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ENHANCING CREATIVITY AND COLLABORATION IN DATA SCIENCE: THE IMPACT OF ARTIFICIAL INTELLIGENCE-AUGMENTED BRAINSTORMING

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Abstract. As artificial intelligence continues to permeate various aspects of creativity, its influence on data science expands, especially in situations where innovative thinking is essential for interpreting complex data and generating actionable insights. This study examines how *ChatGPT*, a generative artificial intelligence tool, impacts brainstorming dynamics among data science students. Utilizing a mixed-method approach, we investigate the effects of artificial intelligence augmentation on participants' satisfaction, as well as the social and cognitive dimensions of brainstorming. Our findings show that artificial intelligence-assisted group sessions significantly boost self-perceived creativity and satisfaction compared to traditional group and nominal individual techniques, particularly benefiting individuals with social low-anxiety. However, artificial intelligence-assisted sessions showed a tendency towards free-riding, with participants relying more on artificial intelligence than their peers for idea generation. This study highlights the need for strategies to mitigate free-riding and ensure balanced contributions in human–artificial intelligence collaborations. The implications of these findings are profound for designing effective brainstorming sessions in educational and corporate environments, suggesting that artificial intelligence, when thoughtfully integrated, can significantly enhance creativity and collaborative efforts.

Keywords: artificial intelligence-augmented brainstorming, collaborative creativity, design thinking in data science, free-riding in hybrid teams, generative artificial intelligence, human–artificial intelligence collaboration.

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1. Introduction

The intersection of creativity and technology, particularly in computer and data science, is an evolving area of study. Research on creativity in computer science is mainly focused on the field of education (Daker et al., 2022; Žižić et al., 2017).

The study of some authors (Daker et al., 2022) reveals a significant link between the skill of analogical reasoning – the capacity to connect seemingly unrelated concepts – and success in computer science courses. The research also finds that students who perceive computer science as a creative discipline tend to achieve higher success. This perception fosters a mindset conducive to creativity and innovation, an approach that is just as beneficial in the field of data science.

These insights suggest that creativity is not just an add-on in computer science but a fundamental aspect that needs to be integrated into the curriculum and teaching methodologies. The focus on building creative products and enhancing student motivation through a supportive learning environment is crucial for developing the next generation of innovative computer scientists.

Based on the research and literature available, it appears that there is a research gap in the specific area of creativity in data science. While there is extensive literature on data science and its methodologies, as well as on creativity in broader fields like computer science and education, the intersection of creativity specifically within the context of data science seems less explored.

Even though data science is strongly related to computer science, it is, in fact, a broader field that utilizes methods and principles from various disciplines (Cao, 2017). In computer science, creativity involves developing new techniques and solutions to solve problems, often requiring innovative thinking and the application of established methods in novel ways (Barnett & Romeike, 2017) while in data science creativity is essential for uncovering insights, creative problem solving and creative skills related to designing effective communication (Donoghue et al., 2021).

Data science is a compilation of methods and practices from different fields, and while computer science provides essential tools and techniques for data processing and algorithm development, other disciplines like statistics and domain expertise play a crucial role in interpreting and applying data insights.

Creativity in data science is crucial because of the endless possibilities for interpreting vast amounts of data. While artificial intelligence can effectively analyze data, human creativity is needed for outstanding interpretations and novel insights. This aspect is particularly important when creatively packaging data in a manner that is understandable and meaningful for broader business applications. It highlights that data science is not an isolated field but rather intersects significantly with other business areas, necessitating a creative approach to ensure maximum impact.

Central to understanding creativity is the concept of creative thinking, a cognitive process characterized by the ability to generate or recognize ideas, alternatives, or possibilities that may be useful in solving problems, communicating with others, and entertaining ourselves and others (Runco & Jaeger, 2012).

Boden's (2004) categorizes creativity into three primary types: 1) combinatorial creativity which involves making novel combinations of familiar ideas. It is about linking ideas that were previously unrelated, to generate something new and interesting. This type of creativity is often seen in poetry, music, and metaphorical thinking; 2) exploratory creativity is based on the exploration within a conceptual space and happens when someone explores this space and discovers new ideas or concepts that are already implicit within the rules of that domain; and 3) transformational creativity which is the most radical form of creativity, where the actual rules and boundaries of the conceptual space are transformed or extended, leading to entirely new possibilities that were inconceivable within the original framework.

Concerning cognitive aspects, the literature on creativity distinguishes between two processes that are both unique and interconnected: divergent and convergent thinking.

The concepts of convergent and divergent thinking were developed by the American psychologist Joy Paul Guilford in 1956. Guilford's (1956) research marked a significant shift in the understanding of intelligence, moving away from the traditional view of intelligence as a single, general ability. He proposed that intelligence is multi-dimensional, including various types of cognitive abilities. In this context, divergent thinking was described as a process used to generate creative ideas by exploring many possible solutions. It involves thinking in a non-linear, spontaneous, and free-flowing manner.

Convergent thinking, on the other hand, was defined as the ability to give the "correct" answer to standard questions that do not require significant creativity. It is more linear and logical, focusing on narrowing down the multiple possibilities to find the best answer. Guilford's (1956) theory emphasized the importance of creative thinking in intelligence.

2. Brainstorming

Brainstorming, a technique originally conceptualized by Osborn (1957), serves as a prominent method for fostering divergent thinking within a group setting. Group idea generation has been widely examined as a foundation for organizational creativity, highlighting how interactive processes shape both the quantity and quality of ideas produced (Paulus & Yang, 2000). The primary objective of brainstorming is to stimulate the generation of innovative ideas by encouraging participants to think freely and without judgment. This technique operates on the premise that the inhibition of criticism during idea generation enhances creativity by creating a permissive and non-threatening environment.

Since the introduction of brainstorming technique researchers have explored several effects that occur in the realm of brainstorming sessions and can shape the dynamics of idea generation. Some authors (Pinsonneault et al., 1999) categorize these effects as process gains and process losses referring to their negative or positive impact on the brainstorming results. These effects can also be seen as social and motivational, and cognitive influences (Goldenberg & Wiley, 2011). Camacho and Paulus (1995) explained factors causing productivity loss as procedural, social psychological, and economic mechanisms. The social domain encompasses the interpersonal interactions that occur during collaborative brainstorming, while the cognitive domain focuses on the thought processes that occur both in individual and group settings. Economic or motivational mechanisms are related to the motivation deterioration that occurs due lack of transparency of contribution while working in a group. The effects discussed in the literature are briefly introduced in Table 1.

These effects, ranging from social dynamics to cognitive processes, play roles in the success and productivity of brainstorming sessions. Understanding these dynamics can help in structuring more effective brainstorming strategies and environments.

In addressing the varied effects of traditional brainstorming, researchers have developed several innovative variations of the technique aimed at mitigating these drawbacks. One such methodology is "nominal brainstorming", which was introduced as a way to reduce the negative impact of social dynamics.

