When Should Robots Speak?

The Effect of Proactive vs. Reactive Robot Interventions on Perceived Autonomy in Creative Group Ideation

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Abstract

This study investigates whether proactive robot interventions undermine autonomy compared to reactive interventions during collaborative ideation tasks. A Pepper robot was implemented as a conversational agent capable of generating spoken solution suggestions using a locally hosted large language model, speech recognition, and text-to-speech functionality. The study used a between-subjects design with two conditions: a proactive condition, in which the robot autonomously intervenes based on conversational cues such as silence or signs of struggle, and a reactive condition, in which it only responds when explicitly addressed. Participants completed a collaborative task focused on improving campus life, after which perceived autonomy was measured using an adapted autonomy subscale of the Basic Psychological Need Satisfaction and Frustration Scale. Behavioral data, including robot intervention frequency, timing, and number of ideas generated, were also collected. Results showed no statistically significant differences between conditions, suggesting that proactive interventions do not substantially reduce participants' sense of autonomy. Groups in the proactive condition generated an average of 7.70 ideas compared to 5.80 in the reactive condition, but this difference was not significant ($p = .067$). These findings suggest that unsolicited robot participation may not inherently undermine perceived autonomy in short brainstorming tasks, while highlighting the importance of intervention design.

1 Introduction

Creative group ideation is widely used in education, design, and innovation to generate ideas and explore possible solutions (Osborn, 1953). In these settings, participants collaborate to explore a problem space and develop potential solutions. Successful ideation requires not only idea generation, but also that participants feel ownership over both the process and the outcomes of their work (Ryan and Deci, 2000). Research in creativity and motivation has consistently shown that autonomy, self-direction, and intrinsic motivation play an important role in supporting creative engagement and performance (Deci and Ryan, 2000).

Recent developments in Human-Robot Interaction (HRI) have made social robots increasingly capable of supporting collaborative activities, including brainstorming and group discussions (Geerts et al., 2021). Conversational systems powered by speech recognition and large language models (LLMs) now allow robots to generate contextually relevant suggestions in real time, making them capable of actively shaping the ideation process (Addlesee et al., 2024). These systems move beyond passive support roles and toward active participation in idea generation.

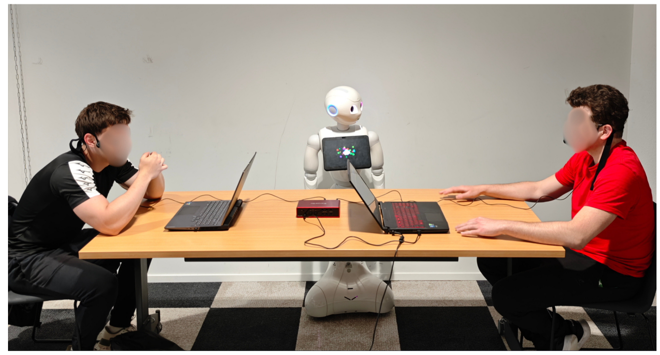

Figure 1: Experimental setup for the 15-minute brainstorming task. Two participants sit in a face-to-face configuration with the Pepper robot positioned centrally.

This shift introduces an important design tension. When a robot contributes ideas proactively, it may help groups overcome creative blocks and maintain momentum (Osborn, 1953; Nijstad and Stroebe, 2006). However, it may also influence the direction of the discussion and potentially reduce participants' sense of ownership over the ideas being generated (Amabile, 1996; Mueller et al., 2012). Proactive robots initiate actions without being explicitly prompted and can provide suggestions or solutions based on their assessment of the situation (Buyukgoz et al., 2022). While such behavior may improve efficiency and keep discussions moving, it may also shift control away from participants and reduce their perceived autonomy. In collaborative ideation, autonomy is particularly important because it supports intrinsic motivation and encourages individuals to explore and develop their own ideas (Deci and Ryan, 2000). Recent HRI research has increasingly highlighted the importance of balancing robot initiative with human control, as users often respond negatively when robots appear overly directive or reduce opportunities for human agency (Hinds et al., 2004).

