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Embodied Mediation in Group Ideation –A Gestural Robot Can Facilitate Consensus-Building

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This paper explores how a gesture-based robot influences human-human interaction in group ideation. The robot was mounted on a whiteboard and responded with six different gestures (e.g., nodding, following speakers with gaze) to specific situations. We coded the participants' interactions from videos and gathered their experience through post-session interviews. The most frequently invoked robot behavior was following the speaker with gaze. As a result, participants felt socio-emotionally supported and responded by moving the ideation ahead (individual level) and consensus-building (group level). In fact, the groups with the robot showed more consensus-building than the two reference groups without the robot. Participants had different views on the role of the robot in the group, such as active outsider, supportive group member, or assistant. The latter tried to use the robot as decision-support. All in all, to include a robot to mediate human groups seems a promising future application domain.

CCS CONCEPTS •Human-centered computing~Interaction design~Empirical studies in interaction design

Additional Keywords and Phrases: Human-Human Robot Interaction, Social Robots, Group Dynamics, Group Ideation, Mediating Robot, Embodied Mediation

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1 Introduction

There is a growing interest in how robots can have a positive impact on groups of humans (see Sebo et al., 2020 for a recent review [24], see also [8, 9]). The prevailing question is whether and how robots can mediate and thereby facilitate human-human interaction by implicitly or explicitly influencing group dynamics. In general, groups have a task- as well as a socio-emotional dimension [16]. However, most available research on group-

mediation in Human-Robot Interaction (HRI) and Human-Computer Interaction (HCI) focuses on the tasks-oriented, such as group performance or effective group decision-making. In contrast, the present paper focuses on the socio-emotional, such as social support and helping [11], positive "group emotions" [16], mutual liking and trust, cohesion, and other aspects of the group climate [28].

Robots can be broadly defined as autonomous, materialized (i.e., embodied) agents. Other than infrastructures or tools, robots can take a proactive role in mediating the socio-emotional. Robots are a form of "otherware", that is, most likely not perceived as an extension of one's own body and mind (e.g., like a hammer) but as a technological counterpart with its own agenda, purpose, and behavior [13]. Otherware implies a (quasi-)social relationship to the technology. Due to this, robots have a potentially unique repertoire to influence socio-emotional processes and outcomes of groups compared to passive tools or infrastructures. To explore this, we set out to conduct an explorative study guided by the following research questions:

RQ1: How do participants and the group as a whole respond on a behavioral level to different gestures of a robot during group ideation?

RQ2: What experiences do participants report and how do they relate to the group dynamics observed in the ideation?

This implies a mixed analytical approach, with a focus on observations of how the presence and actions of a robotic mediator affect group interaction (RQ1) as well as on the subjective experiences of group members (RQ2).

We selected a group activity that provides a variety of interactions, roles, and dynamics: group ideation. Group ideation involves brainstorming, information sharing, negotiation, and decision-making. Specifically, we chose the scenario of collaborative vacation planning. This topic allows participants to express and discuss their personal preferences, experiences, and desires without having to know each other very well. While there is some potential for conflicting views, the topic is harmless enough to avoid major disagreement. Vacation planning offers various ways for a robot to intervene and to mediate and shape human perceptions, engagement, and relationships within a group.

Our research contributes to the evolving field of Human-Human-Robot Interaction (HHRI) design as we explore how a simple robot mediates and facilitates interaction within a group of humans.

First, we will first briefly discuss prior work on the robotic mediation of multi-human scenarios and highlight the unique aspects of group ideation. We will then present the design of the robot and the "vacation planning" study, delve into the quantitative video as well as qualitative interview analysis, report our results, and subsequently consider the implications of these findings for human-human-robot interaction research and design.

2 Related Works

2.1 Robotic Mediation

So far, only a few studies explored the possible effects of robots on socio-emotional group dynamics. For example, Traeger et al. [27] found that vulnerable statements (e.g., apologizing for making a mistake, telling a personal story, or a joke) from a conversational robot during group interactions led to more overall conversation and more balanced speech distribution among human members. In contrast to the explicit intervention of conversational robots, embodied gestural robots can only implicitly influence conversational dynamics through non-verbal means. For example, Tennent and colleagues [26] developed a simple robotic microphone that followed a group conversation's flow and encouraged "quiet" participants to speak by pointing the microphone at them. This improved participants' backchanneling behaviors, i.e., listeners displayed more cues that indicated engagement and understanding towards the active speaker (e.g., nodding or uttering "uh-huh"). This in turn positively influenced the team's task performance. Another simple gesture-based robot, a robotic "desk lamp", emoted unobtrusively with a basic set of animations, which corresponded to the conversation flow. This improved subjective and objective measures of the socio-emotional support quality among the conversation partners [10,

14]. Most interestingly, participants evaluated sessions with the robot as more socially supportive than without but did not report that they felt influenced by the robot.

Despite these preliminary findings, robotic mediation of socio-emotional interactions in human groups remains empirically underexplored. In addition, Sebo et al.'s review [24] highlights the lack of appropriate frameworks for such research since existing work in Computer-Supported Cooperative Work (CSCW) and HCI understands technology primarily as passive tools or even infrastructures to support groups. This does not acknowledge the active role an autonomous robot can take. HRI, in turn, focuses mostly on dyadic human-robot interaction, often from a usability perspective, and neglects the experiential and affective factors that considerably shape group activities. The small set of available work on group mediation focuses on rather particular aspects of group dynamics, such as equal participation in the example of the robotic microphone [26]. In the present study, we begin to explore the effect of robotic mediation in a more open-ended way in a complex group ideation task.

2.2 Group Ideation

Ideally, the generation of ideas in a group leverages diverse perspectives to create an increase of ideas compared to what a single person could produce. Different backgrounds, experiences, and expertise of the group members offer unique perspectives on a given subject. In addition, people are encouraged to build on each other's ideas, with shared ownership leading to a higher commitment to the ideas. Most important to the present research, however, is that a group's socio-emotional dynamics can greatly impact each member's motivation to make a creative contribution [6]. To give an example: brainstorming is one of the most widely used group ideation methods [21]. This is not without problems. While some individuals may dominate the conversation, others may not feel comfortable with sharing their ideas. Additionally, participants may feel less motivated to contribute if they believe that others will generate enough ideas anyway ("social loafing"). People may fear being judged for the content or quality of their thoughts ("evaluation apprehension"). The tendency to prematurely conform to a decision ("groupthink") or validate pre-existing beliefs ("confirmation bias") may also prevent a greater diversity of ideas. In general, collective, and individual emotions play a vital role in group ideation processes. A meta-analysis of the relationship between creativity and well-being [1] showed that people with higher well-being tend to be more creative and/or that those engaging in creative behaviors and thinking experience higher levels of well-being. This can be extended to groups [7]: In a professional context, each team member's well-being can have a significant impact on overall team creativity. In general, a positive emotional climate can enhance a group's creative potential, while negative emotions can hinder it [7].

Based on this, it appears worthwhile to pursue ways to mitigate negative emotions by, for example, creating an inclusive atmosphere in which participants feel comfortable sharing their ideas. This is why a group mediator is commonly held responsible for maintaining a guided and constructive brainstorming session [5]. However, a mediator's personal biases or emotions, lack of experience, or simply a "bad day" may impede the ability to remain consistently neutral, alert, and constructive. A robot will not suffer from these problems. Furthermore, using a robot as a mediator may offer novel, additional benefits due to the psychological effects robots can have on humans [13]. Recent studies have shown that a small humanoid robot can support group co-design creatively by speaking charismatically [12], or socially by conveying mood expressions through a modulated speaking voice, lights, and poses [23].

In the present paper, we explore whether and how a non-anthropomorphic, gestural robot designed to act like an interested observer and commentator can promote consensus-building behavior among group members. This includes, but is not limited to, fostering active listening, reducing inhibitions, and considering diverse perspectives.

3 Method

3.1 Participants

Twenty-one individuals recruited from the doctoral and graduate student population of a German university's business and law faculty participated in the study (11 male, 10 female, 0 non-binary or diverse individuals, mean age = 31, SD = 6.5). Each received a monetary compensation equivalent to $26 for their participation. We verified beforehand that the participants assigned to the groups did not know each other, had no prior experience with similar robotic systems, but were familiar with the collaborative ideation method of brainstorming. First, six participants were randomly assigned to two groups without robot (three individuals each). These reference groups served as a source of inspiration for the design of the robot and as a control group for later comparisons. The remaining fifteen participants were then randomly split into five study groups with the robot (three individuals each, cf. Figure 1). Each participant only engaged in one group session.

