). With these insights into successful practices, practitioners can avoid common pitfalls and streamline their efforts by applying proven strategies.

3. Methodology and Data Collection

In the Summer of 2023, the senior author of this paper and the CEO of a leading provider of Group Support systems met to discuss the potential of including GAI in group collaboration. For this purpose, they invited the CTO, the company's lead architect, and three members of the senior author's group into the research team. The CEO and the CTO had more than a decade of practical experience running electronic meetings, so their input was regarded as particularly relevant data.

The development process generally followed the guidance on conducting DSR proposed by Peffer et al. (Peffers et al., 2007). In the first workshop, the research team identified the problem and defined the goals and requirements for a brainstorming agent. As with all other workshops, this workshop was recorded. As their understanding progressed, goals and requirements were further refined in subsequent workshops.

In the next step, the researchers abstracted their insights on augmenting *ThinkLets* and collaboration engineering. For this purpose, the senior authors initially developed the idea of an *AI-ThinkLet* and further refined and generalized it through workshops to derive the abstract solution (see section 5.1).

In the following phase, the Group Support systems provider agreed to further explore this idea by designing and building an instance solution (see section 5.2). The pilot system aimed to integrate a Digital Agent into brainstorming sessions, chosen for its popularity, simplicity, and error tolerance. While GAI is known for its hallucinations, an unusual idea in brainstorming is often seen as a feature rather than a bug. In close collaboration with the lead software architect of the company, the second author used these goals and requirements to develop a prototype of the agent.

Applying a design science approach, we developed a proof-of-concept prototype to "demonstrate the functional feasibility for a potential solution to an important class of unsolved problems in the field." Correspondingly, our evaluation approach followed the human risk and effectiveness strategy of FEDs (Venable et al., 2016). In the spirit of HICSS, we present promising early ideas to trigger a discussion. Thus, we present the results of formative evaluations conducted in an experimental setup in a class on collaborative technologies taught by the senior author.

The second author analyzed the evaluation results, which were then discussed by the research team in a workshop. This paper synthesizes the primary insights

from the workshop discussion. We describe the results following the framework of Lee et al. (2011).

4. Solution

4.1 Abstract Solution: AI-ThinkLets

According to CE, the design of repeatable collaboration processes relies on the careful sequencing of specific *ThinkLets*, representing structured moderation measures within-group processes that aim to foster the desired patterns of collaboration between team members (Kolfschoten et al., 2004). As we integrate Digital Agents into collaboration processes, the traditional *ThinkLets* structure falls short. This integration demands an evolution of *ThinkLets* into *AI-ThinkLets*, acknowledging Digital Agents' complexity and leveraging their AI capabilities. Unlike typical *tools*, Digital Agents have autonomous capabilities, necessitating a new component in collaborative workflows. *AI-ThinkLets* retain the core elements of *ThinkLets* for human actors but are tailored to accommodate the specific nature and functionalities of Digital Agents. As the requirements gathered in section 4 show, Digital Agents do not have the tacit understanding of human participants. On top of the information provided to humans, they require additional setup configurations and a script specific to Digital Agents.

Similar to traditional *ThinkLets (Briggs & De Vreede, 2009)*, each *AI-ThinkLet* includes instructions and tools applied. In addition, the Digital Agent (single or multiple agents) component describes the general functionality of the Digital Agents (see Figure 1). The *Digital Agent* represents the instances of Digital Agents involved in the collaborative activity.

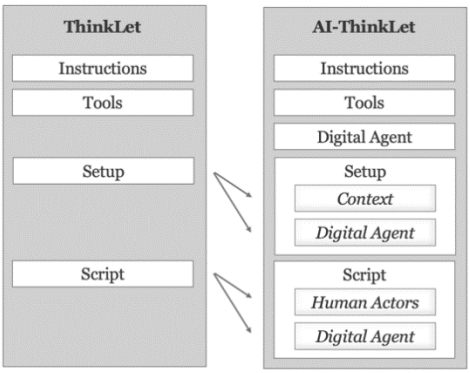

Figure 1. ThinkLet and AI-ThinkLet components.