Developed within the field of management information systems, electronic brainstorming incorporates technology to facilitate and enhance the brainstorming process. In electronic brainstorming, participants are connected via a computer network, allowing them to input ideas through a computer interface, often simultaneously. This setup can include a feature for anonymous submissions, which was designed in order to reduce the apprehension of

Table 1. Social, motivational, and cognitive effects on brainstorming (source: created by authors)

Social and motivational effects		Cognitive effects	
Arousal/ motivation	The act of observing others performing a task or being observed while performing a task can increase energy investment (Lamm & Trommsdorff, 1973).	Observational learning	It is a cognitive process through which individuals learn from the experiences and creative expressions of their peers, influencing their own approach to idea generation, allowing individuals to build on the creative insights of others (Lamm & Trommsdorff, 1973).
Social recognition	It refers to the desire for acknowledgment and validation of one's contributions within a group setting (Pinsonneault et al., 1999). Social recognition serves as a form of positive reinforcement, reinforcing the value of individual contributions within the group.	Production blocking	This is a phenomenon in brainstorming and group creativity where individuals experience delays or disruptions in the generation and communication of their ideas due to the structure of the group setting (Diehl & Stroebe, 1987; Mullen et al., 1991). In many brainstorming sessions, participants are often required to contribute ideas sequentially, taking turns to share their thoughts within the group. While waiting for their turn to speak, individuals may experience delays in expressing their ideas. This waiting time can result in a loss of momentum and make it challenging to maintain a steady stream of creative thoughts.
Evaluation apprehension	It is an opposition to social recognition and it is the concern or fear of individuals who may have about being judged or evaluated negatively during the brainstorming process, which can impact their willingness to express ideas freely (Diehl & Stroebe, 1987).	Cognitive inertia	In the context of brainstorming refers to the tendency of individuals to adhere rigidly to their own ideas, perspectives, or mental frameworks during a group creative process (Pinsonneault et al., 1999). It reflects a resistance to deviating from one's initial thoughts or preconceived notions, hindering the exploration of alternative viewpoints and potentially limiting the diversity of ideas within the group.
Social loafing	Individuals within a group exert less effort or contribute fewer resources than they would if working alone. It is characterized by a diffusion of responsibility within a group, leading to decreased motivation and productivity (Latané et al., 1979; Simms & Nichols, 2014).	Cognitive conformity	It happens when group members align their thinking and ideas with perceived group norms or expectations, even if those ideas do not necessarily align with their personal perspectives. This phenomenon is characterized by a desire for social harmony and a reluctance to deviate from what is perceived as the consensus within the group. The desire for social recognition can influence cognitive conformity. Individuals might conform to what they perceive as socially acceptable to increase the likelihood of receiving positive acknowledgment from their peers (Hackman & Kaplan, 1974).

***End** of Table 1*

Social and motivational effects		Cognitive effects	
Free-riding	It is a tendency of some individuals to contribute less actively to idea generation, relying more on the efforts of others within the brainstorming group (Diehl & Stroebe, 1987).	Effort redundancy	It is an occurrence of overlapping or duplicated efforts within a group, where individuals contribute similar or identical ideas or solutions to a given problem. This redundancy may arise due to various factors, and while it can sometimes lead to inefficiencies, it also has the potential to contribute positively to the creative process (Pinsonneault et al., 1999).
Sucker effect	It is conceptualized by Kerr (1983), who suggests that when one member of a team is engaged in social loafing, their partner may decrease their own efforts to avoid being perceived as a "fool". The research revealed the existence of the "sucker effect", and in some extreme instances, partners were even willing to fail at a task rather than feel like they were being taken advantage of.	Cognitive stimulation	It happens when interactions and exposure to diverse ideas within a group setting enhance an individual's cognitive processes, leading to increased creativity and the generation of novel ideas. This phenomenon emphasizes represents a process gain of collaborative thinking on individual creative thought processes. The dynamic interaction among group members during brainstorming fosters a continuous flow of ideas. As individuals contribute, react, and build upon each other's thoughts, cognitive stimulation is sustained throughout the session (Lamm & Trommsdorff, 1973).
		Blank canvas paralysis	It represents a psychological barrier or hesitation that individuals experience when faced with the initial stage of idea generation. Blank canvas paralysis manifests as a moment of uncertainty, self-doubt, or feeling overwhelmed when individuals confront an empty space for idea generation, especially at the beginning of a brainstorming session, it is often driven by a fear of the unknown or the pressure to generate ideas from scratch (Wingström et al., 2024).

being evaluated on the ideas shared. As ideas are submitted, they are displayed on a shared screen, visible to all participants, which encourages a continuous flow of ideas and facilitates parallel communication, allowing multiple participants to contribute ideas at the same time, thus overcoming the limitation of production blocking found in traditional brainstorming.

3. Artificial intelligence-augmented brainstorming

Utilizing artificial intelligence in brainstorming tasks has been so far the least explored brainstorming methodology. Chiu Yu-Han and Chen Chun-Ching (2023) see the primary goal of employing artificial intelligence for brainstorming is not to seek its direct input, but rather to foster the problem-solving process by enabling users to gain a more comprehensive insight into their own ideas and requirements through interaction with artificial intelligence. In the realm of creativity, artificial intelligence is increasingly being recognized as a collaborative entity that aids humans in sparking new ideas and inspirations. It assists in breaking free from rigid thought patterns and overcoming the "blank canvas", by fostering both divergent and convergent thinking processes (Wingström et al., 2024).

Human and artificial intelligence collaboration is a complex relationship. Nowadays, computers are not just viewed as simple tools, but rather as collaborative partners in creating shared value through interactive processes (Siemon, 2022). The term *hybrid intelligence* was introduced by some authors (Akata et al., 2020) and stands for synergistic combination of human and machine intelligence, aiming to augment human capabilities and intellect rather than replacing them. The goal is to achieve outcomes that are unattainable by either humans or machines alone.

Bittner et al. (2019) have developed a taxonomy to aid researchers and designers in comprehending the complex field of human–artificial intelligence collaboration. This taxonomy is particularly focused on the role of artificial intelligence within teams, which is a crucial design decision in the collaboration engineering process and team composition. The authors have identified specific roles such as facilitator (*e.g.*, tutors or teachers), peer (*e.g.*, teammate or sparring partner), and expert (*e.g.*, analyst or evaluator) that can be assumed by artificial intelligence-based team members.

One of the studies that explores brainstorming with artificial intelligence in facilitator role was conducted by Geerts et al. (2021). Traditional brainstorming is some cases involves a human facilitator who helps maintain creativity and productivity so the study examined whether the presence of a robot facilitator influenced productivity and if any change in productivity could be attributed to the robot's impact on social anxiety and evaluation apprehension among participants and revealed no significant difference in productivity between groups facilitated by a human and those facilitated by a teleoperated robot.

The research of Memmert and Tavanapour (2023) adopted a different role of artificial intelligence introducing *ChatGPT* as a peer in the brainstorming process and aimed to understand how individual brainstorming can be transformed into a collaborative effort between a human and artificial intelligence. The findings revealed familiar group dynamics from human brainstorming, such as cognitive stimulation, where the presence of artificial intelligence can inspire new ideas. However, it also identified a potential risk of "free-riding", where individuals might rely too heavily on the artificial intelligence for ideas, reducing their own contribution.

This issue has been highlighted in previous studies (Siemon & Wank, 2021). Memmert and Tavanapour (2023) suggest future research should explore how free-riding and the withdrawal of effort are conceptualized and measured in human–artificial intelligence-augmented groups. They note that focusing solely on the quantity of human-generated ideas might not accurately represent engagement in human–artificial intelligence-augmented groups, as humans might be more involved in curating artificial intelligence suggestions rather than generating new ones. Humans might reduce their effort to conserve cognitive resources and improve efficiency, believing the artificial intelligence will compensate. This concept, termed *smart loafing* (Stieglitz et al., 2022) indicates a new role for humans in these collaborations and raises questions about the extent of human responsibility for the outcomes.