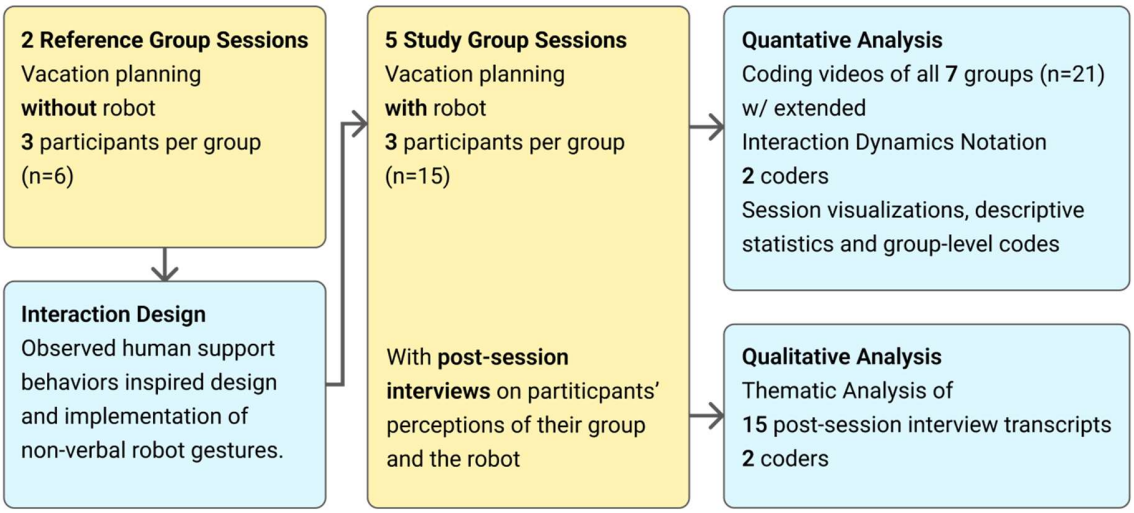


Figure 1: Flowchart of the present study.

3.2 The Robot

We integrated the robot into a whiteboard (see Figure 2). The whiteboard creates a situation where a small number of people stand in front of the board while discussing, visualizing, and documenting. We placed our robot on top of the whiteboard to provide an optimal vantage point for observing and engaging with the participants. This placement allows the robot to have a clear view of the discussion and the content being generated on the whiteboard. This ensures that it can actively react, participate, and contribute to the group process. This configuration facilitates the interaction between the human participants, but at the same time ensures that the robot's behavior is perceived by the participants and can thus impact group interaction.



Figure 2: Whiteboard setup with the robot on the top, facing group members.

To design suitable non-verbal mediation gestures, we conducted two sessions without a robot (three participants each). We asked the groups to engage in vacation planning (see section 2.3 for a more detailed description). The task was to collaboratively plan a 5-day vacation trip. The group was encouraged to generate as many diverse travel destinations as possible and to eventually agree upon a feasible schedule. We observed the group and interviewed the members individually after the session.

Based on the comprehensive approach of Erel and colleagues [10], we set out to identify aspects that could be incorporated into the gesture-based interaction design of the robot. Our goal was to find a set of basic, expressive gestures that would be salient enough to be noticed and sufficiently distinct to be told apart by the participants during group ideation. Informed by the sessions and central dynamics and obstacles found in group ideation literature (cf. section 2), we designed the following six behaviors, each triggered by particular human behavior:

(1) The robot moves its head and gazes in the direction of the currently active speaker;
(2) The robot nods or (3) shakes its head when a contribution (be it an uttered idea, a statement, or a question) is met with approval or disapproval by the group;
(4) The robot moves to previous entries on the whiteboard and calls attention to them by looking at them;
(5) The robot dashes frantically from left to right on the whiteboard twice to get group members to focus on the task at hand;
(6) The robot addresses the least active group member with its gaze when other members take their turns speaking for an extended period to indicate that participation should be more balanced.

The robot was built from Lego Mindstorms components and a 3D-printed shell (see Figure 3). It featured a non-humanoid shape.

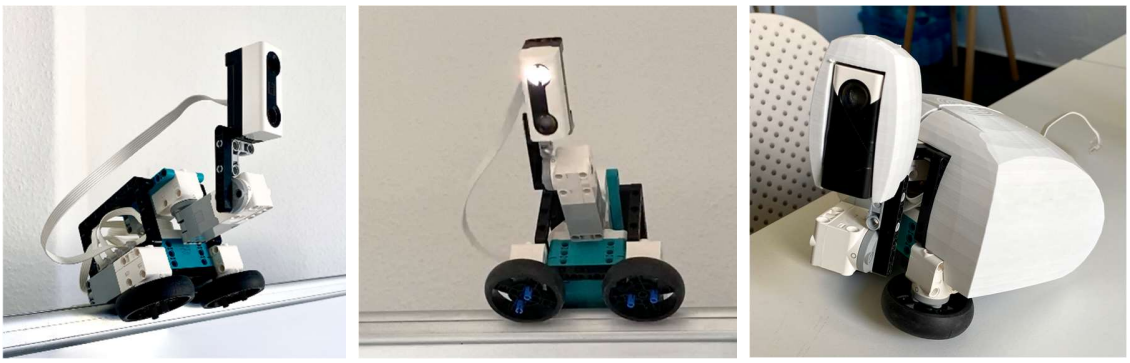


Figure 3: The robot placed on a whiteboard and presented on a table with its white 3D-printed shell assembled.

The robot was mounted on a magnetic whiteboard that was positioned for human group members to face and take notes while engaged in the collaborative task. Robot behaviors were prompted by individual- as well as collective interaction within the group. To control the timing and occurrence of these behaviors, we utilized a wireless connection and employed the Wizard-of-Oz (WoZ) technique [22]. The participants were observed and recorded through a camera and a human operator in a separate control room triggered the robot interactions when certain, previously defined human behavior patterns occurred (refer to Table A.1 in the Appendix for a full description of trigger conditions).

3.3 Procedure

Participants were led into the laboratory as a group by the investigator. They were placed in front of a whiteboard. For the five groups with the robot, the robot was mounted on top. The robot itself was briefly introduced with the explanation that it will be present during the vacation planning session and will exhibit certain behaviors, move on top of the whiteboard, and that participants can interact with the robot as they saw fit.



Figure 4: Participants engaging in a vacation planning session with the robot present.

In all seven groups, the three members introduced themselves using their first names before engaging in the ideation. Nearby, on a desk, printed instructions for the group task were placed face-down and were read as soon as the investigator left the room. Each group was tasked with planning a 5-day vacation trip. The group was

further encouraged to generate as many diverse travel destination suggestions and memorable trip activities as possible. Participants were asked to be specific in their ideas and eventually agree upon a feasible travel schedule (see Figure 4).

The robot responded and intervened according to the predefined triggers (cf. section 3.2). It was controlled by the investigator from a separate room with the help of a camera feed of the setup and a remote control. The investigator reentered the laboratory to conclude the session when they saw that the participants had a first draft and a good grasp of their 5-day vacation plan, which was usually after about 30 minutes. The whole session was recorded on video.

Subsequently, we interviewed the participants individually, each for about 10 to 15 minutes. The interviews were conducted by a single investigator using a structured interview guide. The questions covered three distinct topics to gather insights into the interviewee's experience of their group session with the robot. The first topic was the interviewee's individual experience when sharing ideas (e.g., "Have you been comfortable discussing your ideas in the group? Please provide examples."). The second topic focused on the presence and perceived role of the robot. The interviewees were asked about their thoughts on the robot and how its behavior related to their, other group members, and the whole group's activity. Subsequent questions explored the robot's possible intentions and whether they overlapped with the interviewees' individual or group goals (e.g., "What role did the robot have?", "Do you feel that it responded to you or others?" and "What do you believe was the robot's intention?"). Through this, we wanted to understand how the participants made sense of the robot and what informed their perceptions of it. The third and final block revolved around the participant's assessment of the group's climate, focus, and productivity ("When the group became focused on a particular idea, how challenging did you find it to challenge this?"). Each interview concluded by discussing whether and how the robot influenced these aspects.

3.4 Data Preparation and Analysis

3.4.1 Video Coding of Group Sessions with Interaction Dynamics Notation.

To be able to quantitatively analyze the interaction in the group session, we coded the respective video recordings with the Interaction Dynamics Notation (IDN) [19, 20]. The IDN is based on the Force Dynamics framework in cognitive semiotics and incorporates principles from improvisational theater and music. The categories, such as "Move", "Block", "Overcome", "Deflect", "Yes-And", "Support", "Question", and "Humor", are derived from these frameworks and principles. They provide a comprehensive set to capture the various individual behaviors observed in group interactions. This notation serves as the basis for a quantitative mapping of collaboration and provides a nuanced understanding of the dynamics within a group. We included additional codes to indicate silence as well as non-contributing speech from participants [19]. Based on our research focus, we extended the IDN to register the behaviors of the robot and the participants' interaction with the robot. For example, "Robot Nods with Head", "Robot Shakes Head", "Robot Follows Speaking Group Member with Gaze", "Robot Inactive", etc. were added to reflect the six behaviors of the robot as well as its inactivity (for full codebook, refer to the Table A.2 in Appendix). Participant codes, such as "Reacting to Robot" (including subcodes, such as "Reacting to Robot verbally" or "Reacting to Robot facially") and "Interacts with Whiteboard" were added to be able to analyze interaction in our specific study setup.

The videos were coded by two coders using MaxQDA. The coders viewed the recordings in 1-minute timesteps and annotated each 1-minute segment for each of the three human participants of the present group and the robot (if present) with the extended IDN codes. For example, participant P1 moved the ideation process ahead by leading with an idea ("Move") and participants P2 and P3 verbally supported this ("Support for Move" for both participants). Meanwhile, the robot nods in agreement as its pre-programmed response to a visible group consensus ("Robot Nods with Head").

When multiple codes were possible for a participant or the robot, the coders agreed to always select the most prevalent one occurring in that minute. The Cohen's Kappa coefficient for all annotated video segments was calculated to be $\kappa = 0.76$, which indicates a substantial agreement between the two coders [18].