To investigate this issue, this study compares two robot intervention strategies during creative group ideation sessions using the robot Pepper, a humanoid social robot developed by SoftBank Robotics (Pandey and Gelin, 2018). In the reactive condition, the robot only responds when participants explicitly address it. In the proactive condition, the robot can also intervene autonomously based on conversational cues such as prolonged silence or expressions of difficulty. The study follows a between-subjects design with 40 participants working in groups of 2 on the topic of improving campus life. After each session, participants complete a questionnaire based on the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) (Chen et al., 2015) adapted to the context of human-robot collaboration.

The main research question guiding this work is:

> *Does a proactively intervening robot that provides direct solutions reduce participants' perceived autonomy compared to a robot that only responds when directly addressed?*

In addition, this work examines the following sub-questions:

- SQ1: How does the robot's intervention strategy affect how frequently participants actively engage with the robot during creative group ideation?
- SQ2: How does the robot's intervention strategy influence when participants choose to interact with the robot during the ideation process?
- SQ3: What is the relationship between the number of robot interventions and participants' perceived autonomy?
- SQ4: How does the robot's intervention strategy affect the number of creative ideas generated by the group?

This study found no statistically significant differences in perceived autonomy between the proactive and reactive conditions. Participants in the proactive condition reported slightly lower autonomy satisfaction and slightly higher autonomy frustration, but these differences were small and not significant. Similarly, no significant differences were observed in participant engagement with Pepper or in the timing of interactions during the brainstorming process. Although groups in the proactive condition generated more ideas on average, this difference did not reach statistical significance. Overall, these results suggest that proactive robot interventions did not substantially affect perceived autonomy in short collaborative ideation tasks.

The contributions of this work are twofold:

1. An empirical comparison of the effects of proactive and reactive robot intervention strategies on participants' perceived autonomy during collaborative ideation.
2. Insights into how proactive and reactive robot interventions influence participant engagement and idea generation during collaborative ideation.

2 Related Work

2.1 Robots in group ideation and creative collaboration

Research on group creativity has shown that brainstorming groups do not always reach their creative potential (Paulus and Nijstad, 2003). While collaboration can expose participants to diverse perspectives, group ideation is often hindered by challenges such as production blocking, fixation on existing ideas, and difficulty sustaining idea generation over time (Nijstad and Stroebe, 2006). As a result, groups may struggle to maintain momentum, explore a broad solution space, or move beyond their initial ideas.

To address these challenges, researchers have investigated various forms of facilitation and creativity support. Prior work suggests that external prompts, questions, and suggestions can stimulate new directions of thinking and help groups overcome creative blocks (Paulus and Nijstad, 2003). At the same time, creativity research emphasizes that participants should retain a sense of ownership over the ideation process, as autonomy and self-directed exploration are important factors supporting creative engagement (Amabile, 1996).

Recent work in HRI has explored whether social robots can provide this type of support during collaborative ideation. Geerts et al. (2021) found that a robot facilitator increased idea fluency compared to human facilitation, partly because participants experienced less evaluation apprehension. Similarly, Buchem et al. (2024) reported that embodied conversational agents can encourage participation and create a more engaging collaborative experience. These studies suggest that robots can influence not only group interaction dynamics but also the creative process itself.

However, existing research has primarily focused on creativity outcomes such as idea quantity, participation, or engagement. Less attention has been given to how robot contributions are experienced by participants, particularly when robots actively shape the direction of discussion through unsolicited interventions. Consequently, it remains unclear whether robot support during ideation is experienced as helpful guidance or as interference with participants' sense of autonomy. Our work addresses this gap by examining how proactive and reactive robot intervention strategies affect perceived autonomy during collaborative ideation.

2.2 Turn-taking and intervention timing

A major challenge in conversational HRI is determining when a robot should speak (Skantze, 2021). Human conversations rely on subtle turn-taking mechanisms that allow speakers to coordinate smoothly with minimal interruption (Sacks et al., 1974). These mechanisms become more difficult in group settings, where several people compete for conversational turns.

Skantze (2021) provides a broad review of turn-taking in conversational systems and HRI, showing that spoken interaction depends on verbal, prosodic, and non-verbal cues such as pauses, gaze, and intonation. The review argues that turn-taking remains one of the main open challenges in conversational agents.

Several studies have explored turn-taking specifically in robots interacting with groups. Johansson and Skantze (2015) proposed models for identifying opportunities for robots to take turns in collaborative multi-party interaction. Their work used multimodal signals, including speech activity and dialogue context, to determine appropriate moments for robot intervention.