In addition, the language of the Digital Agents must be adapted to the group's needs in the *setup*. This means that the length of the contributions, the conciseness or depth, and the vocabulary must be adapted to the level desired or used by the team. These settings ensure that Digital Agents can integrate seamlessly into the collaboration process and deliver relevant and contextualized contributions. We summarized the design knowledge on an AI-ThinkLet as a design principle in Table 1, which is structured based on Gregor et al. (2020)

The *script* outlines the sequence of actions human participants perform when using the tool within the defined *setup* and provides guidance, prompts, and instructions for navigating the collaborative activity. The script assists participants in effectively managing their roles and contributions, thereby ensuring consistency and coherence in the collaborative process. Digital Agents require additional instructions (scripts) tailored to their specific capabilities. The *scripts* guide the Digital Agents through the collaborative activity by providing them with relevant information about the task and the contributions of the other group members.

The introduced concept of *AI-ThinkLets* supports the design, organization, structuring, as well as execution of collaborative processes involving Digital Agents (i.e., integration of LLM in *ThinkLet* such as "FreeBrainstorm" or “OnePage”). The subsequent section on the instance solution demonstrates how *AI-ThinkLets* can be implemented.

Title	**AI-ThinkLet**
Aim, implementer, and user	To enable facilitators (implementer) to run meetings (aim) with human and digital participants (users)
Context	Collocated or distributed meetings where creativity or structured problem solving are required.
Mechanisms	Set up participating human and digital agents with their roles, capabilities and desired behaviours, provide them with the goal and contextual information and control them with scripts and real-time feedback based on participant input. Human participants are controlled by training, scripted instructions and tool settings; digital agents are controlled by scripted prompts or similar mechanisms.
Rationale	Digital Agents can improve group productivity by acting as participants or an assistant of the facilitator. The *AI-Thinklet* has to provide the mechanisms and information to allow the facilitator to control both human and digital participants. As human input remains crucial, the digital agent has to be constrained to behave in a way that it is acceptable and productive for the human participants.

Table 1. Design Principle of an AI-ThinkLet

4.2 Instance Solution: The AI-ThinkLet AI-OnePage Brainstorming

The primary design goal for the instance solution was developing a Digital Agent that functions as a natural participant in Brainstorming. Thus, groups using the augmented brainstorming session get one participant at no extra cost. The research team agreed on this goal because they felt they first needed to understand how a 'Digital Brainstorming Agent' (DBA) can be naturally included in Brainstorming before assigning it a particular role. This goal leads to the following requirements:

1. The DBA must be able to contribute ideas to the brainstorming platform.
2. The DBA must be able to understand and interpret the brainstorming question to contribute relevant ideas.
3. When contributing, the DBA should be aware of the existing contributions. Furthermore, given the existing ideas, the AI agent must be able to decide whether to build on existing ideas or contribute something new.
4. The DBA should adjust its communication tone and language to the group.
5. The DBA should adjust the length of a brainstorming comment to align with the group's contribution length.
6. The DBA should adjust its contribution frequency to the group's communication frequency.
7. The contributions of the Digital Agent should be as valuable and creative as the human actors' contributions.

Note that all those parameters could also be set differently by a human facilitator to impact the group's brainstorming behavior, but this was not the research team's goal.

The instance solution augments the One-Page Brainstorming *ThinkLet* with a Digital Agent acting as a regular participant. The *OnePage ThinkLet* was designed to facilitate efficient and focused brainstorming sessions. The underlying idea is to capture all participants' ideas on a single page, thereby promoting clarity and conciseness (De Vreede et al., 2009). By limiting the space available for contributions, participants are encouraged to prioritize their most valuable and relevant ideas, leading to more targeted and productive discussions. This method facilitates streamlining the brainstorming process and the subsequent review and synthesis of the generated ideas into actionable insights.

The resulting *AI-OnePage ThinkLet* extends the *OnePage ThinkLet* by adding a *setup* and *script* for the Digital Agent, as described in Table 2. The Digital Agent's *setup* regulates the Digital Agents' fundamental behavior, specifying the roles they should adopt, their language and style, and their participation level in the collaboration process. The script of the Digital Agent guides the Digital Agents through the idea generation process, providing them with the brainstorming question or task, as well as ideas that have already been contributed to the discussion. Thus, introducing a Digital Agent to the collaboration process strives to increase the group's access to information and generate synergies that can lead to cognitive stimulation (Memmert & Tavanapour, 2023; Nunamaker et al., 1991).