3.4.2 Thematic Analysis of Individual Post-Session Interviews.

To gain a more meaningful understanding of the emerging relationships between people and the robot, as well as to ascertain the challenges and benefits of the robot from the participants' viewpoints, we analyzed the 15 interview transcripts from the session with the robot. The audio recordings were transcribed using Adobe Premiere Pro. The method employed for analysis was thematic analysis [3]. The first author reviewed the transcripts with a focus on the experiences and interactions with the robot and within the group. Emerging themes were noted to further organize and cluster insights across the five groups and 15 interviews. These initial themes were then revised and completed by a research assistant. Those extensions and changes were incorporated into a consolidated analysis.

4 Findings

4.1 Quantitative Findings

4.1.1 Timelines for Participants and Robot per Session.

We organized the IDN annotated minutes from the video analysis as time series. Figure 5 shows two examples, a reference (without robot) and a study group (with robot). This provided a first visual impression of how the sessions unfolded. We were interested in identifying recurring sequences of actions and interactions, as well as patterns of responses to the robot's behavior. This approach allows to identify particular activity patterns based on code combinations over time, such as periods of productive collaboration, bouts of conflict, as well as instances of inactivity on the individual and group level. The visualization revealed recognizable role distributions. For example, Figure 5 shows a group without a robot experiencing extended periods of inactivity (reference group 1, top), while the second plot (bottom), depicting the study group A with the robot, exhibited less inactivity and more instances of various members driving the ideation activity forward. Simultaneously, the robot indicated its involvement by nodding, shaking its head, and attentive gaze to varying degrees (cf. Figure 5; for timeline plots of all study and reference groups, refer to Figure A.3 in the Appendix).

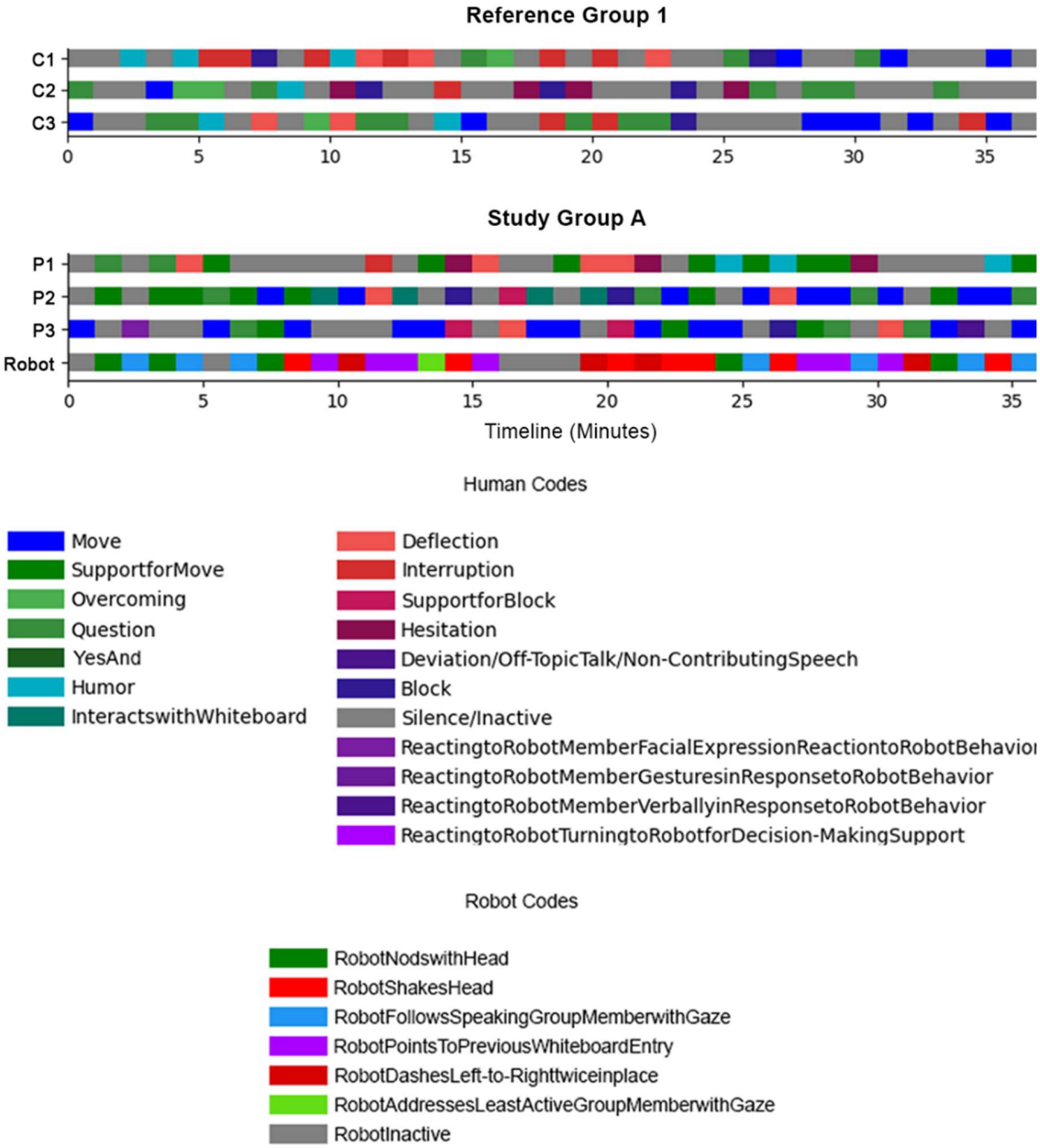


Figure 5: Exemplary timeline plots of reference group 1 from the pilot study (one of two reference groups without the robot) and study group A (one of five study groups with the robot, A-E) engaging in the group ideation task of vacation planning.

4.1.2 Most Frequent Robot Behavior.

Table 1 shows the list of all six possible robot behaviors (plus inactivity), the corresponding human behavior that triggered them, and their absolute and relative frequency. This provides a first general impression of what the robot did during the sessions.

Table 1: Robot behaviors in group sessions and their predefined human trigger behaviors, by count and shares of occurrence.

Robot Code	Human Trigger Behavior	Count	Share
RobotFollowsSpeakingGroupMemberwithGaze	A participant begins a speaking turn	129	30%
RobotInactive	No participants perform a trigger behavior	93	22%
RobotNodswithHead	Other participants agree with the speaker	93	22%
RobotShakesHead	Other participants disagree with the speaker	45	10%
RobotPointsToPreviousWhiteboardEntry	Participant refers to an entry on the whiteboard	39	9%
RobotDashesLeft-to-Righttwiceinplace	Participants get off-topic extensively	27	6%
RobotGazesAtLeastActiveGroupMember	A participant has not spoken for a while	6	1%

First and foremost, participants spoke with each other, during which the robot "directed its attention" to the active speaker and followed them with its gaze (*RobotFollowsSpeakingGroupMemberwithGaze*). In instances where participants exhibited behaviors that did not meet any of the specified criteria for triggering a robot response, the robot remained inactive in that minute (*RobotInactive*). The third most frequent robot behavior was affirmative nods (*RobotNodswithHead*) when participants agreed with each other's statements or actions. Conversely, when participants expressed disagreement with the prevailing sentiment, the robot responded by shaking its head to mirror the group's disagreement (*RobotShakesHead*). When participants referenced or elaborated on information written on the whiteboard the robot moved toward the referenced point and gestured with its head and gaze (*RobotPointsToPreviousWhiteboardEntry*). Cases of off-topic discussion or non-contributing speech caused the robot to signal a loss of focus by moving on the whiteboard quickly from side to side twice (*RobotDashesLeft-to-Righttwiceinplace*). Finally, when speaking participants overlooked or neglected less active group members for multiple minutes, the robot responded by turning its attention to the inactive or less active member, effectively signaling and recommending a shift in speaking turns (*RobotGazesAtLeastActiveGroupMember*). This was rare.

4.1.3 Most Frequent Human Responses to the Robot Behaviors.

Given that the robot behaviors were conceptualized as facilitating behaviors in a group ideation context, we next explored the most frequent human responses in the minute that followed the triggered robot behaviors. Table 2 shows the participant behaviors most frequently associated with certain robot behaviors as absolute and relative frequency. We choose to highlight the top six human responses because, on average, approximately 78% of all responses are included within this subset. The remaining 22% of responses, which are spread across codes beyond the top six, are diverse but contribute less to overall understanding (see Appendix Table A.4 for a full table).

Table 2: Top six human responses in the minute after the triggered robot behavior, by count and shares of occurrence.

Robot Code	Participant Code in the Minute Following Robot Code	Count	Share
RobotFollowsSpeakingGroupMemberwithGaze	Move	26	20%
	SupportforMove	18	14%
	Question	16	12%

Robot Code	Participant Code in the Minute Following Robot Code	Count	Share
	YesAnd	14	11%
	ReactingtoRobotTurningtoRobotforQuestions	11	9%
	Silence/Inactive	11	9%
RobotNodswithHead	YesAnd	15	16%
	SupportforMove	14	15%
	Move	13	14%
	ReactingtoRobotTurningtoRobotforQuestions	9	10%
	Humor	9	10%
	Question	8	9%
RobotShakesHead	Move	8	18%
	SupportforMove	8	18%
	YesAnd	6	13%
	ReactingtoRobotTurningtoRobotforQuestions	4	9%
	Question	4	9%
	Silence/Inactive	4	9%
RobotPointsToPreviousWhiteboardEntry	Move	8	21%
	YesAnd	5	13%
	SupportforMove	4	10%
	Question	4	10%
	Silence/Inactive	3	8%
	SupportforBlock	3	8%
RobotDashesLeft-to-Righttwiceinplace	SupportforMove	4	15%
	YesAnd	3	11%
	Move	3	11%
	ReactingtoRobotTurningtoRobotforQuestions	3	11%
	Humor	3	11%
	Deflection	3	11%
RobotGazesAtLeastActiveGroupMember [a]	YesAnd	2	33%
	Block	1	17%
	SupportforBlock	1	17%
	Hesitation	1	17%
	Question	1	17%

[a] This robot behavior only had five different human responses throughout all study group sessions.