Similarly, Zarkowski (2019) examined turn-taking behavior in repeated human-robot group interactions. Their results showed that robots following human conversational norms improved communication quality and were perceived as more cooperative and natural by users.

More recent work has explored conversational robots powered by LLMs in open-ended group discussions. Abbo et al. (2026) developed a multi-party conversational robot system capable of managing speaker transitions and generating contextually relevant responses during open-ended discussion. Their findings show that coordinating turn-taking remains challenging even with modern language models, particularly in dynamic group interactions.

While prior work studies how robots can identify good moments to speak, most research evaluates conversational fluency, naturalness, engagement, or system performance. Less is known about the psychological effects of intervention timing on users.

Our work differs by examining whether the robot's intervention strategy affects participants' perceived autonomy during collaborative ideation. Instead of optimizing turn-taking performance, we compare proactive and reactive intervention styles and study how these influence users' sense of control.

2.3 Autonomy and control

Autonomy is a central concept in psychology and human-computer interaction. Deci et al. (1994) define autonomy as the feeling that one's actions are self-chosen and self-endorsed. This concept becomes important in interactive systems where control can shift between the user and the system.

Horvitz (1999) examines mixed-initiative systems and shows that system-initiated assistance can improve task efficiency, but also shifts control depending on when and how interventions occur. Parasuraman et al. (2000) describe a similar pattern in automation systems, showing that higher levels of automation can transfer decision authority from humans to systems, reducing user involvement in task execution. Together, these works establish a general trade-off between system initiative and user control.

In HRI, Hinds et al. (2004) examine authority dynamics in collaborative human-robot tasks and show that more directive robot behavior increases compliance while reducing users' perceived influence over the interaction process. Dautenhahn (2007) discusses social robots in collaborative settings and emphasizes that maintaining human control is critical when robots take on facilitation roles. Across these works, system initiative affects both task performance and perceived user control.

A similar pattern appears in creativity support systems. Amabile (1996) shows that external input during idea generation can influence individuals' sense of ownership over creative outcomes, especially when suggestions become frequent or directive. This suggests that system contributions during ideation do not only affect performance, but also how people perceive their role in the creative process.

Across these domains, system initiative is consistently linked to changes in perceived control, agency, or ownership. However, these effects are typically measured using different constructs depending on the field, such as trust, compliance, or task ownership, rather than a unified psychological definition of autonomy.

Our work builds on this line of research by focusing specifically on autonomy as defined in Self-Determination Theory (Deci et al., 1994). We examine how proactive versus reactive robot interventions during collaborative ideation affect perceived autonomy, using a group-based embodied interaction setting where system initiative is expressed through conversational timing.

3 Experimental Setup

3.1 Participants

A total of 40 participants took part in the study. Participants were aged between 18 and 30 years. All participants were English-speaking university students. Recruitment was conducted through online announcements in computer science-related student groups and through in-person recruitment on campus.

Participants were excluded if they had prior experience with the Pepper robot or prior involvement in this research project, in order to reduce familiarity bias. No additional exclusion criteria were applied.

Participants were randomly assigned to one of two experimental conditions: a proactive robot condition ($n = 20$) or a reactive robot condition ($n = 20$). Random assignment was performed while ensuring balanced group sizes across conditions.

Participants were organized into groups of two, resulting in 20 interaction groups in total. Each group participated in one brainstorming session together.

No monetary compensation was provided. Participants were informed that participation was voluntary.

3.2 Materials

The experiment was conducted using a Pepper social robot (SoftBank Robotics, Pepper 2.5 hardware platform running NAOqi 2.5 software). Pepper was used as a conversational agent capable of speech production and interaction during group ideation.

Speech recognition was handled using the Deepgram automatic speech recognition service, specifically the *base* model through the EU endpoint. Robot speech synthesis was performed using Pepper's ALTextToSpeech service. A locally hosted large language model (Phi-3.5-mini-instruct, 3.8B parameters) running through LM Studio was used to generate robot responses.

Microphone input was captured using separate external microphones for each participant to enable speaker diarization and improve speech attribution during transcription.

The experiment was conducted in a quiet indoor room. Participants were seated at a rectangular table in a face-to-face configuration, with Pepper positioned so that it remained visible to both participants. The experimenter remained in the room but did not participate in the interaction.