In the *AI-OnePage*, team members engage in collaborative brainstorming sessions using an electronic brainstorming platform that is accessible to all. This platform facilitates the sharing of ideas between team members, who contribute content in accordance with the guidelines set by the facilitator.

In February 2024, the second author implemented the pilot system based on GPT 4. During the development, it became clear that *ThinkLets* were a good starting point for prompting GPT 4. Still, it also became evident that they needed to be augmented. The *AI-OnePage* was implemented as a GPT-4-prompt. A prompt template-based environment was developed to structure and deliver prompts efficiently. This environment is based on the identified *AI-ThinkLet* components and is envisioned as a future facilitator cockpit. The system uses pre-defined prompt templates, into which necessary information and the group's comments are injected to create consistent and tailored prompts for the session that provide the DBA with the relevant context. An API to the commercial Group Support system provides GPT 4 with the completed prompt templates and feeds GPT-generated ideas into the ongoing brainstorming session.

5. Evaluation

5.1 Design

After the first running prototype was finished in April 2024, we evaluated it in an experimental setup in a class on collaborative technologies taught by the senior author. As part of a student assignment, the 42 students enrolled in the course were divided into six groups of seven each and asked to participate in an experiment on large-group collaboration. One participant was excluded from the analysis due to late arrival and missing the first measurement.

To ensure that introducing an additional factor did not confound the results, the experimental design employed a single-blind, within-subject design with counterbalancing (Charness et al., 2012). The Digital Agent was randomly included in one of two measurements, the first or second. In addition, the students were not informed about the specific objective of the experiment, which left them unaware of the nature of the treatment.

In *AI-OnePage* the team members brainstorm ideas in response to a single question or prompt. The team members are working simultaneously on the same page. They contribute ideas or reactions to previous ideas.	
Choose this AI-ThinkLet…	… to quickly generate ideas on one topic a at a time … brainstorm with 5 or fewer participants or with a group of 6 or more people in less than 10 minutes. … to cause team members with narrow, parochial views quickly to see the big picture, to quickly create a shared vision in a new, heterogeneous team.
Do not choose this AI-ThinkLet...	… if you expect a lot of ideas (more than 80) as participants may suffer from information overload. … if your group has more than 6 members brainstorming for more than 10 minutes. Consider using FreeBrainstorm instead to avoid information overload. … if you are discussing more than one topic. Consider LeafHopper instead.
Input	One brainstorming question or task
Output	A set of unstructured brainstorming comments
Tool	Electronic Brainstorming platform
Digital Agents	GAI-based Digital Brainstorming Agent
Setup Context	Create a page in Electronic Brainstorming allowing participants to contribute ideas in parallel.
Setup Digital Agents	Setup is a system prompt. Within the system prompt a Inform the agent about the brainstorming question or task b Inform agent on its role and the perspective it should adopt c Define language, style, and tone of contributions d Additional sources and information to be considered when generating ideas, if any Sample system prompt: *You are {{role}}. Your role is to contribute ideas while adhering to the following four rules for effective brainstorming, established by Alex Osborn:* *1. Aim for quantity - The greater the number of ideas generated, the greater the likelihood that quality concepts will emerge. Try to contribute as many ideas as possible.* *2. Defer judgement - During the brainstorming session, you should not criticize or evaluate the ideas as they are proposed. All ideas, no matter how unconventional or seemingly silly, should be accepted initially.* *3. Encourage wild ideas - The more creative and out-of-the-box the ideas, the better. Do not self-censor. Feel free to put forward even the most radical or crazy ideas.* *4. Build on others' ideas - Suggest how other people's ideas could be combined, improved or used as a starting point for new concepts.* *This is the context of today's brainstorming:* *{{additional information}}* In addition, the following parameters must be defined: a The frequency of Digital Agents' inputs (i.e. time intervals, share of ideas, when inactivity of others is observed, on demand, etc.) b The model (i.e. GPT3.5, GPT4, etc.), depending on the requirements and input c The model parameters (i.e. temperature, top-p, presence penalty, etc.) to account for variations in creativity and lexical diversity
Script Human Actors	a Ensure the participants understand the brainstorming question or prompt. b Give instructions to the participants: If you have any questions about the brainstorming question or task, please speak up. c If necessary, facilitate a verbal discussion to clarify any misunderstandings. If necessary, reformulate the question. d Inform participants of any time limits. e Let participants make comments until they run out of ideas or until the time is up.
Script Digital Agents	If the Digital Agent's input is required, provide it with the ideas generated so far. Then ask it to generate a new idea or expand on other ideas. Chain of sample prompts: *1. In response to the question {{question}}, your peers have proposed the following ideas:* *{{list of generated ideas so far}}* *Analyse the overall tone of the examples above.* *2. Generate multiple ideas for the brainstorming question below. Ensure that your ideas are different from the existing ideas provided.* *Question: {{ question}}* *Answer: When contributing your ideas, you should adhere to the following tone: {{tone}}* *3. Select one of the generated ideas that you consider to offer the most value in terms of creative thinking, and that you believe will be of the greatest benefit to the wider group in the course of the brainstorm.* *<selected_idea type=...>[Insert idea here]</selected_idea>*
You are done if	… participants run out of ideas or until the time is up.

