Hub types and their translational actions in research meetings: a conversation analytic approach

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Abstract

Background Translation is an indispensable prerequisite for effective functioning in interdisciplinary research teams. However, the translational approach remains largely a black box, with very limited available knowledge on how such an approach can be fostered in practice. By uncovering the foundations of translation in communication, research groups can more readily take action to adapt to the increasingly interdisciplinary research climate.

Methods We recorded and transcribed meetings of the Department of Anatomy and Neuroscience at VU Medical Centre in Amsterdam. We applied both conversation analysis and network theory to identify specific roles in the team, and how these roles relate to each member's position within the meeting, respectively. We constructed a systematic conversation-analytic approach to identify such roles from recorded meetings. We analyzed correlations between these roles, network measures and meeting evaluations.

Results From 11 meetings (~15 hours of recordings), we identified six coherent role patterns that impacted the translational capacity of the meeting. These roles were related to both global characteristics of each meeting, as well as to the individual position of each member in the group. The role that a specific member took on was not correlated with that member's rating of the meeting, apart from the member's understanding of the topics discussed.

Discussion Combining qualitative and quantitative approaches, we show which types of behaviors are of relevance to a group's translational capacity. We also show that the role one takes on within a meeting impacts their position within that meeting. We discuss important implications for interdisciplinary research groups aiming to foster a translational approach.

Keywords: translational science; team science; conversation analysis; graph theory

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Introduction

As modern scientific problems are becoming increasingly complex, researchers rely more than ever on interdisciplinary teamwork to solve them. Interdisciplinarity is defined as "a cooperative team effort motivated by the need to address complex problems that cut across traditional disciplines, and the capacity of new technologies to both transform existing disciplines and to generate new ones" (CohenMiller & Pate, 2019; Lorenzetti et al., 2022). The primary aim of this approach is to integrate knowledge from different scientific disciplines, and thereby achieve a solution to complex problems that cannot be tackled by one research discipline alone. It is integral to distinguish interdisciplinarity from multidisciplinarity. In multidisciplinary teams, researchers work mainly as independent specialists, with occasional overlap in roles and goals. In contrast, interdisciplinary teams collaborate on joint projects, in which boundaries between scientific disciplines are less demarcated (Chamberlain-Salaun et al., 2013; Choi & Pak, 2006). Interdisciplinarity requires not only adding the knowledge of different researchers together, but also recombining respective knowledge in novel ways that foster creativity and practicality for innovative practices (Vestal & Mesmer-Magnus, 2020). In practice, besides providing and adding onto each other's knowledge, interdisciplinarity involves negotiation between the participating fields of study, which each have their own preference with respect to definitions, methodologies and relevant outcomes (Mol & Hardon, 2020).

In the setting of clinical neuroscience, interdisciplinary collaboration fundamentally relies on translational processes, which transfigure and recombine knowledge into novel approaches or ideas. Therefore, the translational approach is defined by a synthetic process in which two different ideas, that seem to be incommensurate, are integrated and together form a solution that is more than the sum of its parts (Mol & Hardon, 2020; Tuertscher et al., 2014). Translation can occur 'from bench to bedside', where it refers to the implementation of

scientific knowledge in clinical practice; from academia to the public; from teachers to students in educational settings; and from within and between research disciplines and research groups. The latter will be the focus of this study. Although translation is integral for researchers to perform in the modern interdisciplinary climate, it remains unknown which communication patterns foster translation 'on the ground' to promote effective interdisciplinary teamwork. Thus, translational science largely remains a 'black box'.

While teams composed of members with different expertise have greater innovative potential, collaborations between scientists are not translational per se, and most teams are not very adept at sharing and integrating their knowledge. This is problematic because without effective integration, their maximal innovative potential may never be realized (Vestal & Mesmer-Magnus, 2020).

To some extent, translational team features have been described before. An extensive literature review identified eight key features of an effective translational team (Lotrecchiano et al., 2021). The most important facilitating factor was a strong trust in competency, benevolence and integrity of all other team members, resulting in the team being perceived as psychologically safe. Other factors included clearly demarcated team roles, team-oriented communication, shared vision, a high capacity of team members to understand complex concepts, flexible and adaptive behaviors contributing to a learning environment, adequate management of meetings, and frequent interdisciplinary collaboration. However, most of these factors are quite abstract and can only be achieved at the team level.