Another study exploring collaborative "peer role" brainstorming with *ChatGPT* was dedicated to more complex problem: formulating the regional development plan. Lavrič and Škraba (2023) proposed a methodology for integrating human and artificial intelligence participants to improve brainstorming and decision-making processes, highlighting the potential of artificial intelligence tools in enhancing the quality and diversity of ideas in strategic planning contexts.

3.1. Artificial intelligence limitations

It is, however, also important to recognize limitations when collaborating with artificial intelligence. Artificial intelligence-generated content currently faces several challenges, including generating false information, producing harmful instructions, biased content or ethically questionable ideas (Lavrič & Škraba, 2023) and limited knowledge (Yu-Han & Chun-Ching, 2023). Another limitation of artificial intelligence models is their inability to grasp common sense and contextual understanding. While these models are capable of producing text and language that appears coherent and may even seem advanced, they fall short in comprehending the subtleties in human communication. Artificial intelligence technologies struggle to interpret sarcasm, irony, or metaphor, all of which are crucial elements of human language. This can result in misunderstandings and errors in the artificial intelligence-generated content (Holt, 2023). In the brainstorming experiment conducted by Lavrič and Škraba (2023) it has been noted that *ChatGPT* repeatedly generates identical ideas, which goes against the guidelines of brainstorming principles. It is uncommon for humans to come up with the exact same concepts. However, researchers put forward the hypothesis that the repeated emergence of a particular idea might suggest its greater significance.

4. Methodology

The current study explores how the application of *ChatGPT* changes the brainstorming process and its characteristics, focusing on the feelings and perceptions of the participants, thus the research question can be formulated as follows: how does the use of *ChatGPT* influence brainstorming dynamics, participant experience, and social and cognitive effects in brainstorming sessions among data science students, compared across traditional, nominal, traditional with *ChatGPT*, and nominal with *ChatGPT* techniques?

Brainstorming experience to a large extent is shaped by the cognitive and social effects which were discussed in the literature review chapter and are the subject of the study. Hence, the hypotheses are related to these effects.

4.1. Social effects hypotheses

1. Arousal/motivation: group brainstorming sessions may be more engaging than those involving artificial intelligence-only interaction, as the social dynamics and direct interaction among participants can enhance arousal and motivation;
2. Evaluation apprehension: it is likely to decrease in sessions augmented with *ChatGPT* due to the artificial intelligence's impersonality, which promotes an environment where participants feel more open to sharing ideas without fear of judgment;

3. Free-riding: it could increase in artificial intelligence-enhanced brainstorming sessions, as some participants might expect the artificial intelligence to offset their reduced contribution, relying on the artificial intelligence to fill gaps in the idea generation process.

4.2. Cognitive effects hypotheses

1. Cognitive stimulation: it is expected to rise in brainstorming sessions that incorporate *ChatGPT*, with the artificial intelligence's varied inputs fostering more innovative and diverse ideas than sessions without artificial intelligence assistance;
2. Production blocking: it is effectively eliminated in sessions where *ChatGPT* is used, as the artificial intelligence can generate ideas on request, ensuring a continuous flow of input without the typical wait times seen in traditional group brainstorming;
3. Effort redundancy: it might rise in sessions augmented with *ChatGPT*, especially if the artificial intelligence generates ideas that are too generic, potentially mirroring common human-generated thoughts and leading to overlapping contributions;
4. Blank canvas paralysis: it is likely lessened in brainstorming sessions involving *ChatGPT*, as the artificial intelligence's ability to prompt early ideas helps overcome the initial hesitation to start the idea generation process.

Additionally, to the social and cognitive effects analysis it is worth to explore the overall experience and satisfaction of participants, including the social anxiety dimension:

1. Satisfaction and self-perceived creativity. Participants in brainstorming sessions that incorporate *ChatGPT* are likely to report higher satisfaction and an increase in self-perceived creativity compared to those in traditional brainstorming sessions;
2. Social anxiety dimension: the satisfaction levels of participants with social high-anxiety are likely to increase when engaging in brainstorming sessions utilizing the nominal *ChatGPT* technique.

4.3. Methods

The capacity to create original data interpretations, choose significant elements, and build creative models are examples of how creativity is applied in data science, but in computer science it frequently entails creating new algorithms and streamlining computational procedures. In order to reconcile theoretical viewpoints with real-world applications, the study design evaluates how artificial intelligence-augmented brainstorming affects students' capacity to approach data-driven problem-solving creatively. Considering the study's focus, a mixed-method approach is chosen, incorporating both an experiment and a survey. The experiment allows for the creation of controlled environments with the independent variable (the use of *ChatGPT*) to observe its direct impact on the dependent variables (brainstorming dynamics, participant experience, social and cognitive effects). The survey, which includes both pre- and post-questionnaires, is designed to capture participants' expectations, impressions, and attitudes toward artificial intelligence-assisted brainstorming. This approach provides insights into how participants' perceptions and experiences change through their interaction with *ChatGPT*.

4.4. Experiment design

Experiment parameters or factor levels as referred by some authors (Pinsonneault et al., 1999) consist of determining the number of groups, group size, total participants, session timing, number of brainstorming questions and their content. Group size varies across studies starting from four until twelve. In the current study group size of five participants is chosen based on existing research, which indicates that groups of five to six members tend to be more effective in brainstorming sessions than smaller groups of three to four (Benbasat & Lim, 1993). According to some authors (Pinsonneault et al., 1999), larger groups, such as those with twelve or more members, are less common and considered less important in organizational settings compared to smaller groups. The number of groups is based on the number of brainstorming techniques, with two groups for each technique to allow for a more balanced output.

The timing of the experiment session per one question found in the academic literature starts at 6 minutes (Memmert & Tavanapour, 2023) and goes up to 15 minutes (Geerts et al., 2021). A 10-minute limit for the session should allow enough time to produce ideas maintain high focus and prevent fatigue.

4.5. Brainstorming question

It is important to wisely choose a brainstorming question or brainstorming problem so that the question does not become a factor that has an impact on the process and results. For instance, according to Boden (2004), creativity is based on knowledge, therefore, for the case of the experiment, the brainstorming task should not require specific domain knowledge that may vary across the participants. The criterion for selecting the question in this study is that it should be relevant to all participants while being broad enough to allow for a wide range of ideas.

Moreover, brainstorming question defines which cognitive processes are engaged within the session. A study by Taylor et al. (1958) includes three different brainstorming questions, known as “tourists”, “thumbs”, and “teachers” problems. The “tourists” problem encourages practical thinking and problem-solving skills focused on marketing and policy. The “thumbs” problem demands high creativity and imagination to explore unreal absurd scenarios. The “teachers” problem requires analytical thinking, and resource management to address challenges in education.

Another important dimension is the sensitivity of the problem. The level of social sensitivity plays a significant role in determining individual motivation and productivity during idea-generation processes (Pinsonneault et al., 1999). Specifically, topics that are perceived as more controversial or sensitive tend to result in higher levels of motivation among participants. Thus, in academic literature socially sensitive topics are often used for brainstorming experiments, *e.g.*, *how can you help to reduce mental illness among students?* (Geerts et al., 2021).

Combining the mentioned criteria, the current study will borrow the brainstorming question from the authors Memmert and Tavanapour (2023): how can universities support society to become more sustainable? This question aligns with global priorities such as the Sustainable Development Goals by United Nations, it bridges different domains and is relevant to students as it is related to universities.