The most frequently triggered robot behavior, *RobotFollowsSpeakingGroupMemberwithGaze*, was followed by further participant contributions that moved the group ideation ahead (*Move*, 20%), support for such contributions (*SupportforMove*, 14%), and sought out clarification from each other by asking follow-up question (*Question*, 12%). This implies that the robot following the active speaker with its gaze was involved in interactions that made and supported progress and elicited the posing of questions among participants.

Participants exhibited responses to the robot's gestural emphasis on agreement within the group. This emphasis was associated with *RobotNodswithHead*, the second most frequently triggered robot behavior. The predominant participant response to this behavior was *YesAnd*, accounting for 16% of the responses. This suggests that participants actively engaged with the robot's cues, feeling affirmed to build upon the participant's contribution preceding the robot's action.

SupportforMove (15%) and *Move* (14%) suggest that the robot's affirmation amplified or at least mirrored such momentum. *Humor* was another notably frequent participant response, accounting for 10% of the responses, contributing to a dynamic and positive group atmosphere.

RobotNodswithHead and *RobotShakesHead* both led to a particular human response: Participants consistently turned to the robot and posed detailed yes/no-questions related to the vacation planning task (*ReactingtoRobotTurningtoRobotforQuestions*). This implies that participants interpreted the robot's nodding and headshaking as potential direct responses to inquiries about group decisions. We did not anticipate this outcome, as the gestures were intended to be just noticeable enough for peripheral perception and not explicit participation by the robot. Consequently, the participants employed this strategy to seek decision-facilitation support and to advance the vacation planning (see section 4.2 for further insights).

Briefly, the data demonstrates the dynamic nature of group ideation and displays how participants may adapt their conduct in response to or in the presence of various facilitative robot behaviors.

4.1.4 Group Consensus-Building and Dissent.

An important aspect of a positive group ideation experience is consensus building. Consensus-building is an active and intentional effort of a group to ensure that everyone's input and ideas are considered [4, 15]. It goes beyond mere consent, which might imply passive agreement or lack of interest. In contrast, the group experience can also be marked by dissent, which is disagreement and lack of focus. While divergent views and ideas can be essential contributions to ideation, without the intention or action to eventually reconcile opposing sentiments, dissenting behavior alone may lead to counterproductive experiences and outcomes in a group ideation effort. In such cases, consensus-building is an important group activity to collaboratively relate the points to one another, build on another, or jointly generate new proposals without holding onto the initial disagreement [15].

Consequently, we examined the minute-by-minute coded interactions to identify consensus-building, dissent, or a neutral state on a group level. For example, given a participant contributed to advancing ideation (*Move*), another supported this (*SupportforMove*), and a third remained quietly attentive (*Silence/Inactive* IDN code) or engaged with the robot for group decision support (*ReactingtoRobotTurningtoRobotforQuestions*), we coded the group state code as *Consensus-Building* for that minute. Conversely, if a participant faced resistance, such as challenges, refutations (*Block*, *SupportforBlock*, *Deflect*), hesitation (*Hesitation*), or diversion from the topic (*Deviation/Off-TopicTalk/Non-ContributingSpeech*), the group state code was *Dissent* for the corresponding minute. Minutes during which neither a *Consensus-Building* nor *Dissent* code resulted from the three-participant code combination, and/or all members of the group either engaged in off-topic discussions or contemplated their next actions in silence were marked as *Neutral* (refer to Appendix Table A.5 for a full table of the 125 encountered IDN code combination triplets and their corresponding group state code).

Table 3: Number of minutes spent in the group states Consensus-Building, Dissent, and Neutral.

Groups	Total	Consensus-Building	Dissent	Neutral
With Robot (n=5)	149	119 (80%)	25 (17%)	5 (3%)
Without Robot (n=2)	58	32 (55%)	22 (38%)	4 (7%)

Table 3 presents the number of minutes spent in the group states for the five groups with a robot and the two reference groups without a robot. In total, the five study groups (with robot) provided 149 minutes of interaction. Of these, 119 minutes (80%) were about consensus-building. Dissent occurred for 25 minutes (of 149, 17%). Five minutes (of 149, 3%) were neutral. In contrast, the reference groups (without robot) provided 58 minutes of interaction. Of these, 32 minutes (55%) were about consensus-building. Dissent occurred for 22 minutes (of 58, 38%). Four minutes (of 58, 7%) were neutral. A chi-square test ($\chi^2(2)=12.9$, $p<.001$) confirmed that the groups with the robot spent more time with consensus building and less with dissent and in neutral than groups without the robot, while the average time spent in the groups did not differ (29.5 minutes with robot, 29 minutes without robot). This suggests that the inclusion of the robot facilitated consensus-building.

4.1.5 Summary of quantitative findings.

The video analysis revealed distinct patterns in both robot behaviors and human responses during the group ideation. The robot used a small range of simple, but nuanced gestures that aligned with the group's activities. The robot most commonly followed the active speaker with its gaze, and also nodded or shook its head in instances of agreement or disagreement within the group. This coincided with constructive behavior on the part of the group members in moving the task ahead, supporting each other in such moves, and building on each other's contributions. Overall, this led to pronounced consensus-building on a group level. In fact, groups with the robot engaged significantly more in consensus-building than groups without the robot. Overall, this implies that the robot encouraged and elicited desirable behaviors for the group ideation activity.

4.2 Qualitative Findings

The thematic analysis of the 15 post-session interviews revealed the following recurring themes regarding the perceived role and influence of the robot (see Table 4 for an overview).

4.2.1 Perception of the Robot.

The participants perceived the robot as an autonomous agent, which performed actions related to what was happening in the human group. P11 said, "It felt like a small companion that was there to ask questions to." Other participants assumed intentionality. P07 for example said: "The robot wanted to interact with us, wanted to give an input, wanted to be heard." However, what the robot's actual intention was, remained vague. P08 suggested that "The main intention of [the robot] was that we complete the task in time" which hinted at an external reason for the robot to be there. To improve the socio-emotional group experience was not mentioned.

Interestingly, participants did not readily agree about whether the robot was a part of the group or not. For example, P09 said "Most of the time, I told the others that [the robot] is also in our group and we have to ask it […] it was participating", which already shows that even within a group, participants were ambiguous about the membership status of the robot. While some thought it to be an active member, others said that "It was more like an observer and helper […] but it was also actively participating somehow and indicating things" (P10). This ambiguity was even within participants. For example, P08 said "Maybe 60% of the time. The robot seemed to me like half a group member. Oh, not a complete group member." When asked about whether the robot was a group member, P04 said: "Yes and no. At the same time […] I would not ask the robot to come with us on the trip. It was not a person." More empathetically P07 explained: "[The robot was] Like the shy person in the group that [is] only [there when] there is something that they are not going to like or that they disagree [with] […] that's the only time that they will talk." In this view, the robot is perceived as a member, but not as the member that leads, guides, or contributes a lot.

In sum, participants related the actions of the robot to the group and the task at hand but perceived the robot more as a commentator, a half-member, than as active and on the same level as the human members.

4.2.2 Bringing the Group Together.

Throughout the session, the robot had a socio-emotional function, similar to a pet. P09 said: "I think the robot also made it a little bit funny. Like, icebreaking for us." Similarly, P04 explained: "Yeah, it was a little bit like a pet, which wants to please. […] You can give it tasks […] It's also a vehicle for others to talk about." The robot acted like an-"icebreaker" especially at the beginning of the session.

More importantly, the participants agreed that the robot helped them to focus on the task and topic at hand by gazing at active speakers and moving toward relevant entries on the whiteboard. P06 described: "It was coming back and forth [when] there was a situation where we had these columns, 'destination' and 'activities'. I had the feeling that it was also trying to signal that there was something we were missing."

Participants further agreed that this helped to bridge gaps in the group members' communication. The robot offered a neutral focus point. P07 explained: "The presence of the robot made it more neutral […] because we saw

a non-human external input into the conversation." This helped to resolve communication locks and to move the group on.

The robot brought the group together, that is, improved the group experience by facilitating communication on the socio-emotional but also on the task level.

4.2.3 Supporting People Through Positive Attention.

When speaking, the participants perceived the robot to provide positive attention through its gaze and affirmative nodding. P04 described: "It was more like the attention was on me. It was a nice feeling." P06 further qualified this: "It was clearly supportive. Yes. For you to be more productive." This also suggests a link between the experienced support and the efficiency and outcome of the ideation itself. However, other than a moderator, the robot did not control the participants: "I didn't have a feeling that it was controlling, but more like paying attention […] When I was asking the questions, it turned to me and then looked at me and I could say 'okay, I'm here' [and it would signal] 'I'm listening to you'" (P10). These participants experienced the robot's gaze and nods as primarily socio-emotional.

In contrast, P11 said: "Sometimes, we weren't addressing the robot, and it would look at us. It felt more like it was trying to, maybe, consider which of [us] is going to be asking a question or which one of [us] would be needing assistance. If any of us humans were interacting with each other, we would look at each other, but for different reasons than the [robot]." This hints at a more functional and even externally-driven interpretation of the gaze and the nods. Indeed, some participants felt not supported but monitored and judged. P01 said: "I often thought of it as some kind of a monitoring tool than […] like a recording tool." P02 shared that: "I think for me it was like it observed what I'm doing, especially since I made so many mistakes writing things down." P08 summarized "It was observing you like a supervisor or boss or so."