Translation may also be promoted at the individual level by adopting a *'translational attitude'*. Such an attitude is characterized by cognitive openness and self-awareness, passion and perseverance, and proactive facilitation of information exchange (Lotrecchiano et al., 2021). Indeed, openness, humbleness or self-awareness, and a willingness to learn and share one's own knowledge have been shown to improve the performance of interdisciplinary

research teams (Tkachenko & Ardichvili, 2020). Team members may already (subconsciously) take actions that facilitate translation, but such behaviors could also be learned or stimulated, for example through team building activities or by specific interventions (McCormack & Strekalova, 2021; Wooten et al., 2015).

While previous research has focused on which factors are necessary for translation to occur in theory, we aim to discover how these key elements of translation can be established in practice, i.e. in research meetings. Science communication research at the level of team meetings is scarce, and therefore the fundamental processes and discourse that takes place at the root of scientific knowledge and innovation is often obscure (van der Sanden, 2016). To this end, we combine qualitative and quantitative approaches to investigate translational communication processes within research groups.

Communication within meetings is a prime example of a phenomenon that can be elegantly modeled and visualized in terms of a network. In this network, each team member is a node, and their respective connections are edges. Network theory provides an excellent framework to relate individual team members' turn-taking during meetings to the overarching structure of the meeting as a whole. However, to analyze the contents of discourse, and thereby establish what roles people fulfill in the meetings, we will additionally take a conversation analytic approach to analyze the data. This method allows us to study which actions people perform with their communication, how they are received by team-members, and consequently also how these actions relate to translation.

By combining these two approaches, the current paper will consider how translation can be 'unpacked' from communication within interdisciplinary research teams. In this way, we aim to characterize how knowledge from various fields of expertise can be translated and integrated, thereby stimulating effective interdisciplinarity in practice.

Methodological framework

Network theory

Network theory is based on the mathematical framework of graph theory, although both terms may be used interchangeably. Network theory views systems as networks, consisting of nodes that are interconnected through edges (Euler, 1741). Network theory is often used in the context of neuroscience, but as it relies on fundamentally mathematical concepts, can be applied to any other system with network-like organization, of which group-level communication is a prime example (Bassett & Sporns, 2017; Kostic et al., 2020; Sporns, 2018). Network theory allows to visualize meeting structure by quantifying turn-taking during a research meeting, and therefore is a useful tool in this context.

Conversation analysis

Conversation Analysis (CA) is an inductive approach to analyze naturally occurring talk-in-interaction. It assumes that there is an underlying social organization in all talk, through which orderly and intelligible social interaction is made possible (Sacks, 1992). One of the most important aspects of CA is that it orients to talk as actions. Therefore, CA is not focused on what people say, but on what people "do" or achieve with what they say. Translation, in this case, then should not be considered as an abstract component that might accompany some exchanges between researchers, but as something people can actually *do*.

CA is committed to examining the details of actual events, rather than analyzing stipulated data or simulated data. This makes it possible to research what actually happened in the conversation, rather than the meaning of utterances being attributed afterwards. In this respect, CA allows research to stay close to the activities as they are naturally organized by the participants themselves (Hoey & Raymond, 2022). Moreover, working with audio data allows these interactions to be analyzed in great detail, as also minor elements of interaction, which

would normally go unnoticed, are captured and analyzed (Hoey & Raymond, 2022). The next-turn-proof procedure also allows CA to stay close to activities as they are organized by the participants themselves. Here, the analyst checks the correctness of their interpretation against co-participants' interpretation as expressed in the subsequent turns. These turns should provide proof that the analysts' interpretation is correct (Sacks et al., 1974). In this context, this means that assumptions as to whether utterances might have translational properties are based on the uptake of the members of the research team. For example, if someone makes a suggestion based on the integration of different knowledge-forms, it can only function as a translational action if the other person also responds positively to this suggestion. Consequently, translation will be investigated as an interactionally established phenomenon, rather than something that can be established by one person themselves.

Because of the properties described above, CA has proven itself an effective method to translate abstract communication concepts, such as for example "empathy" or "rapport" into concrete actions that happen at the conversation-level (Heritage, 2011; Prior, 2018). Consequently, CA was evaluated as a very appealing method to research how translation is interactionally established in research-meetings.

Methods

Data collection

From 2017 to 2019, 65 research meetings from the Clinical Neuroscience research section of the department of Anatomy and Neurosciences at Amsterdam UMC were recorded. This multidisciplinary research group consisted of 26 members, most of whom had a background in neuroscience and neurobiology. Further, team members' expertise extended from the fields of neuroimaging, pathology and neurophysiology, neuroimmunology, psychology and psychiatry, to movement and health science, medicine, philosophy, artificial intelligence, computational science and biomedical engineering.