All interaction data were recorded as transcripts for later analysis and no video recordings were used.

3.3 System Architecture

The conversational system consisted of interconnected modules responsible for speech recognition, intervention management, response generation, and robot speech output.

Participant speech captured through the external microphones was transcribed using Deepgram automatic speech recognition. The transcribed text was processed by a Python system responsible for determining whether Pepper should respond according to the intervention strategy assigned to the experimental condition.

When a response was required, conversational context was sent to a locally hosted Phi-3.5-mini-instruct model through LM Studio. The model generated spoken suggestions guided by a fixed system prompt designed to position Pepper as a solution-oriented brainstorming partner. Generated responses were spoken through Pepper's onboard speakers using the ALTextToSpeech service.

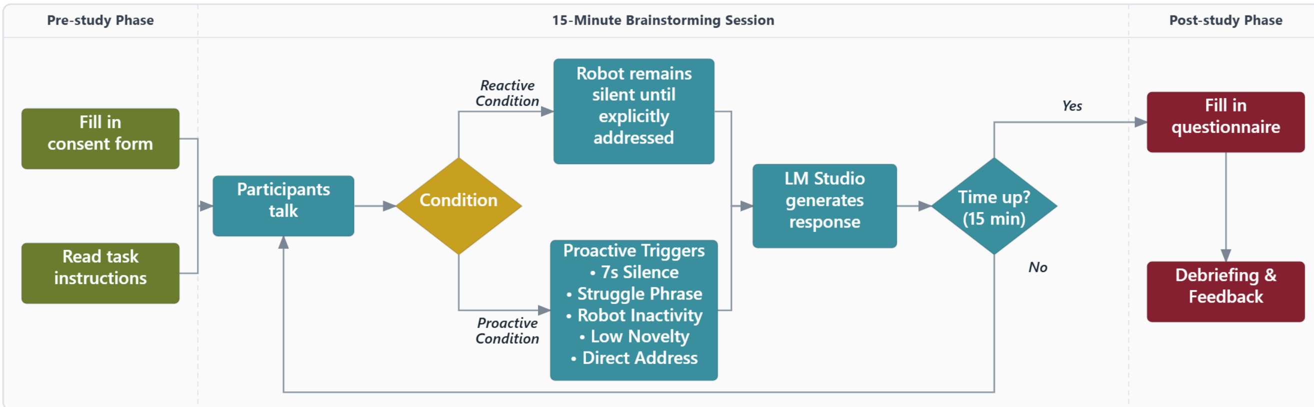

Figure 2: Overview of the experimental procedure.

The system operated through a dual-module implementation using Python 3.14 for system coordination and Python 2.7 for compatibility with the Pepper SDK.

3.4 Procedure

Upon arrival, participants were briefed about the study and asked to complete a consent form. Participants were informed that they would take part in a collaborative brainstorming activity involving a social robot (see Figure 1).

Participants were then seated and given written instructions describing the brainstorming task. The task focused on generating ideas for improving campus life, including topics such as student wellbeing, social interaction, services, events, and safety. This topic was selected because it is familiar to the student participants while remaining sufficiently open-ended to allow for diverse creative solutions. Participants were informed that there were no correct or incorrect answers and that the goal was to generate as many meaningful and creative ideas as possible.

Participants were also instructed on how to interact with Pepper. In both conditions, participants were informed that Pepper could contribute to the brainstorming session by providing suggestions and that they could address the robot directly using the words "Pepper" or "Robot" to invite participation.

The instructions differed slightly between conditions. In the proactive condition, participants were also informed that Pepper might contribute autonomously during the discussion. In the reactive condition, no autonomous robot behavior was described.

Each brainstorming session lasted 15 minutes. Participants freely discussed ideas while Pepper participated according to the intervention strategy assigned to the experimental condition.

After the brainstorming session, participants completed a post-task questionnaire individually on a digital device.

The session concluded with a short debriefing in which participants were informed about the purpose of the study and the difference between the experimental conditions (see Figure 2).

A pilot study with two participants (not included in the final dataset) was conducted beforehand to test system stability, speech recognition performance, and robot responsiveness.

3.5 Intervention Strategy

In the reactive condition, Pepper only responded when explicitly addressed by participants.