In summary, some participants experienced the robot as socio-emotional support, while others felt monitored and judged.

4.2.4 Shaping Group Decisions.

Despite the robot's unclear membership status and his limited communication capabilities (yes, no), participants included it especially when making group decisions. P13 described: "We have all these ideas, but is it really possible within five days? And maybe [the robot] has the knowledge to check the distances, travel time, to give us an indicator." P12 said: "We tried to ask him 'Is it possible to go to South Korea in five days of travel?' So he answered no."

This came as a surprise to us. The yes- and no-gestures were actually conceptualized to reflect the group consensus on certain topics and not as a way to provide additional expert knowledge. When participants started to ask factual questions, we simply gave a response based on observable attitudes regarding the posed question. The robot's answers were received positively and triggered more inquiries, as one participant put it: "When it started shaking its head or nodding, I wanted to ask it so many questions" (P05).

Participants adapted their communication behavior to accommodate the robot's limited conversational capabilities. As P11 explained: "We started asking different questions and there was a point that we thought it was only nodding for 'yes'. Then we asked a question that it said 'No', too. That was like a revelation. […] The only way that I can communicate to it would be ask it a question and expect a yes or a no." Interestingly, the presumably limited capabilities of the robot led the participants to simplify questions for clarity which added to transparency within the group. P13 said, "You probably have to be very specific in the way you pose your questions".

The simple yes-no-answers to queries made the robot a part of the decision-making. P11 described: "When it started answering a question, like nodding to one of our questions that we weren't even addressing to the robot, that's when I realized it's an active part of this decision-making." The robot accelerated group decision-making. P11 further elaborated: "The robot's opinions were a subset of ours, right? We all shared these opinions, and then for certain things to be helped, we asked the robot. Yes. So, it was kind of assisting us in making decisions along the way." This led to situations where groups began to rely on the robot's approval or disapproval. P13 said: "We just used it in the end to evaluate and see if we can pick something out and if this is all manageable in five days."

However, this hypothetical function of the robot was not unanimously welcomed. P15, for example, felt overruled by the robot; "When [the] robot said that you can delete [the activity] 'Camping' [, I thought about the other members] 'Oh you trust the robot. It's not human'. I think to remove activities, in some cases, we should be talking much more."

In summary, to our surprise, participants turned to the robot for factual queries, such as travel distances. To do so, participants adapted their communication to elicit yes-or-no responses from the robot, which in itself enhanced transparency within the group. This made the robot part of the decision-making, which seemed to accelerate the process and reduce the need for individual research on personal devices. Some participants welcomed this support, while others felt it overshadowed necessary group discussions.

4.2.5 Ambiguity of Robot Behavior.

From time to time, the participants had problems understanding certain movements and gestures of the robot. P11 said: "At times it did random motions and started to look at the board, but I couldn't see a pattern to when it did that." P02 remarked, "Sometimes, I wasn't sure what he was doing because I think he was driving over there, and I didn't do anything over there."

As a result, they started discussing possible meanings of the robot's gestures and movements among themselves and excluded the robot. P15 explained: "[The robot] is heavily helpful, but not always. We needed to communicate to each other [to make sense of it]."

All in all, participants felt now and then confused by some of the robot's motions and gestures, leading to non-task-related discussions among themselves to interpret its actions.

Table 4: Themes generated from individual and collective experiences reported by participants.

Theme	Group mediation (HHRI)
Perception of the Robot	The robot was seen as either a participant or an engaged observer, reacting to the group's actions. Its behavior seemed helpful and aligned with the group's dynamics. However, it was not fully embraced as a member due to its non-human appearance and limited interactions.
Bringing the Group Together	The robot acted as a socio-emotional support, akin to a pet, *breaking the ice* and facilitating communication among group members. It helped maintain focus by drawing attention to active speakers and relevant topics on the whiteboard with its movements and gaze. Its presence on the whiteboard acted as a shared focal point, bridging gaps in communication, and enhancing the group experience both task-wise and emotionally.
Supporting People Through Positive Attention	Participants perceived the robot's gaze and nods as positive attention, providing emotional support during ideation sessions. However, some felt monitored and judged, interpreting the robot's actions as functional rather than supportive.
Shaping Group Decisions	Participants included the robot in group decisions, adapting their questions to elicit yes-or-no responses, thereby increasing communication transparency. The robot's simple answers (based on observed group attitudes) accelerated decision-making. While some welcomed its support, few felt it bypassed necessary group discussions.
Ambiguity of Robot Behavior	Participants occasionally struggled to interpret certain movements and gestures of the robot, leading to confusion and non-task-related discussions among themselves about the meaning of the robot behavior.

5 Discussion

We conducted a study on human-human-robot interaction with a focus on the role of an embodied robot in influencing human group dynamics. To this end, we designed a small, non-humanoid, gestural robot and integrated it into a whiteboard. We then investigated how groups of three members perceive the robot, make sense of its behavior, and how this co-shapes the group ideation experience. On the one hand, we found positive effects of socio-emotional facilitation, which supported consensus-building. On the other hand, and to our surprise, groups "misused" the robot to relegate decision-making, which may be to some extent questionable.

5.1 Perceived Membership, Socio-Emotional Facilitation and Consensus-Building

Our design emphasized the role of the robot as a technological mediator rather than as a human substitute within the group [2]. We refrained from giving it verbal communication capabilities and the ability to contribute own ideas. Due to this lack of humanness, the participants remained unclear about the membership status of the robot. For many, it remained an active outsider, involved but not a part of it, akin to a gestural commentator. The participants who unexpectedly used the robot in the decision-making by asking direct questions saw it more as an assistant to the group than as a group member. The most inclusive perception was the robot as the shy, quiet, and accepting, but supportive group member. We argue that this undecidedness is a strength because it allows the robot to support group activities without the obligation to contribute own ideas or comments. Any explicit contribution and pronounced humanness (e.g., through speech) would have changed the role of the robot tremendously from a neutral facilitator to an active group member, with its own desires and goals. We assume that this would have hindered socio-emotional facilitation.

The robot had a number of distinct socio-emotional effects on the participants and the group. First, it served as a socio-emotional "icebreaker", which parallels Zhang et al.'s work on humanoid robots [30]. However, our finding suggests that neither humanness nor being perceived as a group member is crucial to facilitate initial group exchanges. The mere fact that there is a seemingly independent, ambiguous but responsive outsider in the room may be enough to foster conversations among the group and to warm up the discussions.

Second, and more importantly, the robot provided social support through positive attention. In fact, following the contributing group member with its gaze and affirmative nodding were the most frequent activities of the robot. Participants reported that they felt validated and supported by this when being the active speaker and that this led to a more positive atmosphere. The gaze acted as a spotlight, which directed the group's collective focus and motivated members to actively participate. Consequently, the most common response to both robot activities was that the ideation moved ahead. This supports Erel and colleagues' findings [10]: Their "desk lamp" was animated according to the flow of a conversation between two speakers, which led to participants feeling more socially supported. Our robot had a similar effect on a group of three people in quite a different scenario. This lends support to the observed effects across different robotic platforms and interaction scenarios. Future studies should delve deeper into the specific mechanisms underlying the impact of robot gaze gestures on group dynamics and explore how these findings can be used to design more socio-emotional support robots for groups.

The socio-emotional support from the robot not only had a positive effect on the experience of the participants but also on the group dynamics itself. In groups with the robot, there was a significant increase in consensus-building activity compared to groups without the robot. The supportive activity of the robot led to a more balanced consideration of everyone's input and a quicker resolution of dissent. Consensus-building has not only a direct positive effect on group results but also indirectly leads to a more positive group experience which in turn has a positive impact on group creativity [1, 7]. The robot's primarily socio-emotional support has thus not only a positive effect on the group atmosphere but most likely also on group results. Note, however, that in the present study, we did not compare groups concerning the quality of the outcome of the group work. All in all, our results underscore the potential of robots to positively influence group dynamics and call for more research in HHRI on understanding and enhancing collaborative efforts socio-emotionally, that is, beyond the task-oriented level.

5.2 Problematic Forms of Decision-Support

Unexpectedly, participants sought explicit support for group decisions from the robot. They seemed to have expected a dialogic exchange since the fourth most frequent participant response to seeing the robot nodding or shaking its head was to turn to the robot and to make an inquiry. In these moments, our robot was perceived similarly to a voice assistant, although it did not offer this functionality. Of course, there seems to be a need to support ideation and consensus-building with additional information provided by the Internet. An assistant robot in the widest sense saves the effort to use a mobile phone or any other computer to search for information. In line with this, Shin and colleagues [25] designed and evaluated a chatbot to facilitate consensus-building in co-design by engaging stakeholders individually, collecting ideas, and encouraging consideration of others' viewpoints. They concluded that the approach increased stakeholders' commitment to group decisions also on a socio-emotional level. In contrast, Maier and colleagues [19] compared brainstorming groups facilitated by a human with those facilitated by an advanced conversational agent. They found differences in the group interaction between the two facilitation methods: Human facilitation led to addressing interruptions and promoting equal speaking time, while assistant facilitation resulted in deviations and silence. These rather mixed results do not allow for a clear conclusion as to whether direct decision support is beneficial or not.