Each of the recordings was replayed by one of the department members to perform voice recognition, who listed turn-taking by each of the team members in chronological order using time stamps. Using these lists, 11 of the 65 recorded meetings were transcribed. This was done manually for a number of reasons. First, there was limited freely accessible software available to automatically transcribe spoken language in Dutch. The few options that were available yielded such qualitatively bad transcripts that we opted to transcribe the meetings manually instead. Second, automatic transcription software did not automatically perform voice recognition. Third, automatic transcription software skipped over small utterances that may have seemed insignificant, but were critical for our analysis using the next-turn-proof procedure. For example, if a suggestion was replied to with a confirming 'mm-hm', then this would prove the suggestion to be considered valid by at least one team member; however, available software did not pick up on these subtle utterances.

Because all meetings were in Dutch, and because the speakers lists and transcripts were not anonymized, transcripts will not be published apart from some illustrative examples in the Results section and Supplementary Data.

After every meeting, an evaluative survey was distributed among all present department members, asking them to rate the meeting on multiple aspects, using a 5-point scale in all but one item, which was rated on a 3-point scale. The items included in these meeting evaluations are provided in Supplementary Materials 1.

By analyzing naturally occurring speech in the research meetings using CA, we aimed to identify, characterize and describe different communication-specific role patterns that may contribute to translation, which we dubbed 'hub types'. Further, we aim to use graph theory to quantify the importance of each of these hub types within the meetome, and to evaluate their impact on the translational capacity of the meeting.

Study procedures

Initially, six hours of audio material were collectively and exploratively discussed among all authors, to identify actions that we believed contributed to the translational capacity of the meeting. Such actions included, but are not restricted to, directly addressing another member or the entire group with a question or task; formulating a problem or idea and inviting input; relating a proposed idea to previous ideas or own experience; asking for more explanation; proposing solutions to proposed problems; explaining phenomena, ideas or methods; being critical of someone's statements; and many more. Using the insights from these explorations, we extracted the actions implied in speech and related them to one another to form coherent role patterns for specific team members, which we dubbed 'hub types'. As we analyzed more transcript data, this classification of hub types was expanded on and fine-tuned according to the principles of conversation analysis. To ensure consistency and reproducibility of our method, we implemented a systematic approach, described in the following section.

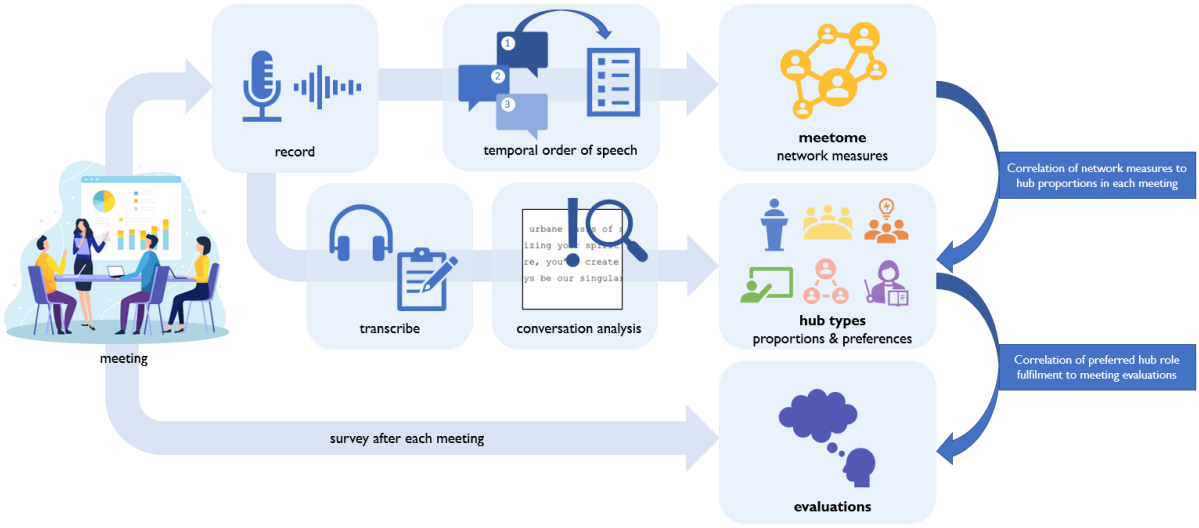


Figure 1. Overview of study procedures

Six of the eleven transcripts, corresponding to about eight hours of audio material, were analyzed in full detail. First, taking on a conversation analytic approach, we marked all turns that significantly contributed to a more fruitful discussion or allowed a window of opportunity for translation to occur. We did so by using the next-turn proof procedure, as explained previously. In the context of our study, this meant that the assumptions as to whether utterances might have translational properties were based on the uptake of the members of the research team themselves. For example, a question was deemed important if other team members reacted to it as such, by for instance starting a new discussion, defending their previous position or engaging the help of others to answer the question. However, if the question was ignored or otherwise disregarded by the rest of the team, it was not deemed important.