Table 2. AI-ThinkLet "AI-OnePage," based on OnePage ThinkLet described in Briggs & De Vreede (2009)

The experiments followed the following agenda: (1) Introduction, (2) Pre-session survey, (3) Measurement I, (4) Interim survey, (5) Break, (6) Measurement II, (7) Interim survey, (8) Post-session survey, (9) Disclosure. The experiment produced various data, including the ideas proposed by the students and the DBA and the survey results, all of which can be used to assess the design goal and requirements.

During the introduction, the experimenter reminded the students of the four rules for brainstorming established by Osborn (1953): (1) aim for quantity, (2) encourage wild ideas, (3) defer judgment, and (4) build on other's ideas. The pre-session survey yielded descriptive statistics regarding the characteristics of the group. Both measurements included three group activities. (1) ideation, (2) organization of ideas into key themes, and (3) evaluation of ideas by means of importance. The ideation activities lasted for 12 minutes each. In the first session, students generated ideas on how the computer science association could improve its services to attract new members and foster community. In the second session, they brainstormed ways to enhance the university's learning experience. A Digital Agent was randomly included in one of the two ideation activities in each session. Interim surveys collected feedback on the quantity and quality of ideas, students' performance, and their feelings. After both sessions and interim surveys, a post-experiment survey inquired about the potential integration of an LLM-based agent, its impact on students and group behavior, and their experienced differences in large group collaboration between the two measurements. Students also provided written reflections on the possible gains and losses of including an AI agent in brainstorming. Finally, students were informed about the treatment and in which session the AI agent was incorporated.

5.2 Results

The first running prototype, released in April 2024, fulfilled the overall design goal of developing a DBA that behaves similarly to human participants in a brainstorming session. The answers to the post-experiment survey indicate that the DBA exhibited human-like behavior and was, thus, not identified by most students. Of the 41 students surveyed, 33 could not determine whether an AI agent was involved in any brainstorming sessions. After disclosing that an AI agent was integrated into one of the sessions, the students were asked if they noticed any difference between the ideation activities. Approximately half of the students did not perceive any notable differences between working in an all-human group compared to a group of humans and AI, except for the higher number of ideas generated (see Table 3). The remaining half of the students argued that there was a more consistent flow of ideas and that AI-generated ideas were helpful to expand on. Also, these students stated that the session involving an AI agent contained fewer specific ideas, which were nevertheless valuable for further development, as well as more diverse and unconventional ideas.