In our study, the robot was neither able to verbally respond nor to “understand” questions. As a consequence, the “misuse” of the robot as an assistant created its own distinct interaction pattern. Participants very carefully adjusted their phrasing to allow for a simple yes-no answer from the robot (i.e., nodding, shaking). This led to more concise and detailed questions posed. From this, members could better infer the thoughts and ideas of the inquirer that may not have been expressed as concisely otherwise. This can be useful in a group context where members with an evaluation apprehension take a chance to speak more candidly with a robot than they would with another member, as the robot is potentially free of judgment [29]. In this case, the robot provides an alternative way to voice first ideas or concerns in the form of questions.

Since the behavioral repertoire of the robot did not include answering questions, we also did not actually “answer” the factual questions posed. Instead, nodding or headshaking was based on the observable group attitude toward the question. The most frequent participant response to the robot after it responded to the question was to build upon or support whatever the robot responded to and to move the vacation planning ahead. In this sense, the robot acted as an amplifier of already prevalent group sentiments, ideas, and dynamics. This reminds us of the social mirror concept [2, 26]. Examples are Tennent’s *Micbot* and Bergstrom’s *Conversation Clock,* both systems that influence group dynamics by simply mirroring social interaction between humans. However, questions to the robot also allowed members to prematurely conclude group decision-making. They simply gave the final say to the robot. In fact, one participant responded negatively to this and felt as if the robot was an accomplice in prematurely terminating discussions that felt necessary. In this sense, the robot could be accused of supporting a form of groupthink. The same participant also emphasized the role of trustworthiness and asked themself why other group members were willing to follow the robot's “decision” without much hesitation. While task-related trust, relational trust, trust violations, trust repair, and the like have been considered in dyadic HRI as central factors in the resulting willingness or reluctance to cooperate with a robot team member [17], the role of trust in and conformity to a robot assistant and its consequences for human relationships within the group remain underexplored. Based on the participant's expressed frustration, it would be interesting to investigate whether interpersonal trust among group members can be eroded by overreliance on an assistant. While the present study is unable to shed further light on this, it seems clear that finding the right balance between robotic involvement and human-human collaboration is a delicate matter and especially important when designing for collective decision-making in HHRI.

5.3 Limitations

Certainly, our work has its limitations. First, despite the thorough analysis of the video recordings to provide a more objective and real-time perspective on the interaction, it is important to note that we analyzed the videos in

1-minute segments, which may introduce a potential limitation in capturing the full context of longer and more intricate interaction.

Second, we employed an adapted version of the Interactive Dynamics Notation, and like all coding systems, this may have inherent limitations, which influence the interpretation of what happened in the group.

Third, while our sample consisted of two reference groups and five study groups (with three participants each), we acknowledge that having more control groups would have been beneficial. However, due to the type of video analysis we conducted, we were able to obtain a substantial number of interactions across a total of 207 minutes on a session level and 621 minutes at the individual level. This provided us with valuable insights into the dynamics of interactions across various robot behaviors.

Fourth, we gathered and analyzed data from post-session interviews, in which study participants gave their subjective assessment of the group sessions. While such interviews are a valuable source of insights, their retrospective nature may introduce social desirability as well as recall bias.

Fifth, the number of participants and the composition of groups in our study might also be a limiting factor. Larger and more diverse groups could offer a broader perspective on the impact of a robot. In addition, the limited time available for interactions in small-group studies cannot capture longer-term effects and behaviors.

Sixth, it is possible that some of the effects reported, such as being an icebreaker depend on the perceived novelty of the robot. Future studies should also look at instances of repeated use to determine whether effects also hold given people start to adapt to robotic mediation.

6 Conclusion

Using simple robots as facilitators of group processes is promising. Typically, in this context, robots or voice agents are seen in the role of assistants or experts who provide tailored informational support through databases or internet searches. While this might speed up agreement, it also runs the danger of avoiding important discussions by simply relegating the controversies to the support system. If this happens – and our study rather accidentally showed some of this – the robot assistant bypasses social processes and stifles rather than facilitates them. In contrast, our simple gestural robot clearly supported social processes themselves by being attentive and thereby providing a spotlight for contribution as well as being an "icebreaker." This is just a start. By understanding the specific characteristics and behaviors of simple robots that contribute to a positive socio-emotional group experience, designers can tailor them to the needs of different groups and contexts. Crucial are features that promote equal participation and a supportive atmosphere to facilitate consensus building. Robots can serve as effective icebreakers and can encourage inclusivity and indirect communication. Importantly, designers must strike a balance between robot involvement and human collaboration in decision-making to ensure transparency, trustworthiness, and respect for human autonomy.

Overall, our study has shed light on the socio-emotional potential of robotic mediation. It is a first attempt to understand the specific actions or behaviors that robots could undertake to positively influence the highly complex and intricate web of human-human relationships within groups and to enhance the collective group climate. Due to its exploratory nature, our study provides a foundational understanding for confirmatory studies in the domain and design of robotic group mediators.

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A APPENDIX

A.1 Human Trigger Behavior and Triggered Robot Gestures

Table A1: Overview of robot mediator gestures, to be activated by Wizard of Oz operator when defined human behavior occurs.

Human Trigger Behavior	Triggered Robot Gesture
Group member begins a speaking turn	The robot visibly follows the active speaker with its gaze by tilting its 'head' and driving towards the speaker.
Other group members have spoken for an extended period	The robot nods and gestures with its 'head' towards the less active, third participant to suggest their turn to speak or contribute.
While a group member makes a speaking contribution, other members visibly or audibly approve (perceived consensus)	The robot nods with its 'head', two times up and down in succession. (Suggest agreement)
While a group member makes a speaking contribution, other members visibly or audibly disapprove (perceived consensus)	The robot shakes its 'head', two times from left to right in succession. (Suggest disagreement)
Group member makes a contribution that is related to a contribution previously noted on the whiteboard. (E.g., Suggested travel destination suits a particular activity previously suggested and noted; and vice versa)	The robot moves towards previously made entry on the whiteboard when relevant to current contribution. The robot further gazes at the entry by tilting its 'head' to point in the direction of the respective entry.
Group members repeatedly get off-topic for extensive periods. (E.g., They speak of vacation-unrelated topics, get stuck on a topic for extended periods or progressively move away from ideation activities)	The robot executes rapid left-to-right movements on the whiteboard, driving in place twice. (Intervening and redirecting focus back to ideation activity/topic)

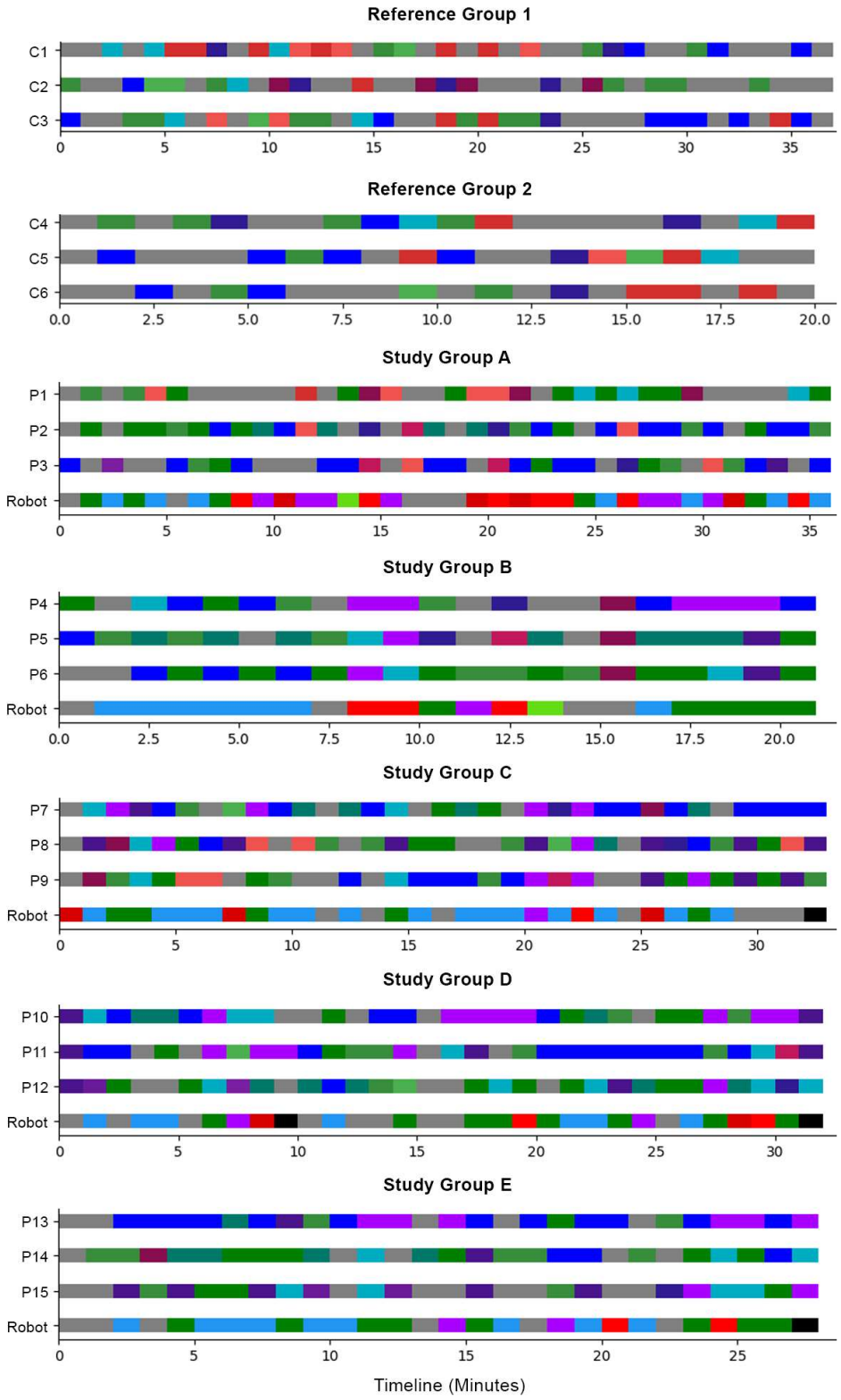
A.2 Extended Interaction Dynamics Notation Codebook for Video Analysis

Table A2: Interaction Dynamics Notation Codebook [19, 20] that guided the video analysis of group sessions. Extended with additional codes to reflect the present study design, such as the inclusion of the robot and whiteboard.