In the proactive condition, Pepper could respond both when directly addressed and when triggered by predefined behavioral signals.

Proactive interventions were triggered by five conditions: (1) detection of 7 seconds of silence, (2) detection of direct address (e.g., "Pepper" or "Robot"), (3) detection of predefined struggle phrases (e.g., "I don't know", "we're stuck", "this is hard", "no ideas", "we need help"), (4) prolonged robot inactivity, where Pepper contributed after three minutes of not speaking once a natural pause in conversation occurred and (5) reduced conversational novelty, operationalized as fewer than five new content words across the previous four participant turns compared to the preceding eight turns, without taking into account words of two characters or fewer and common words (e.g., "the", "and", "we", "you").

3.6 Measures

Perceived Autonomy

Perceived autonomy was measured using an adapted version of the BPNSFS. While the full BPNSFS framework consists of 24 items distributed across three subscales, autonomy, competence, and relatedness, this study explicitly utilized only the 8 items corresponding to the autonomy subscale, as the remaining 16 items fell outside the scope of this research. These 8 items were then modified to reflect the specific interaction context with the robot.

Participants rated eight statements on a 5-point Likert scale (1 = Not true at all, 5 = Completely true). Items were divided into autonomy satisfaction and autonomy frustration.

Autonomy satisfaction items included:

- During the interaction, I felt a sense of choice and freedom in the things I undertook.

- I felt that my decisions during the task reflected what I really wanted.
- I felt my choices during the interaction expressed who I really am.
- I felt I was doing what really interested me during the interaction.

Autonomy frustration items included:

- Most of the things I did during the task felt like things "I had to" do.
- I felt forced to do things I wouldn't have chosen to do.
- I felt pressured to do too many things during the task.
- The tasks I completed felt like a chain of obligations.

For analysis, autonomy satisfaction and autonomy frustration were treated as separate dependent variables.

Idea Generation

Group-level creative output was measured as the number of unique ideas generated during the 15-minute brainstorming session (SQ4). An idea was defined as a distinct suggestion for improving campus life that introduced a new concept, service, activity, or improvement. Repeated or reformulated ideas were not counted.

Interaction Measures

System logs were used to measure:

- Number of robot utterances
- Number of participant-initiated interactions with Pepper (SQ1)
- Timing of interactions during the session (SQ2)

3.7 Design and Analysis

The study used a between-subjects experimental design with one independent variable: robot intervention strategy, with two levels (proactive vs reactive).

Each group participated in one 15-minute brainstorming session with a single assigned condition. The primary unit of analysis for questionnaire data was the individual participant ($n = 40$), while the unit of analysis for idea generation was the group ($n = 20$).

The main dependent variables were: (1) autonomy satisfaction, (2) autonomy frustration, (3) number of ideas generated, and behavioral interaction metrics.

All analyses were conducted using Python-based statistical analysis tools. Data preprocessing and aggregation were performed prior to statistical testing.

For perceived autonomy (satisfaction and frustration), group differences between conditions were analyzed using Mann–Whitney U tests due to non-normal distributions observed in the data. Descriptive statistics (mean and standard deviation) were computed for each condition.

For participant-initiated interaction frequency (SQ1), group means were compared across conditions using an independent samples t-test.

For interaction timing (SQ2), descriptive statistics were computed for participant-initiated interactions across three predefined time windows: early (0–5 min), middle (5–10 min), and late (10-15 min). No inferential tests were applied to temporal distributions; results were reported descriptively.

For the relationship between robot activity and perceived autonomy (SQ3), Spearman rank correlation coefficients were computed between total robot utterances per session and autonomy satisfaction and frustration scores.

For creative output (SQ4), group-level differences in the number of ideas generated were analyzed using an independent samples t-test.

All statistical tests were two-tailed and evaluated at a significance level of $\alpha = 0.05$.

4 Results

4.1 Perceived Autonomy

Table 1: Descriptive statistics for the main dependent variables by condition. Mean values are reported, with standard deviations shown in parentheses.

Variable	Proactive	Reactive
Autonomy satisfaction	3.73 (0.78)	3.95 (0.74)
Autonomy frustration	2.03 (0.56)	1.83 (0.59)
Ideas generated	7.70 (2.58)	5.80 (1.62)
Times Pepper addressed	7.20 (4.02)	7.40 (2.76)
Robot utterances	10.60 (5.19)	7.40 (2.76)

Perceived autonomy was analyzed through two separate dimensions: autonomy satisfaction and autonomy frustration. Questionnaire responses were aggregated into mean scores per participant (Table 1).