4.6. Pilot test of experiment

A pilot test was conducted before the main experiment, in order to improve the design of the experiment and survey. The purpose if the pilot test was to gather participants feedback on the clarity of the instructions for the brainstorming session and the survey questions in an informal format.

In the pilot test, a single group of six thesis course participants engaged in a brainstorming session that lasted six minutes, instead of ten minutes for the final session. The pilot test's brainstorming question *how can universities promote mental health?* was very similar to the final experiment's question but not the same.

Participants provided valuable feedback on the survey's clarity, leading to several adjustments. For instance, the question on the social effect of recognition was refined to include description of behavioural cues, such as nodding, smiling, and providing positive feedback, to ensure it was clear what stood behind of "recognition of other participants".

Another adjustment was related to rules of the session. The pilot session took place in a room where participants stood around a table with post-its, recording ideas and placing them on the wall. A laptop was provided with access to *ChatGPT*; however, participants did not actively engage with it as expected, instead focusing on generating ideas independently. This observation led to a change in the experiment design, where in the actual experiment, a requirement was added to use *ChatGPT* after the first 5 minutes of the session.

Overall, rules and design of the pilot session proved to be clear for the participants and after minor changes the flow of the experiment was finalized.

4.7. Survey

The survey for this study is designed to capture an overview of participants' backgrounds, experiences, and perceptions before and after the brainstorming sessions. The pre-test section collects demographic information and assesses participants' familiarity with brainstorming sessions, their previous experience with artificial intelligence-assisted brainstorming, comfort with artificial intelligence in brainstorming contexts, and expectations regarding artificial intelligence's contributions to creativity. Additionally, it includes the Social Interaction Anxiousness Scale (SIAS) (Camacho & Paulus, 1995; Lee Nichols & Webster, 2015) to measure social anxiety aspects and questions about self-perceived creativity.

For the post-survey, participants are asked to evaluate their satisfaction with the ideas generated during the session and reassess their ability to generate creative ideas post-participation. The survey is tailored to each group (classic brainstorming, classic brainstorming with *ChatGPT*, nominal group with *ChatGPT*) to explore specific dynamics such as motivation, apprehension, participation levels, social pressure, cognitive stimulation, and challenges encountered during the brainstorming process. Through this survey, the study aims to assess changes in participants' creativity self-perception, the impact of artificial intelligence on group dynamics and idea generation, and the overall effectiveness and satisfaction with the brainstorming process.

5. Results

5.1. Data collection

The survey, conducted in compliance with all ethical requirements, included informed consent. Responses remain anonymous and participants were informed that the responses would only be used for academic purposes. Experiments and survey completion took place between 20 March, 2024 and 9 April, 2024.

The study aimed to compare four different brainstorming techniques: 1) traditional group refers to conventional in-person group brainstorming without artificial intelligence; 2) nominal group refers to individual idea generation without group interaction or artificial intelligence; 3) artificial intelligence-augmented group involves in-person group brainstorming supported by *ChatGPT*; and 4) artificial intelligence-augmented nominal refers to individual brainstorming supported by *ChatGPT* (Table 2).

Table 2. Brainstorming techniques variables (source: created by authors)

Variable name	Brainstorming technique definition
Traditional group	Traditional group brainstorming (in-person group without artificial intelligence)
Nominal group	Nominal brainstorming (individual brainstorming without artificial intelligence)
Artificial intelligence-augmented group	Group brainstorming using *ChatGPT*
Artificial intelligence-augmented nominal	Individual brainstorming using *ChatGPT*

Ten participants were recruited for each group type, leading to a total of 40 participants. All participants were students in bachelor's degree or master's degree programmes at a leading data science school in Europe, and the prerequisite was that they were either currently enrolled in or had completed Data Science courses. Participants were recruited through an online feedback form and in person.

The sample consisted of 70% female and 30% male participants. Most participants were under 34 years old. Specifically, 45% were aged between 18–24, 32.5% between 25–34, 15% between 35–44, and 7.5% between 45–54 (Table 3).

Table 3. Sample demographics (source: created by authors)

Gender	Percentage of total
Male	30%
Female	70%
Age range	Percentage of total
18–24	45.%
25–34	32.5%
35–44	15.%
45–54	7.5%

5.2. Data analysis

5.2.1. Data preprocessing

For data analysis, *Python* (programming language) 3.0 was used within the *Jupyter* environment, which is ideal for this study due to its robust data processing capabilities and its extensive visualization libraries that help in effectively communicating findings.

The first step in data preprocessing was handling missing data. The missing values were replaced with not a number, acknowledging that the missing data was not random but due to the structure of the study. For instance, artificial intelligence-related variables were absent for participants who did not have exposure to artificial intelligence. After ensuring that all variables had appropriate data types, the focus shifted to measuring reliability and creating composite scores for subsequent analysis.

Composite scores are essential for consolidated measures of survey items, reducing data dimensionality and multicollinearity. They group related items into a single metric, reducing redundancy and improving analysis robustness by reducing multi-collinearity (Harlow, 2002).

All Cronbach's alpha scores were sufficiently high, supporting the creation of composite variables (Table 4).

Table 4. Composite scores (source: created by authors)

Composite score	Variables	Cronbach's alpha
creativity_composite	creativity_1, creativity_2, creativity_3	0.82
ias*_composite	IAS* scale_1, IAS scale_2, IAS scale_3	0.70
ai**_perception_composite	AI** perception_1, AI perception_2, AI perception_3	0.90
creativity_results_composite	creativity_results_1, creativity_results_2, creativity_results_3	0.87
result_satisfaction_composite	result_satisfaction_1, result_satisfaction_2, result_satisfaction_3	0.86
experience_satisfaction_composite	experience_satisfaction_1, experience_satisfaction_2, experience_satisfaction_3	0.90
ai_satisfaction_composite	ai_satisfaction_1, ai_satisfaction_2, ai_satisfaction_3, ai_satisfaction_4	0.76
blank_composite	blank1, blank2	0.88

Note: *ias or IAS – Social Interaction Anxiousness Scale; ** ai or AI – artificial intelligence.

After composite variables creation dataset includes 23 variables, descriptive statistics are present in the Table 5.

Table 5. Descriptive statistics (source: created by authors)