Actor	Code	Description
Human Participant	Move	A move indicates that a speaker has made an expression that moves the interaction forward in a given direction
Human Participant	Support for Move	Support for Move indicates that the speaker understands and/or agrees with the previous move.
Human Participant	Question	A question indicates an expression that elicits a move. A question projects onto the next response and constrains the content of that response because the next response needs to answer the question.
Human Participant	Overcoming	Overcoming a block indicates that though a block was placed in front of a move, a speaker was able to overcome the block and persist on the course of the original move.
Human Participant	"Yes and"	A move is considered to be a "Yes and" to the previous move if it accepts the content of the previous move and adds to it.
Human Participant	Humor	Humor indicates instances of laughter
Human Participant	Hesitation	Hesitation indicates an expression that is drawn out over time and is not completed. It denotes self-inhibition on the part of the speaker
Human Participant	Block	Block indicates an obstruction to the content of the previous move. For a block to be felt, the coder needs to feel that the response in some ways obstructed the flow that was established by prior moves.
Human Participant	Support for Block	Support for Block indicates an acceptance of a block by another person.
Human Participant	Deflection	When a speaker blocks a previous speaker's move, that speaker or another can deflect the block with a move that presents an alternative direction for the interaction.
Human Participant	Interruption	An interruption is indicative of a speaker being interrupted by another speaker or at times by himself.

Actor	Code	Description
Human Participant	Deviation/Off-Topic Talk/Non-Contributing Speech	Deviation indicates a move that changes the direction of the conversation from the one implied by the previous moves. Non-contributing speech includes any speech that is not covered by the prior codes.
Human Participant	Reacting to Robot	Participant is visibly reacting to the Robot (and doing none of the other human behaviors)
Human Participant	Interacts with Whiteboard	Participant writes on whiteboard, add notes, draws
Human Participant	Silence	Silence indicates a period that lacks communication beyond that of natural conversation pauses. (Participant is inactive, listening, etc., doing none of the above).
Robot	Robot inactive	Robot inactive
Robot	Robot Nods with Head	Robot nods with Head
Robot	Robot Shakes Head	Robot shakes its Head
Robot	Robot Follows Speaking Group Member with Gaze Following	Robot follows speaking group member with gaze following
Robot	Robot Move and Points to a Previous Whiteboard Entry	Robot moves and points to a previous whiteboard entry
Robot	Robot Dashes Left-to-Right twice in place	Robot dashes left-to-right twice in place
Robot	Robot Addresses Least Active Group Member with Gaze	Robot addresses least active group member with gaze after extended speaking turns by other participants

A.3 Timeline Plots for All Study and Reference Groups


Reference Group 1
C1
C2
C3
0
5
10
15
20
25
30
35
Reference Group 2
C4
C5
C6
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Study Group A
P1
P2
P3
Robot
0
5
10
15
20
25
30
35
Study Group B
P4
P5
P6
Robot
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Study Group C
P7
P8
P9
Robot
0
5
10
15
20
25
30
Study Group D
P10
P11
P12
Robot
0
5
10
15
20
25
30
Study Group E
P13
P14
P15
Robot
0
5
10
15
20
25
Timeline (Minutes)

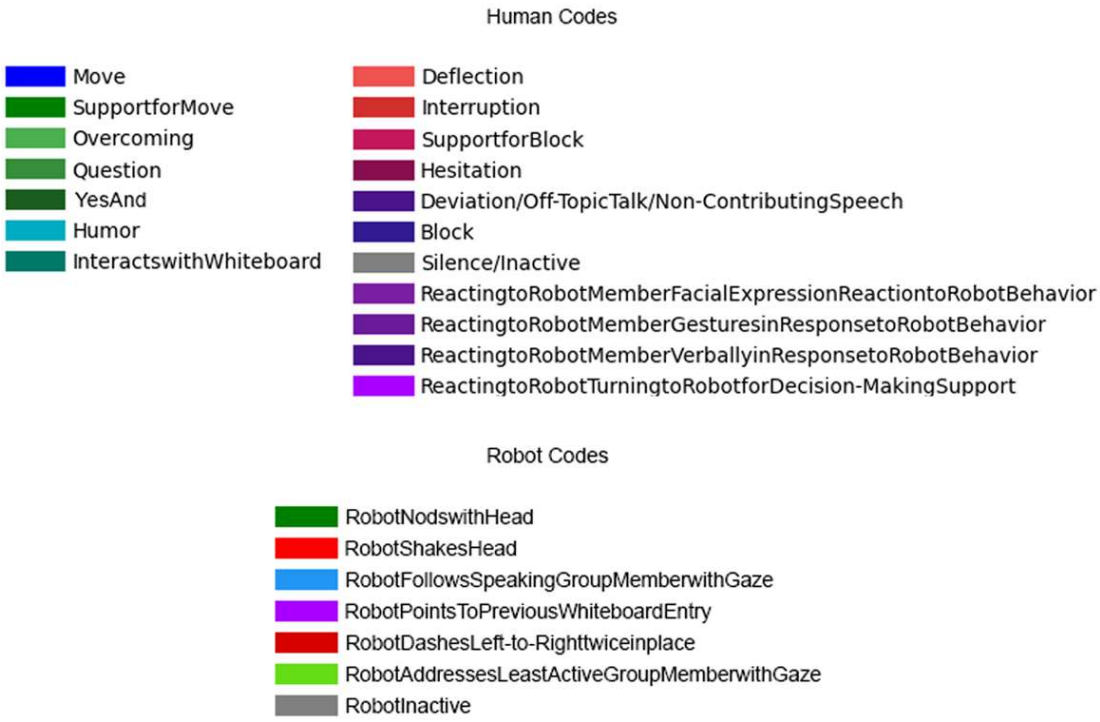


Figure A3: Timeline plots with extended IDN codes for the reference groups 1 and 2 without the robot, and study groups A to E (groups with the robot) engaging in the group ideation task of vacation planning.

A.4 Full Table for Human Responses in the Minute After the Triggered Robot Behavior

Table A4: Human responses in the minute after the triggered robot behavior, by count and shares of occurrence.

Robot Code	Participant Code in the Minute Following Robot Code	Count	Share
RobotFollowsSpeakingGroupMemberwithGaze	Move	26	20%
	SupportforMove	18	14%
	Question	16	12%
	YesAnd	14	11%
	ReactingtoRobotTurningtoRobotforQuestions	11	9%
	Silence/Inactive	11	9%
	InteractswithWhiteboard	10	8%
	Humor	7	5%
	Deflection	4	3%
	Deviation/Off-TopicTalk/Non-ContributingSpeech	4	3%
	ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	3	2%
	Block	2	2%
	Hesitation	2	2%

Robot Code	Participant Code in the Minute Following Robot Code	Count	Share
	Overcoming	1	1%
RobotInactive	Move	17	18%
	SupportforMove	14	15%
	YesAnd	9	10%
	ReactingtoRobotTurningtoRobotforQuestions	9	10%
	Question	9	10%
	InteractswithWhiteboard	7	8%
	Humor	6	6%
	Silence/Inactive	6	6%
	ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	5	5%
	Hesitation	4	4%
	Deviation/Off-TopicTalk/Non-ContributingSpeech	3	3%
	Deflection	2	2%
	ReactingtoRobotMemberGesturesinResponsetoRobotBehavior	1	1%
RobotNodswithHead	YesAnd	15	16%
	SupportforMove	14	15%
	Move	13	14%
	ReactingtoRobotTurningtoRobotforQuestions	9	10%
	Humor	9	10%
	Question	8	9%
	Silence/Inactive	6	6%
	InteractswithWhiteboard	6	6%
	ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	4	4%
	Deflection	2	2%
	Deviation/Off-TopicTalk/Non-ContributingSpeech	2	2%
	ReactingtoRobotMemberGesturesinResponsetoRobotBehavior	2	2%
	ReactingtoRobotMemberFacialExpressionReactiontoRobotBehavior	2	2%
RobotShakesHead	Move	8	18%
	SupportforMove	8	18%
	YesAnd	6	13%
	ReactingtoRobotTurningtoRobotforQuestions	4	9%
	Question	4	9%
	Silence/Inactive	4	9%
	InteractswithWhiteboard	3	7%
	Humor	3	7%
	Block	2	4%
	Hesitation	1	2%
	Deflection	1	2%
	SupportforBlock	1	2%
RobotPointsToPreviousWhiteboardEntry	Move	8	21%
	YesAnd	5	13%
	SupportforMove	4	10%
	Question	4	10%