Autonomy Satisfaction

Participants in the proactive condition reported slightly lower autonomy satisfaction ($M = 3.73$, $SD = 0.78$) than participants in the reactive condition ($M = 3.95$, $SD = 0.74$) (Figure 3). Since normality assumptions were not fully met across conditions, a Mann–Whitney U test was used. No statistically significant difference was observed between conditions ($U = 149.5$, $p = .169$).

The pattern shows a small downward shift in perceived autonomy when the robot intervened proactively, but the overlap between conditions suggests that both interaction styles were experienced in a broadly similar way in terms of perceived choice and self-direction.

Autonomy Frustration

Participants in the proactive condition reported slightly higher autonomy frustration ($M = 2.03$, $SD = 0.56$) than participants in the reactive condition ($M = 1.83$, $SD = 0.59$) (Figure 3). A Mann–Whitney U test found no statistically significant difference between conditions ($U = 252.0$, $p = .156$).

Overall, both conditions showed relatively low levels of frustration, with only minor differences between them.

4.2 Frequency of Participant-Initiated Interaction (SQ1)

To examine how often participants actively engaged with the robot, participant-initiated interactions were measured as the

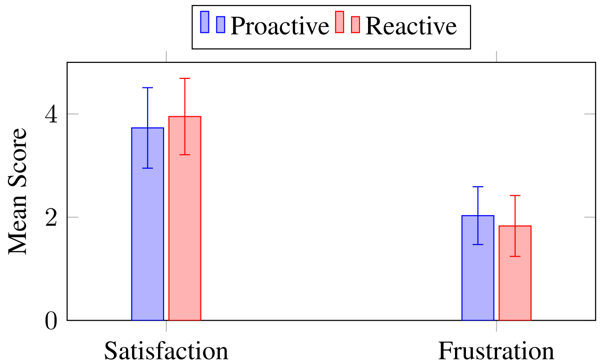

Figure 3: Mean autonomy satisfaction and autonomy frustration scores by condition. Error bars represent one standard deviation.

number of times Pepper was explicitly addressed during the brainstorming session.

Groups in the proactive condition addressed Pepper an average of 7.20 times ($SD = 4.02$), while groups in the reactive condition addressed Pepper an average of 7.40 times ($SD = 2.76$). An independent samples t-test indicated no statistically significant difference between conditions, $t(15.93) = -0.13$, $p = .898$.

This indicates that participants interacted with the robot at a similar frequency regardless of whether the robot intervened proactively or only responded when addressed. In both conditions, participants consistently made use of the robot as a conversational resource during ideation.

4.3 Timing of Interaction During Ideation (SQ2)

Table 2: Mean number of participant-initiated interactions with Pepper across brainstorming phases. Standard deviations are shown in parentheses.

Phase	Proactive	Reactive
Early (0–5 min)	2.80 (1.69)	3.00 (1.25)
Middle (5–10 min)	2.00 (1.49)	2.20 (1.40)
Late (10–15 min)	2.40 (1.84)	2.20 (0.92)

To investigate when participants chose to engage with Pepper, participant-initiated interactions were grouped into early (0–5 min), middle (5–10 min), and late (10–15 min) phases of the brainstorming session (Table 2).

In the proactive condition, interactions were relatively balanced across the session. The highest engagement occurred in the early phase ($M = 2.80$, $SD = 1.69$), followed by the late phase ($M = 2.40$, $SD = 1.84$), and the middle phase ($M = 2.00$, $SD = 1.49$).

In the reactive condition, interaction levels were slightly more stable across time. The early phase showed the highest engagement ($M = 3.00$, $SD = 1.25$), while both the middle and late phases remained the same ($M = 2.20$, $SD = 1.40$ and $M = 2.20$, $SD = 0.92$).

Overall, participants in both conditions interacted with the robot throughout the ideation process, with only small differences in how engagement was distributed over time.

4.4 Robot Intervention Frequency and Autonomy (SQ3)

To examine the relationship between robot intervention frequency and perceived autonomy, Spearman rank correlations were calculated between the total number of robot utterances per session and participants' autonomy scores.