	count	mean	std	min	25%	50%	75%	max
duration_sec	40.0	622.675000	220.229529	327.000000	538.500000	600.000000	600.000000	1533.0
BS_experience	40.0	5.550000	1.413307	1.000000	5.000000	6.000000	6.250000	7.0
motivation	30.0	5.700000	0.987857	3.000000	5.000000	6.000000	6.000000	7.0
evaluation_Appreh	40.0	5.600000	1.194002	1.000000	5.000000	6.000000	6.000000	7.0
engagement	40.0	5.400000	1.373747	2.000000	5.000000	6.000000	6.000000	7.0
free_riding_group	20.0	3.250000	1.551739	1.000000	2.000000	3.000000	4.000000	7.0
free_riding_ai	20.0	4.350000	1.460894	2.000000	3.000000	5.000000	5.250000	6.0
recognition	20.0	5.050000	1.316894	2.000000	5.000000	5.000000	6.000000	7.0
conformity	40.0	5.125000	1.343312	2.000000	5.000000	5.000000	6.000000	7.0
group_conformity	20.0	2.750000	1.208522	1.000000	2.000000	2.000000	3.000000	6.0
stimulation_group	20.0	6.150000	0.587143	5.000000	6.000000	6.000000	6.250000	7.0
stimulation_ai	20.0	5.550000	1.190975	2.000000	5.000000	6.000000	6.000000	7.0
block	40.0	5.100000	1.629850	1.000000	4.000000	6.000000	6.000000	7.0
redundancy_group	20.0	4.750000	1.585294	2.000000	3.750000	5.000000	6.000000	7.0
redundancy_ai	20.0	5.100000	1.165287	3.000000	4.750000	5.000000	6.000000	7.0
ai_perception_composite	20.0	5.866667	0.939080	3.000000	5.333333	6.000000	6.416667	7.0
creativity_results_composite	40.0	4.700000	1.471089	1.666667	3.666667	5.000000	5.666667	7.0
result_satisfaction_composite	40.0	5.333333	1.147275	2.666667	4.666667	5.666667	6.000000	7.0
experience_satisfaction_composite	40.0	5.783333	0.974168	3.333333	5.000000	6.000000	6.333333	7.0
ai_satisfaction_composite	20.0	5.600000	0.911910	3.250000	5.312500	5.750000	6.000000	7.0
blank_composite	40.0	3.875000	1.509585	1.500000	2.500000	3.750000	5.125000	6.5
ias_composite	40.0	4.341667	1.332238	1.666667	3.583333	4.333333	5.333333	7.0
creativity_composite	40.0	4.775000	1.135763	2.666667	3.916667	4.833333	5.666667	7.0

Note: sec – seconds; BS – brainstorming; Appreh – apprehension; ai – artificial intelligence; ias – Social Interaction Anxiousness Scale.

5.2.2. Statistical tests

A correlation analysis was performed and revealed no strong correlations between the measured variables, indicating that the constructs measured were distinct and independently contribute to the results.

The following Table 6 outlines the hypotheses formulated to explore the experience and cognitive and social effects of four brainstorming techniques, focusing on artificial intelligence influence.

For hypotheses that involved comparisons across all four groups (artificial intelligence-augmented group, artificial intelligence-augmented nominal, traditional group, and nominal group), analysis of variance (ANOVA) was employed to identify statistically significant differences in group means across these variables. ANOVA is a robust method that can handle multiple group comparisons simultaneously, making it fit for comparing four different brainstorming techniques (Sullivan & Feinn, 2012). For factors applicable to only certain groups, such as like social arousal or artificial intelligence-free-riding, the Student's *t*-test was used to determine differences between these two conditions. The Student's *t*-test is suitable for comparing means between two independent groups, providing a statistical measure of whether the differences observed are significant (Ergin & Koskan, 2023).

Table 6. Hypotheses (source: created by authors)

Experience satisfaction and evaluation	
H1	Participants in artificial intelligence-augmented brainstorming sessions will report significantly higher experience satisfaction compared to those in traditional brainstorming sessions. H0: There is no significant difference in experience satisfaction between participants in artificial intelligence-augmented brainstorming sessions and those in traditional brainstorming sessions.
H2	Participants in artificial intelligence-augmented brainstorming sessions will report a significant increase in self-perceived creativity compared to those in traditional brainstorming sessions. H0: There is no significant difference in self-perceived creativity between participants in artificial intelligence-augmented brainstorming sessions and those in traditional brainstorming sessions.
H3	Participants in artificial intelligence-augmented brainstorming sessions will report significantly higher result satisfaction compared to those in traditional brainstorming sessions. H0: There is no significant difference in result satisfaction between participants in artificial intelligence-augmented brainstorming sessions and those in traditional brainstorming sessions.
Social anxiety dimension	
H4	Participants with social high-anxiety will report significantly higher experience satisfaction in artificial intelligence-augmented brainstorming sessions compared to traditional brainstorming sessions. H0: Participants with social high-anxiety will not report a significant difference in experience satisfaction between artificial intelligence-augmented and traditional brainstorming sessions.
Cognitive effects	
H5	Participants in artificial intelligence-augmented brainstorming sessions will experience significantly higher cognitive stimulation due to varied inputs from *ChatGPT* compared to traditional brainstorming sessions. H0: There is no significant difference in cognitive stimulation between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.
H6	Participants in artificial intelligence-augmented brainstorming sessions will report significantly lower production blocking, as *ChatGPT* generates ideas on request, compared to traditional brainstorming sessions. H0: There is no significant difference in production blocking between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.
H7	Participants in artificial intelligence-augmented brainstorming sessions will report significantly higher effort redundancy, as artificial intelligence-generated ideas may overlap with human-generated ideas, compared to traditional brainstorming sessions. H0: There is no significant difference in effort redundancy between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.
H8	Participants in artificial intelligence-augmented brainstorming sessions will report significantly lower blank canvas paralysis, as artificial intelligence-generated suggestions help overcome initial hesitation, compared to traditional brainstorming sessions. H0: There is no significant difference in blank canvas paralysis between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.
H9	Participants in individual artificial intelligence-augmented brainstorming sessions will report significantly higher cognitive conformity, aligning their thinking with artificial intelligence-generated ideas more than participants in traditional brainstorming sessions. H0: There is no significant difference in cognitive conformity between individual artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.

***End** of Table 6*

Social/motivational effects	
H10	Participants in group brainstorming sessions will report significantly higher arousal/motivation compared to those in artificial intelligence-only brainstorming sessions. H0: There is no significant difference in arousal/motivation between group brainstorming sessions and artificial intelligence-only brainstorming sessions.
H11	Participants in artificial intelligence-augmented brainstorming sessions will report significantly lower evaluation apprehension, as artificial intelligence's impersonality reduces fear of judgment, compared to traditional brainstorming sessions. H0: There is no significant difference in evaluation apprehension between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.
H12	Participants in artificial intelligence-augmented brainstorming sessions will report significantly higher free-riding, as they expect artificial intelligence to offset their reduced contribution, compared to traditional brainstorming sessions. H0: There is no significant difference in free-riding between artificial intelligence-augmented brainstorming sessions and traditional brainstorming sessions.

5.2.3. Cognitive and social effects

Table 7 shows Student's *t*-test results. Although differences in means across the groups were observed, they did not reach statistical significance, *p*-values, as shown in the Table 7 are above 0.05 threshold. Therefore, hypotheses H5 through H11 are rejected.

Table 7. Student's t-test results for cognitive and social effects (source: created by authors)

Comparison	Variable	*t*-statistic	*p*-value
Traditional group versus artificial intelligence-augmented group	Motivation	0.820	0.424
	Recognition	–1.202	0.248
	Evaluation apprehension	–0.293	0.773
	Free-riding (group)	1.322	0.211
	Group conformity	–0.545	0.593
	Stimulation (group)	–0.372	0.714
	Block	0.361	0.722
	Redundancy (group)	–0.414	0.684
	Blank composite	–1.522	0.145
	Conformity	–0.629	0.537
Nominal group versus artificial intelligence-augmented nominal	Evaluation apprehension	0.530	0.603
	Block	–1.070	0.303
	Blank composite	1.395	0.186
	Conformity	–0.499	0.624

Although differences in means across the groups were observed, they did not reach statistical significance; therefore, hypotheses H5 through H11 are rejected. However, these observations, while not statistically significant, they may still offer insights into group dynamics and artificial intelligence interaction:

- The classic brainstorming group demonstrated greater arousal/motivation than the artificial intelligence-augmented group;

- Participants in traditional group brainstorming sessions exhibited a higher level of engagement, (active participation), compared to those in individual artificial intelligence-assisted sessions;
- Cognitive stimulation caused by artificial intelligence was more prominent in group settings;
- The interaction with artificial intelligence revealed a tendency for participants to over-rely on artificial intelligence support more in individual settings than in group contexts.