	Total	Humans	DBA
Ideation with DBA	67.0	52.5	14.5
Ideation without DBA	49.3	49.3	0

Table 3. Average Number of Generated Ideas

We were surprised by this overall positive evaluation as some requirements had some room for improvement. The DBA was able to contribute ideas to the brainstorming platform during the ideation activity of the experiment (fulfilling requirement 1). The generated ideas were related to the tasks (fulfilling requirement 2). When generating ideas, the DBA was provided with the ideas of other participants and itself. However, the agent mostly did not build upon existing ideas but generated novel ideas.

Furthermore, the agent occasionally presented identical ideas with only superficial modifications. Thus, the DBA was only partially aware of other comments (requirement 3). DBA's communication style and language were mostly aligned with the group (requirement 4). While DBA used similar language and formality, the agent's ideas often followed a pattern: a headline followed by a description. As such, these contributions were identifiable by those participants versed in the AI-generated text. In addition, the contributions of the DBA were typically longer than those of the human participants (not fulfilling requirement 5). The DBA adjusted its contribution frequency to align with the group communication frequency but contributed more ideas than specified by the moderator (20% instead of 14%, partially fulfilling requirement 4). During the last activity of each measurement, the students were asked to evaluate the ideas in terms of their importance in achieving the overarching objective delineated at the beginning of the ideation activity. This assessment revealed that AI ideas were perceived as less promising in reaching the objective ($U=40370.0$, $p<0.001$, $RBC=-0.519$, $CLES=0.760$), thereby not fulfilling requirement 7 (see Figure 2).

Nonetheless, a considerable number of students indicated in their written reflections that the ideas of the AI agent could be a source of inspiration. Furthermore, the interim survey results indicated that ideas' perceived quantity, originality, and novelty were slightly higher when the AI agent was included.

We addressed all the issues leading to partial fulfillment or non-fulfillment of requirements in subsequent development cycles, and we are currently analyzing promising data based on testing an improved version.

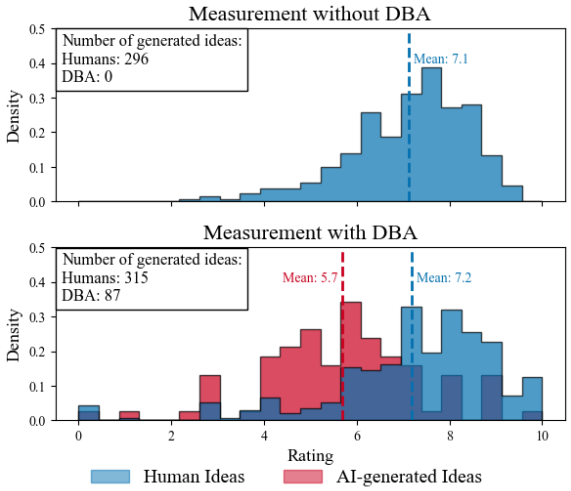

Figure 2. Density of Relevance Rating

6. Discussion and Conclusion

The results are promising even if the first evaluation did not completely fulfill all requirements. The findings of this research are of interest to both practitioners and researchers. Practitioners, such as collaboration facilitators, can gain insights into effective collaboration patterns with Digital Brainstorming Agents and their potential for reuse. Researchers in fields of machines as teammates and collaboration engineering can expand their scholarly discourse to encompass the role of Digital Agents as active participants within collaborations. This way, the research contributes to a more comprehensive understanding of collaborative interactions involving Digital Agents.

A. *Implications for Digital Brainstorming Agents* (DBAs): The group smoothly integrated the DBA into their Brainstorming as a full-fledged team member and communicated naturally with it. Digital Agents based on GAI can act as regular participants in brainstorming sessions, not just as personal assistants to human participants (Haase & Hanel, 2023; Joosten et al., 2024; Stevenson et al., 2022). This may trigger a second round of digital productivity enhancements of Brainstorming activities. While the first round during the last 15 years of the 20th century focussed on removing collaboration process losses and amplifying process gains (cite Dennis et al. CACM), this round of productivity gains is driven by free additional Brainstorming capacity priorly provided by humans. It remains an exciting area of future research to what extent the approach presented here scales to more than one DBA present in a meeting.