A weak negative relationship was observed between the number of robot utterances and autonomy satisfaction ($\rho = -0.27$, $p = .088$), indicating that sessions with more robot interventions tended to correspond to slightly lower autonomy satisfaction scores. However, this relationship was not statistically significant.

No meaningful relationship was found between robot intervention frequency and autonomy frustration ($\rho = -0.02$, $p = .881$).

Overall, higher levels of robot participation were not strongly associated with changes in perceived autonomy.

4.5 Creative Output (SQ4)

Creative output was measured as the number of unique, non-repeated campus improvement ideas generated during each brainstorming session.

Groups in the proactive condition generated more ideas on average ($M = 7.70$, $SD = 2.58$) than groups in the reactive condition ($M = 5.80$, $SD = 1.62$). An independent samples t-test showed that this difference did not reach statistical significance, $t(15.12) = 1.97, p = .067$, meaning that while the proactive robot condition tended to yield a higher average of generated ideas, the variance between groups prevents drawing a definitive conclusion regarding the effect of the intervention strategy.

While the proactive condition shows a higher average number of ideas, the variability between groups suggests that performance differences were not consistent across sessions.

5 Discussion and Future Work

Results suggest that increasing robot proactiveness does not significantly alter participants' sense of autonomy, despite small directional trends. At the same time, proactive intervention appears to slightly increase idea generation, though with high variability across groups.

5.1 Robot Proactivity and Perceived Autonomy

One interpretation is that participants did not perceive proactive interventions as controlling, but rather as part of the expected facilitator role. This aligns with prior HRI findings suggesting that users often attribute agency and intent to social robots in ways that normalize their intervention behavior (Dautenhahn, 2007). In this context, proactivity may have been interpreted as supportive facilitation rather than autonomy-limiting interruption.

However, the qualitative interaction patterns suggest a more nuanced picture. Participants frequently initiated contact with Pepper early in the session, likely driven by novelty effects, although this was not directly measured. Over time, engagement decreased when robot responses were perceived as less useful or too generic, indicating that perceived usefulness may moderate the impact of intervention timing more than intervention frequency alone.

5.2 Interaction Dynamics and Engagement Patterns

A notable behavioral pattern was that participants often attempted to engage Pepper using phrases such as “what do you mean”, forgetting to explicitly say ”Pepper”. These interactions failed to trigger a response, leading participants to either keep trying until remembering to address it, or to shift their attention to the other participant. This suggests that strict triggering may reduce interaction fluidity and highlights a limitation of keyword-based engagement detection.

5.3 Proactive Trigger Mechanisms

Analysis of intervention triggers provides additional insight into system behavior. The most frequently activated trigger was conversational silence, which either failed to activate entirely or triggered more than three times per session. This pattern highlights a clear behavioral variance between groups, with certain sessions relying heavily on Pepper to maintain conversational momentum. The second most common trigger was struggle-related phrases, which were expressed each time by ”I don’t know”. In contrast, low conversational novelty triggered twice, and prolonged inactivity triggered only once across all sessions.

5.4 Creative Output and Collaboration Trade-offs

The way ideas were produced indicates a shift in the structure of the ideation process. Rather than contributing completely independent ideas, Pepper often generated solutions that built directly on ideas introduced by the participants. In many cases, participants would first propose an initial concept and briefly discuss it together. Pepper would then generate additional solution ideas derived from that concept. Once that line of discussion was exhausted or Pepper’s suggestions became less useful, participants would typically move on to an entirely new idea and the process would repeat. This pattern occurred throughout many sessions, suggesting that idea generation emerged through an iterative exchange between participants and the robot rather than through independent contributions from either party alone.

At the same time, the increased idea production in the proactive group appeared to come with a change in conversational depth. When Pepper contributed more frequently, groups tended to generate a larger number of ideas, but each idea was discussed for a shorter period of time before the conversation shifted to a new direction. This suggests a trade-off between idea quantity and elaboration, where proactive participation may encourage faster exploration of ideas at the expense of deeper refinement. This aligns with prior work on facilitation effects in brainstorming, where increased idea quantity can sometimes come at the expense of elaboration and refinement (Paulus and Nijstad, 2003).

5.5 System and Interaction Limitations

Several limitations should be considered when interpreting these findings.