These tendencies can be explored in further research with a bigger sample.

5.2.4. Free-riding

The observed tendencies relate closely to motivation and effort, which is particularly connected to free-riding. Analyzing the duration of individual brainstorming sessions, it can be observed *ChatGPT* assisted sessions were shorter in time than individual sessions. Individuals that brainstormed on their own spent more time on idea generation than those who used *ChatGPT*, which may suggest that *ChatGPT* users were ready to adopt its suggestions and less likely to invest time in independent idea generation, potentially reducing personal effort and increasing the propensity for free-riding in artificial intelligence-assisted settings (Figure 1).

Statistically significant finding within the artificial intelligence-augmented group highlights distinct types of free-riding behaviour: participants demonstrated a significantly higher level of free-riding behaviour attributed to artificial intelligence compared to that attributed to their fellow group members, demonstrated on the Table 8.

This result indicates that participants in artificial intelligence-augmented group brainstorming sessions are more likely to rely excessively on artificial intelligence for idea generation, rather than over-rely on their peers or contribute equally. Observed pattern coincides with research findings of Siemon and Wank (2021).

Although qualitative method was out of scope of this study, it is worth mentioning that some participants comment regarding artificial intelligence free-riding dimension (Table 9).

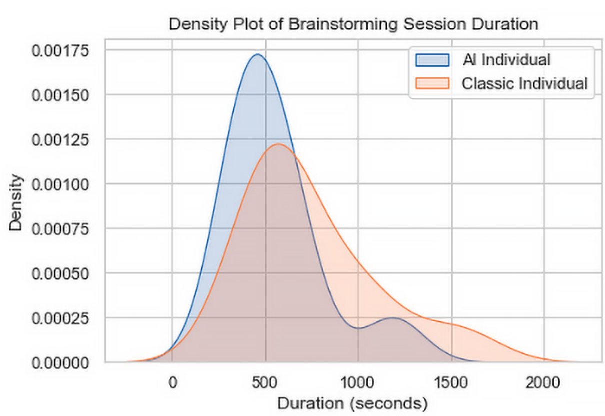


Figure 1. Brainstorming session duration in individual brainstorming (source: created by authors)

Table 8. Group free-riding and artificial intelligence free-riding comparison (source: created by authors)

Comparison	*t*-statistic	*p*-value	Difference	Effect size
Free-riding (group *versus* artificial intelligence)	–2.37	0.042	19	–0.82

Table 9. Participants' comments (source: created by authors)

Brainstorming technique	Comment
Artificial intelligence-augmented group	"To be honest, as I knew we were going to use *ChatGPT*, that made me reluctant to put effort and start thinking on my own. I had this in mind that later on there would *ChatGPT* inputs to build on".
Artificial intelligence-augmented nominal	"As I could choose to use *ChatGPT* or not for my individual idea generation I definitely choose to use it! It will be faster and less work".

H12 is confirmed, which highlights the potential impact of artificial intelligence on collaborative dynamics, suggesting that its assistance may redistribute effort and engagement among participants. Considerations may rise concerning fostering genuine collaboration and maintaining group cohesiveness in artificial intelligence-enhanced brainstorming sessions.

5.2.5. Pre- and post-experiment self-perceived creativity

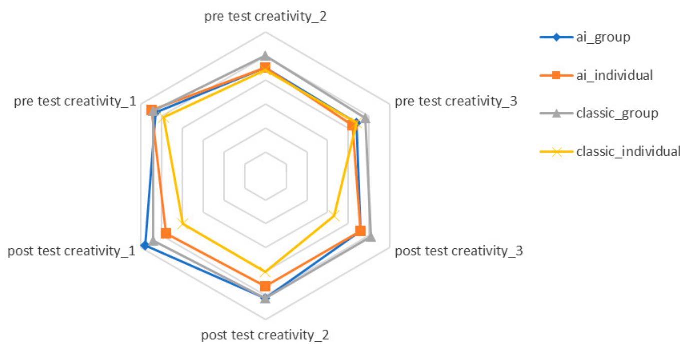
Participants were asked the same set of questions where they assessed their own creativity levels prior and after the brainstorming task in order to measure how their self-evaluation changed when completing idea generation experience. This test has revealed statistically significant differences among brainstorming techniques. Participants in the nominal group brainstorming sessions reported the lowest self-evaluation of creativity after the sessions, showing a significant decrease in their perceived ability to produce a "higher than average" number of ideas (corresponds to item 3 in creativity construct). In contrast, the artificial intelligence-augmented group participants experienced a statistically significant increase in their "ability to generate many ideas" (corresponds to item 1 in creativity construct) (Table 10, Figure 2).

Table 10. Pre- and post-experiment creativity self-assessment comparison across groups (source: created by authors)

Group type	Variable	*t*-statistic	*p-value*	Difference	Effect size
Artificial intelligence-augmented nominal	Creativity 2	–0.2182	0.8321	9	–0.07
Artificial intelligence-augmented nominal	Creativity 3	–1.5000	0.1679	9	–0.47
Nominal group	Creativity 1	1.6462	0.1341	9	0.52
Nominal group	Creativity 2	0.5828	0.5744	9	0.18
Nominal group	Creativity 3	3.1608	0.0115	9	1.00

End of Table 10

Group type	Variable	*t*-statistic	*p-value*	Difference	Effect size
Artificial intelligence-augmented group	Creativity 1	–3.0000	0.0150	9	–0.95
Artificial intelligence-augmented group	Creativity 2	–1.0000	0.3434	9	–0.32
Artificial intelligence-augmented group	Creativity 3	–0.3487	0.7353	9	–0.11
Traditional group	Creativity 1	0.0000	1.0000	9	0.00
Traditional group	Creativity 2	–0.1765	0.8638	9	–0.06
Traditional group	Creativity 3	–0.8955	0.3938	9	–0.28



Note: ai – artificial intelligence.

Figure 2. Pre- and post-test creativity self-assessment (source: created by authors)

Therefore, H2 is confirmed. This suggests that artificial intelligence assistance in group setting may lead to creative outcomes that go above participants expectations and that may be attributed by participants to their own creative capabilities, while in individual settings after facing the challenge participants assess their creative performance lower than expected.

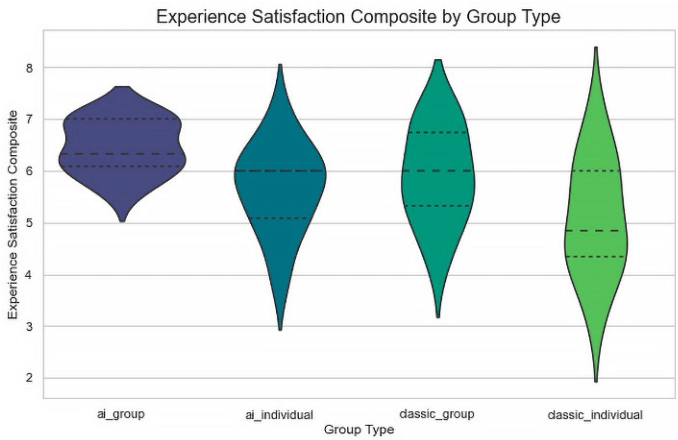
5.2.6. Result and experience satisfaction

Concerning result satisfaction, as a tendency, it is possible to point out that participants brainstorming individually seem least satisfied with the results of idea generation, however, however, so H3 is rejected. On the other hand, H1 is confirmed as significant differences between four groups are observed (Table 11, Figure 3):

- Both artificial intelligence-augmented settings (group and individual) tend to show higher median satisfaction and less spread in scores, indicating a generally positive reception to artificial intelligence integration in brainstorming. Especially when compared to the baseline settings of classic technique satisfaction increase with artificial intelligence assistance become prominent;
- Group settings exhibit wider distributions, suggesting more variability in participant satisfaction compared to individual settings. This could reflect the dynamic nature of group interactions and individual differences in response to group dynamics.