The application of DBAs is not limited to introducing a standard team member. Prior work (Bouschery et al., 2024) and unintended effects in the evaluation indicate that it can fulfill particular roles: For instance, they can act as an icebreaker by initiating the brainstorming process with an initial idea, thereby overcoming hesitancy among team members to contribute first. Alternatively, Digital Agents can be more proactive in idea generation, consistently making new contributions to stimulate ongoing discussions. Furthermore, they can serve as animators, introducing novel perspectives when the team's creativity stagnates. Customizable settings and scripts within the *AI-ThinkLets* enable the versatility of Digital Agents' roles in the brainstorming process.

In any case, the influence of DBAs on team dynamics must be carefully considered, particularly their role in guiding discussions and influencing outcomes. Digital Agents must follow predefined scripts within the *AI-ThinkLet* to ensure their contributions are effective and remain within the collaboration's primary focus. These scripts are crucial for governing the actions and communications of Digital Agents, ensuring alignment with team goals, and promoting productive collaboration. By precisely defining these parameters, we can leverage the potential of Digital Agents to enhance rather than disrupt team dynamics, optimizing their role in collaborative processes.

B. *Implications for collaboration engineering*: Our research extends to Collaboration Engineering as a research domain, opening new avenues for Collaboration Engineering researchers. By applying Collaboration Engineering to groups involving humans and DBAs, we show them how to integrate Digital Agents. Here, there are at least two key contributions:

1. Even if they are not entirely sufficient, *ThinkLets* are surprisingly useful for instructing GAI to behave appropriately despite having different foci (i.e., tone instead of time) when setting up. Nevertheless, it is not necessary to start from scratch when designing DBA (and other Digital Collaboration Agents), as we can build on the facilitation knowledge embedded in them.

2. We extend *ThinkLets* to *AI-ThinkLets* by identifying the first set of parameters with which a DBA needs to be prompted. The parameters meant for human participants (e.g., instructions) can also be used for Digital Agents. A second set of prompting parameters is not made explicit in *ThinkLets* but is rooted in higher layers of collaboration engineering. For example, participants are selected according to the collaboration goals (=top layers). Thus, the basic description

of the Digital Agent has its roots there. A third set of parameters is not explicitly asked for in *ThinkLets*, but experienced collaboration engineers may have included them in their instructions. Examples are the tone or the length of the contributions. A final set of parameters is purely technical, most notably the chosen GAI.

AI-ThinkLets offer collaboration engineers new opportunities to present design patterns for predictable, recurring, and high-value DBA-supported collaboration activities. Collaboration Engineers can formulate new *AI-ThinkLets* or augment existing *ThinkLets.*

C. *Future Work*: The *AI-OnePage* enhances the brainstorming process. The versatility of *AI-ThinkLets* extends to various collaboration patterns beyond idea generation. For instance, exploring their role in organizing tasks is a promising area for future research.

Furthermore, Digital Agents may also be able to support the acting facilitator in setting up, running, and documenting the meeting. Collaboration engineering already replaces the professional facilitator with a non-professional acting facilitator who instantiates prefabricated routines (i.e., *ThinkLets*). *AI-ThinkLets* allow acting facilitators to run meetings supported by Digital Agents. Future research may look into Digital Agents supporting acting facilitators in creating versions of existing *ThinkLets* (and meeting agendas) or even becoming fully functional facilitators. This requires a deep understanding and situational awareness on the part of the Digital Agent that enables it to grasp the team dynamic effectively. In this way, Digital Agents could fundamentally change the way we work together and initiate a new era of collaborative efficiency and innovation.

7. Limitations and Future Work

The empirical evaluation of the *AI-Thinklets* concept involved only six groups, limiting the generalizability of our findings. To strengthen the validity of our solution, future research should include larger and more diverse participant groups. Beyond brainstorming, other *ThinkLets* could also be explored and tested. Although we assessed the impact of Digital Agent support on brainstorming productivity, we did not conduct interviews to understand participants' perceptions of the treatments. Such qualitative insights are crucial for refining the design and implementation of these tools. Future research should incorporate interviews to understand these perceptions and their effects better. Finally, we acknowledge that the requirements collection is focused on researchers and industry partners. We are convinced that considering further perspectives is essential for designing better DBAs.

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