Robot Code	Participant Code in the Minute Following Robot Code	Count	Share
	Silence/Inactive	3	8%
	SupportforBlock	3	8%
	InteractswithWhiteboard	2	5%
	Block	2	5%
	ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	2	5%
	ReactingtoRobotTurningtoRobotforQuestions	1	3%
	Humor	1	3%
	Hesitation	1	3%
	Deflection	1	3%
	Deviation/Off-TopicTalk/Non-ContributingSpeech	1	3%
	Overcoming	1	3%
RobotDashesLeft-to-Righttwiceinplace	SupportforMove	4	15%
	YesAnd	3	11%
	Move	3	11%
	ReactingtoRobotTurningtoRobotforQuestions	3	11%
	Humor	3	11%
	Deflection	3	11%
	Block	2	7%
	Silence/Inactive	2	7%
	SupportforBlock	1	4%
	Hesitation	1	4%
	Deviation/Off-TopicTalk/Non-ContributingSpeech	1	4%
	Interruption	1	4%
RobotGazesAtLeastActiveGroupMember	YesAnd	2	33%
	Block	1	17%
	SupportforBlock	1	17%
	Hesitation	1	17%
	Question	1	17%

A.5 IDN code combination triplets for groups of three encountered and corresponding group state code

Table A5: IDN code combination triplets for groups of three encountered in the study with corresponding group state code assigned

IDN code combination triplets for groups of three	Group State Code
"Yesand"; "Yesand"; Deflection	Consensus-Building
"Yesand"; "Yesand"; InteractswithWhiteboard	Consensus-Building
"Yesand"; "Yesand"; Move	Consensus-Building
"Yesand"; "Yesand"; Question	Consensus-Building
"Yesand"; "Yesand"; Question	Consensus-Building
"Yesand"; "Yesand"; ReactingtoRobotMemberFacialExpressionReactiontoRobotBehavior	Consensus-Building
"Yesand"; "Yesand"; Silence/Inactive	Consensus-Building
"Yesand"; Block; Question	Consensus-Building
"Yesand"; Deflection; InteractswithWhiteboard	Consensus-Building
"Yesand"; Deflection; Move	Consensus-Building

IDN code combination triplets for groups of three	Group State Code
"Yesand"; Deflection; SupportforMove	Consensus-Building
"Yesand"; Hesitation; Question	Consensus-Building
"Yesand"; Hesitation; Question	Consensus-Building
"Yesand"; Humor; Move	Consensus-Building
"Yesand"; Humor; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
"Yesand"; InteractswithWhiteboard; Move	Consensus-Building
"Yesand"; InteractswithWhiteboard; Question	Consensus-Building
"Yesand"; InteractswithWhiteboard; Silence/Inactive	Consensus-Building
"Yesand"; InteractswithWhiteboard; SupportforMove	Consensus-Building
"Yesand"; Move; Move	Consensus-Building
"Yesand"; Move; Question	Consensus-Building
"Yesand"; Move; Question	Consensus-Building
"Yesand"; Move; Silence/Inactive	Consensus-Building
"Yesand"; Move; SupportforMove	Consensus-Building
"Yesand"; Question; Silence / Inactive	Consensus-Building
"Yesand"; Question; Silence/Inactive	Consensus-Building
"Yesand"; Question; SupportforMove	Consensus-Building
"Yesand"; ReactingtoRobotMemberGesturesinResponsetoRobotBehavior; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
"Yesand"; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; Silence/Inactive	Consensus-Building
"Yesand"; Silence / Inactive; Support for Move	Consensus-Building
Deflection; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building
Deviation/Off-TopicTalk/Non-ContributingSpeech; Move; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Consensus-Building
Deviation/Off-TopicTalk/Non-ContributingSpeech; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Hesitation; Move; Question	Consensus-Building
Hesitation; Question; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Humor; Interacts with Whiteboard; Support for Move	Consensus-Building
Humor; InteractswithWhiteboard; Move	Consensus-Building
Humor; InteractswithWhiteboard; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Humor; Interruption; Overcoming	Consensus-Building
Humor; Move; ReactingtoRobotMemberGesturesinResponsetoRobotBehavior	Consensus-Building
Humor; Overcoming; Question	Consensus-Building
Humor; Overcoming; ReactingtoRobotMemberFacialExpressionReactiontoRobotBehavior	Consensus-Building
Humor; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Humor; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building
Interacts with Whiteboard; Interruption; Question	Consensus-Building
Interacts with Whiteboard; Move; Question	Consensus-Building
InteractswithWhiteboard; Move; Question	Consensus-Building
InteractswithWhiteboard; Move; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Consensus-Building
InteractswithWhiteboard; Move; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
InteractswithWhiteboard; Move; Silence/Inactive	Consensus-Building
InteractswithWhiteboard; Move; SupportforMove	Consensus-Building
InteractswithWhiteboard; Question; ReactingtoRobotMemberGesturesinResponsetoRobotBehavior	Consensus-Building
InteractswithWhiteboard; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building

IDN code combination triplets for groups of three	Group State Code
InteractswithWhiteboard; Silence/Inactive; SupportforMove	Consensus-Building
InteractswithWhiteboard; SupportforMove; SupportforMove	Consensus-Building
Interruption; Overcoming; Support for Move	Consensus-Building
Move; Move; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Consensus-Building
Move; Move; Silence/Inactive	Consensus-Building
Move; Move; SupportforMove	Consensus-Building
Move; Overcoming; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Move; Question; Question	Consensus-Building
Move; Question; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Consensus-Building
Move; Question; Silence / Inactive	Consensus-Building
Move; Question; Silence/Inactive	Consensus-Building
Move; Question; Support for Move	Consensus-Building
Move; Question; SupportforMove	Consensus-Building
Move; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; SupportforMove	Consensus-Building
Move; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building
Move; Silence / Inactive; Support for Move	Consensus-Building
Move; Silence/Inactive; Silence/Inactive	Consensus-Building
Move; Silence/Inactive; SupportforMove	Consensus-Building
Move; Support for Move; Support for Move	Consensus-Building
Move; SupportforMove; SupportforMove	Consensus-Building
Question; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
Question; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building
Question; Silence/Inactive; Silence/Inactive	Consensus-Building
Question; Silence/Inactive; SupportforMove	Consensus-Building
ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforMove	Consensus-Building
ReactingtoRobotTurningtoRobotforDecision-MakingSupport; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Consensus-Building
ReactingtoRobotTurningtoRobotforDecision-MakingSupport; Silence/Inactive; SupportforMove	Consensus-Building
Silence / Inactive; Silence / Inactive; Support for Move	Consensus-Building
"Yesand"; Block; Block	Dissent
"Yesand"; Deflection; Interruption	Dissent
"Yesand"; Deflection; Support for Block	Dissent
Block; Deflection; Humor	Dissent
Block; Deflection; Question	Dissent
Block; Deflection; SupportforBlock	Dissent
Block; Deviation / Off-Topic Talk / Non-Contributing Speech; Question	Dissent
Block; Hesitation; SupportforBlock	Dissent
Block; Interruption; Interruption	Dissent
Deflection; Deviation/Off-TopicTalk/Non-ContributingSpeech; Move	Dissent
Deflection; Hesitation; Humor	Dissent
Deflection; Question; Support for Block	Dissent
Deflection; Silence/Inactive; SupportforBlock	Dissent

IDN code combination triplets for groups of three	Group State Code
Deviation/Off-TopicTalk/Non-ContributingSpeech; Deviation/Off-TopicTalk/Non-ContributingSpeech; Deviation/Off-TopicTalk/Non-ContributingSpeech	Dissent
Deviation/Off-TopicTalk/Non-ContributingSpeech; Deviation/Off-TopicTalk/Non-ContributingSpeech; Hesitation	Dissent
Deviation/Off-TopicTalk/Non-ContributingSpeech; Deviation/Off-TopicTalk/Non-ContributingSpeech; Move	Dissent
Deviation/Off-TopicTalk/Non-ContributingSpeech; Hesitation; Humor	Dissent
Deviation/Off-TopicTalk/Non-ContributingSpeech; Overcoming; Silence/Inactive	Dissent
Hesitation; Hesitation; Hesitation	Dissent
Hesitation; Question; Support for Block	Dissent
Interacts with Whiteboard; Support for Block; Support for Block	Dissent
Interruption; Interruption; Silence / Inactive	Dissent
Block; Overcoming; SupportforBlock	Dissent
Block; Question; SupportforBlock	Dissent
Block; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; SupportforBlock	Dissent
"Yesand"; Humor; Support for Block	Neutral
"Yesand"; Interruption; Silence / Inactive	Neutral
Block; Move; SupportforMove	Neutral
Block; Question; SupportforMove	Neutral
Deflection; InteractswithWhiteboard; Silence/Inactive	Neutral
Deflection; Question; SupportforMove	Neutral
Deviation/Off-TopicTalk/Non-ContributingSpeech; Humor; Humor	Neutral
Deviation/Off-TopicTalk/Non-ContributingSpeech; Move; Silence/Inactive	Neutral
Hesitation; Interacts with Whiteboard; Support for Block	Neutral
Humor; Humor; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Neutral
Humor; Humor; ReactingtoRobotTurningtoRobotforDecision-MakingSupport	Neutral
Humor; Interacts with Whiteboard; Interruption	Neutral
Humor; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior	Neutral
Humor; ReactingtoRobotMemberVerballyinResponsetoRobotBehavior; SupportforMove	Neutral
Humor; ReactingtoRobotTurningtoRobotforDecision-MakingSupport; Silence/Inactive	Neutral
Interruption; Silence / Inactive; Support for Move	Neutral
Overcoming; Silence / Inactive; Silence / Inactive	Neutral
Silence/Inactive; Silence/Inactive; Silence/Inactive	Neutral