Table 11. Analysis of variance test for result satisfaction, experience satisfaction (source: created by authors)

Dependent variable	Source	Sum of squares	Difference	*F*-distribution	*p*-value
Result satisfaction composite	Group type	4.49	3	1.15	0.3422
	Residual	46.84	36	–	–
Experience satisfaction composite	Group type	9.61	3	4.21	0.0119
	Residual	27.40	36	–	–



Note: ai – artificial intelligence.

Figure 3. Experience satisfaction by brainstorming technique (source: created by authors)

5.2.7. Social anxiety dimension

To explore social anxiety, dimension the sample was split based on median score of the SIAS composite as a threshold. Participants scoring at or below the median were categorized into the social low-anxiety group, while those scoring above the median were placed in the social high-anxiety group (Table 12, Figure 4). And then Student's *t*-test were performed to compare experience and results satisfaction.

Table 12. Experience satisfaction of high and social low-anxiety participants (source: created by authors)

Anxiety level	Source	Sum of squares	Difference	*F*-distribution	*p*-value
High	Group type	3.5274	3	1.6232	0.2212
Residual	12.3139	17	–	–	
Low	Group type	7.6250	3	3.1042	0.0583
Residual	12.2815	15	–	–	

Hypothesis that high-anxiety participants would report higher satisfaction in artificial intelligence-augmented nominal setting (H4) was rejected. Nevertheless, different perspective on this hypothesis was marginally statistically significant. In artificial intelligence-assisted in-

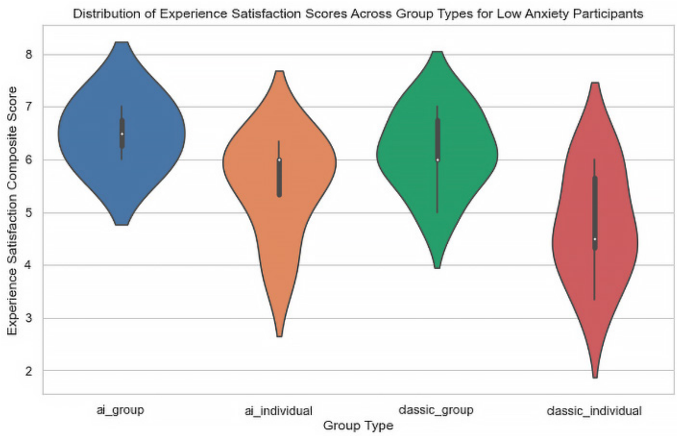


Figure 4. Experience satisfaction of low-anxiety participants by brainstorming technique (source: created by authors)

dividual brainstorming low-anxiety participants showed lower scores, suggesting that group setting is more positively received or that the presence of artificial intelligence in individual sessions does not compensate for the lack of human interaction which low-anxiety individuals might prefer (Table 13).

Table 13. Hypotheses test results (source: created by authors)

Experience satisfaction and evaluation		
H1	Participants in artificial intelligence-augmented brainstorming sessions report higher experience satisfaction.	confirmed
H2	Participants in artificial intelligence-augmented brainstorming sessions report an increase in self-perceived creativity.	confirmed
H3	Participants in artificial intelligence-augmented brainstorming sessions report higher result satisfaction.	rejected
Social anxiety dimension		
H4	High-anxiety participants report higher experience satisfaction in artificial intelligence-augmented brainstorming sessions	rejected
Cognitive effects		
H5	Participants in artificial intelligence-augmented brainstorming sessions report increased cognitive stimulation due to varied inputs from *ChatGPT*.	rejected
H6	Participants in artificial intelligence-augmented brainstorming sessions report reduced production blocking as *ChatGPT* generates ideas on request.	rejected
H7	Participants in artificial intelligence-augmented brainstorming sessions report increased effort redundancy due to generic artificial intelligence ideas mirroring common human thoughts.	rejected
H8	Participants in artificial intelligence-augmented brainstorming sessions report reduced blank canvas paralysis with *ChatGPT* prompting early ideas.	rejected
H9	Participants in individual artificial intelligence-augmented brainstorming sessions report increased cognitive conformity by aligning their thinking with artificial intelligence-generated ideas.	rejected

End *of Table 13*

Social/motivational effects		
H10	Participants in group brainstorming sessions report higher arousal/motivation than in artificial intelligence-only interactions.	rejected
H11	Participants in artificial intelligence-augmented brainstorming sessions report reduced evaluation apprehension due to artificial intelligence's impersonality, promoting open idea sharing.	rejected
H12	Participants in artificial intelligence-augmented brainstorming sessions report increased free-riding if they expect artificial intelligence to offset their reduced contribution.	confirmed

6. Discussion and conclusions

Merging creativity and data science and explorate artificial intelligence-augmented brainstorming implies a solid background in computer science since it enables people to develop scalable solutions, find new approaches to problem-solving, and improve and optimize algorithms. Without this foundation, innovative concepts could find it difficult to be successfully executed or tailored for practical uses.

In this study, by comparing traditional and nominal brainstorming techniques with artificial intelligence-augmented ones, the goal was to understand how artificial intelligence influences the dynamics of idea generation, participant engagement, and satisfaction among data science students. The research contributes to understanding of artificial intelligence's role in creative processes, which is crucial for designing effective artificial intelligence-augmented brainstorming sessions.

6.1. Cognitive and social effects

While differences were observed across groups, they did not reach statistical significance. Participants in the traditional group brainstorming sessions demonstrated greater motivation compared to artificial intelligence-assisted sessions and cognitive stimulation was more pronounced in group settings, suggesting that the presence of artificial intelligence can enrich the idea generation process when used collectively. These observations may be further explored in future research with larger sample sizes.

6.2. Free-riding

Free-riding effect emerged in artificial intelligence-assisted brainstorming sessions. Participants in individual brainstorming session using *ChatGPT* tended to spend less time for idea generation, possibly reducing their personal effort and accepting artificial intelligence-generated ideas. Statistically significant findings show that participants relied more on *ChatGPT* than on their peers for idea generation, which has been previously discussed in literature. This indicates that while artificial intelligence can facilitate brainstorming, it may also jeopardize effort and engagement of participants. Future research should explore strategies to mitigate free-riding and promote more balanced contributions in artificial intelligence-augmented collaborative settings. As highlighted in study of Chaoran Wang (2025) teaching of critical artificial intelligence literacy is becoming urgent.

6.3. Pre- and post-experiment self-perceived creativity

Significant differences in self-perceived creativity were observed among the different brainstorming techniques. Participants who generated ideas individually reported the lowest self-evaluation of creativity, while those in *ChatGPT*-assisted group sessions experienced a significant increase in their perceived ability to generate ideas. This suggests that artificial intelligence assistance in group settings can boost participants' confidence in their creative abilities.