First, system latency introduced delays in robot responses due to computational constraints of running a local language model. While improving model quality would likely enhance response relevance, it would also increase latency, disrupting conversational flow. This highlights a core trade-off in real-time embodied systems between response quality and interaction timing.

Second, idea generation was manually coded based on the predefined definition mentioned earlier. Although this allowed structured analysis, the process remains partially subjective, particularly in borderline cases of idea similarity.

Third, the sample size (40 participants across 20 groups) limits statistical power, particularly for detecting small-to-medium effects. As a result, non-significant trends should be interpreted cautiously.

Finally, the study focused on a single interaction context (campus ideation with dyads), which may limit generalizability to larger groups or different creative tasks.

5.6 Future Work

This study suggests that proactive robot interventions alone may not meaningfully reduce perceived autonomy during collaborative ideation. A key next step is therefore to better understand what characteristics of robot behavior influence autonomy perceptions in human–robot collaboration.

A particularly relevant question concerns the nature of robot contributions. Pepper primarily offered direct solutions during brainstorming, often without elaboration. Future research could examine whether different forms of proactivity, such as asking reflective questions, encouraging elaboration, or summarizing ideas, differentially influence both perceived autonomy and collaborative outcomes. It is possible that participants’ sense of autonomy depends less on intervention frequency and more on whether robot behavior is perceived as supportive, controlling, or disruptive.

More generally, future work should investigate the conditions under which robot facilitation shifts from being perceived as helpful support to unwanted interference. Better understanding this boundary may help inform the design of conversational robots that contribute to collaborative ideation without diminishing participants’ sense of ownership over their ideas.

6 Conclusion

This work investigated whether proactive robot interventions that provide unsolicited suggestions reduce participants’ perceived autonomy during collaborative ideation. Through a controlled between-subjects study comparing proactive and reactive intervention strategies, the findings suggest that proactive robot participation did not substantially reduce perceived autonomy during short brainstorming sessions. At the same time, proactive interventions were associated with a tendency toward increased idea generation, highlighting a possible trade-off between intervention frequency and the depth of discussion.

Beyond comparing intervention strategies, this work contributes empirical insights into how people engage with conversational robots during collaborative ideation. Participants interacted with Pepper consistently across both conditions, while behavioral observations revealed that engagement depended not only on intervention timing but also on the perceived usefulness and relevance of robot contributions. These findings emphasize that conversational support in collaborative settings is not solely a question of whether robots should intervene, but how such interventions are experienced by participants.

As social robots and AI-powered conversational systems become increasingly integrated into educational, workplace, and creative environments, understanding how to support collaboration without undermining human agency becomes increasingly important. This work contributes evidence that unsolicited robot participation may be compatible with maintaining perceived autonomy in brainstorming contexts, helping inform the design of future conversational agents that support, rather than disrupt, collaborative creativity.

7 Responsible Research

This research involved human participants and was conducted in accordance with approved ethical guidelines. Prior to data collection, the study received approval from the Human Research Ethics Committee (HREC). Participants voluntarily consented to take part in the study and were informed about the purpose of the experiment, the interaction procedure, and their right to withdraw.

The study involved collecting participant data, including names and email addresses for scheduling purposes, as well as session transcripts and questionnaire responses. To protect privacy, transcripts were anonymized using labels such as *Participant 1* and *Participant 2*. Research data were securely stored locally and will be retained until 26 June 2026, after which identifying information will be deleted. Raw participant data will not be made publicly available.

To support replicability and reproducibility, the methodology, robot behavior, intervention triggers, and analysis procedures are described in detail throughout this paper. The system was implemented using publicly available technologies, including Deepgram, Pepper's ALTextToSpeech service, and the Phi-3.5-mini-instruct language model. The implementation code is available in a public GitHub repository (*https://github.com/bogdanmicu12/Pepper*). The code corresponding to this study is provided in the `reactive/proactive` branch of the repository.

Potential sources of bias were also considered. Since participants were recruited primarily from university student groups, the findings may not generalize to broader populations. In addition, the novelty of interacting with a humanoid robot may influence participant behavior.

Research integrity was maintained by properly citing prior work and transparently documenting the methods used in this study. ChatGPT was used to assist with code development and writing support; however, all experimental decisions, implementation choices, and final content were reviewed and produced by the researcher.

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