6.4. Social anxiety dimension

The exploration of the social anxiety dimension revealed mixed results. Contrary to initial hypothesis, participants with social high-anxiety did not report higher satisfaction in artificial intelligence-augmented nominal settings. Instead, low-anxiety participants showed lower satisfaction scores in artificial intelligence-assisted individual brainstorming. These findings suggest that while artificial intelligence can enhance certain aspects of brainstorming, it may not replace human interaction, which is preferred by individuals with social low-anxiety.

To sum up, in the context of artificial intelligence-augmented brainstorming among data science students, this study summarizes important findings and potential future directions. Artificial intelligence-augmented brainstorming technique showed boost of self-perceived creativity and overall satisfaction. In contrast, participants in artificial intelligence-assisted sessions relied more significantly on artificial intelligence for idea development, which is raising the issue of free-riding. These findings imply that, even though artificial intelligence can be a useful tool for encouraging creativity, careful design of brainstorming sessions is required to balance the contributions of humans and artificial intelligence.

7. Limitations and future research

7.1. Sample size

The first and quite significant limitation of this study is the sample size. As the experiment took place in person and there were specific requirements on the participant profile (being enrolled in data science courses) large-sized groups were not a feasible solution. This way, ten participants were recruited for each group type, totalling forty participants which makes a relatively small sample size. Increasing the sample size could enhance the likelihood of obtaining statistically significant results. When because no statistical significance was observed, for instance, in differences among group means in cognitive and social effects, it is not clear whether these effects are triggered equally in artificial intelligence and traditional brainstorming or whether the results are related to insufficient observations. Certain tendencies were observed, while not statistically significant in the current study, they can be further explored to understand the impact of artificial intelligence on motivation, engagement, and cognitive stimulation. A larger sample size would allow for a more robust interpretation of these findings.

7.2. Sample demographics

Since the sample was recruited from the students' community, most participants were under 34 years old. This might induce a certain bias, so creating more balanced sample in terms of demographics is a suggestion for future research. Another suggestion is adding the analysis of age-related trends in the experience and satisfaction of participants.

7.3. Methodological constraints

Another limitation is related as well with the sample size, as with forty data entries, only basic statistical tests such as ANOVA and Student's *t*-tests were feasible. Future research could consider more advanced analyses such as regression to identify which factors shape participants' experiences and what is the importance of that influence. A regression model to predict experience and result satisfaction could be built including brainstorming technique type and brainstorming dynamics (social and cognitive effects) as possible predictors.

7.4. Qualitative dimension

Finally, the consideration for future research concerns adding qualitative dimension to the method. The statistical analysis relies on self-reported data obtained through surveys, where participants provide feedback on their brainstorming experience. However, self-reported data may introduce biases, as participants provide subjective answers. Consciously (trying to follow socially acceptable behaviour) or unconsciously (being not fully aware of their emotions and reactions) participants, for example, could report levels of comfort or engagement higher than their actual experiences. To address this limitation, future research could include observation. By observing participants' body language, communication and behaviour during brainstorming sessions, and registering those within observation protocol, study can gain additional perspective on experiences of participants. Another qualitative dimension suggestion is conducting in-depth interviews with participants after the brainstorming sessions. This could provide rich qualitative data to gain insights on nuances of perceptions, attitudes, and motivations.

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Appendix

1. Variables

group_type	The condition assigned to the participant (*e.g.*, control *versus* artificial intelligence-assisted brainstorming).
duration_sec	The total duration of the brainstorming session in seconds.
age	Participant's reported age.
gender	Participant's reported gender.

2. Pre-survey variables

BS_experience	Response to "I am familiar with brainstorming sessions" (1 = strongly disagree, 7 = strongly agree).
creativity_1	Response to "I can generate many ideas when brainstorming" (1–7 scale).
creativity_2	Response to "I find it easy to come up with original ideas" (1–7 scale).
creativity_3	Response to "The number of ideas I can produce in the brainstorming session is higher than average" (1–7 scale).

3. Social Interaction Anxiousness Scale variables

IAS_scale_1	Response to "I often feel nervous even in casual get-togethers" (1–7 scale).
IAS_scale_2	Response to "I wish I had more confidence in social situations" (1–7 scale).
IAS_scale_3	Response to "In general, I am a shy person" (1–7 scale).

4. Artificial intelligence perception variables

ai_perception_1	Response to "I am comfortable with the idea of artificial intelligence assisting in brainstorming sessions" (1–7 scale).
ai_perception_2	Response to "I believe that artificial intelligence can significantly contribute to creative idea generation" (1–7 scale).
ai_perception_3	Response to "I believe that artificial intelligence can improve the experience of the brainstorming session" (1–7 scale).

5. Post-survey variables

creativity_results_1	Response to "I was able to generate many ideas when brainstorming" (1–7 scale).
creativity_results_2	Response to "I found it easy to come up with original ideas" (1–7 scale).
creativity_results_3	Response to "The number of ideas I was able to produce in the brainstorming session is higher than average" (1–7 scale).

6. Social effects variables

motivation	Response to "The presence of other participants influenced my level of motivation and energy during the brainstorming session" (1–7 scale).
evaluation_Appreh	Response to "I felt at ease expressing my ideas without fear of judgment during the brainstorming session" (1–7 scale).

engagement	Response to "I actively participated and contributed to the idea generation process" (1–7 scale).
free_riding_group	Response to "I found myself less inclined to actively engage and more prone to relying on other participants' efforts" (1–7 scale).
free_riding_ai	Response to "I found myself less inclined to actively engage and more prone to relying on *ChatGPT* input" (1–7 scale).
recognition	Response to "It was important to me that other participants approve my ideas" (1–7 scale).
conformity	Response to "I tended to avoid expressing ideas that were different from the perceived consensus during the brainstorming session" (1–7 scale).
group_conformity	Similar to conformity, but specific to influence from other participants.

7. Cognitive effects variables

stimulation_group	Response to "Exposure to the ideas of other participants inspired me to generate novel ideas" (1–7 scale).
stimulation_ai	Response to "Exposure to *ChatGPT* ideas inspired me to generate novel ideas" (1–7 scale).
block	Response to "I experienced a sense of hesitation or uncertainty when starting the brainstorming process" (1–7 scale).
redundancy_group	Response to "I experienced overlapping efforts or duplication of ideas with other participants during the brainstorming session" (1–7 scale).
redundancy_ai	Response to "I experienced overlapping efforts or duplication of ideas with *ChatGPT* during the brainstorming session" (1–7 scale).

8. Satisfaction variables

result_satisfaction_1	Response to "I am satisfied with the outcomes of the brainstorming session" (1–7 scale).
result_satisfaction_2	Response to "The brainstorming session met my expectations in terms of idea quality" (1–7 scale).
result_satisfaction_3	Response to "I believe the brainstorming session effectively addressed the problem at hand" (1–7 scale).
experience_satisfaction_1	Response to "I enjoyed participating in the brainstorming session" (1–7 scale).
experience_satisfaction_2	Response to "The brainstorming session was engaging" (1–7 scale).
experience_satisfaction_3	Response to "I would participate in a similar brainstorming session again" (1–7 scale).
ai_satisfaction_1	Response to "I found artificial intelligence assistance helpful in the brainstorming session" (1–7 scale).
ai_satisfaction_2	Response to "Artificial intelligence improved the quality of ideas generated" (1–7 scale).
ai_satisfaction_3	Response to "Artificial intelligence made the brainstorming process more enjoyable" (1–7 scale).
ai_satisfaction_4	Response to "I would like to use artificial intelligence in future brainstorming sessions" (1–7 scale).