Second, all important utterances were labeled as a particular action that was implied in the speech, e.g. summarizing, challenging the speaker, asking clarifying questions, etc.

Third, sets of actions that together formed a coherent behavioral pattern, were merged into hub types. Finally, based on the hub type to which the majority of a team member's utterances corresponded, team members were classified as specific hub types or as non-hubs within each

meeting. As such, we could conclude who fulfilled key roles in each meeting, and in what way. We also calculated per meeting the relative presence/strength/frequency of occurrence of utterances that were specific for each of the hub types (total no. of hub-specific utterances / total no. of translation-relevant utterances).

Finally, we calculated the relative proportions of hub-like utterances for each team member across all meetings (total no. of hub-specific utterances / total no. of translation-relevant utterances), and in such identified their preferred hub type. Here, we assumed that the hub type to which most of one person's utterances corresponded, was their preferred hub type.

Inter-rater reliability

To evaluate the agreement between two independent raters (authors Antvelink and Bet) on which utterances should be marked as important, we calculated the intra-class correlation coefficient (ICC) over a dataset (one transcript) consisting of 605 utterances in total. We used a two-way mixed effects model for the inter-rater reliability, as the raters were fixed and the utterances were random. We performed two calculations of the ICC; the first was calculated over each of the raters' independent analyses of the same dataset, and the second was calculated after raters had compared their respective analyses, and had exchanged their ideas about the meaning, function and relevance of certain utterances.

Network theory

Most social systems are structured as a network, and can thus be described using connectomics. Connectomics refers to the study of connectomes, i.e. any real-life system that can be described as a connected network including nodes and edges. Research meetings described according to the principles of connectomics, i.e. represented as a network, will be referred to as 'meetomes' throughout this work; the **meet**ing's connect**ome**. A meetome in this context is a network representing a research meeting, in which nodes correspond to team

members, and edges correspond to the respective interactions between team members. Specifically, these interactions are defined by the chronological order of speaking turns, i.e. in what sequence people follow up on each other's speech. Thus, if node A produces an utterance, and thereafter node B produces an utterance, then node A and B share an edge weight of 1, irrespective of whether node B's utterance was intended as a response to that of node A or not. Within a meetome, the weight of an edge between two members represents the sum of all occurrences where node A spoke after node B or vice versa (Figure 2).

Depending on the communicative processes in the underlying system (the meeting), the general organization or *topology* of a communication network (meetome) can vary tremendously. The topology of a network can be quantified using various properties, called network measures. Network measures are mathematically defined, but do not intrinsically have meaning in the system that the networks describe; these meanings have to be attributed through general consensus in the corresponding scientific discipline. In the context of our study, namely group communication, there is currently no standard for the meaning that should be ascribed to network measures. However, in the following sections, we will describe network measures in terms of network theory and their meaning in the field of neuroscience, to provide some context. In our study, we used network measures to evaluate whether the relative occurrence of hub-specific actions in each meeting could impact the network topology of a meetome.

Network measures

Most networks exhibit a tendency to be organized as a collection of smaller subnetworks or modules, which is described by the global measure of *modularity* (Sporns, 2018). In communication networks, this represents certain groups of people who have a higher tendency to respond to one another than to the rest of the group, and this may be linked to certain topics being discussed, which are relevant for some members but not for others. Throughout a meeting, not all members will follow up each other's turn, and therefore, some pairs of team

members will not show a direct connection in the meetome. Instead, such members exchange information via an extra step, i.e. a third member that is connected to both of them. The steps taken between two non-connected members together form a path through the meetome (Figure 2). The length of the **shortest path** between any two members holds information about the efficiency of node-to-node information flow through a network. Therefore, we measured **global efficiency** as the mean of all shortest path lengths taken together, representing the global capacity of a meetome to transfer information via short paths (Sporns, 2018).

Besides the global hub proportions that indicate the relative occurrences of each hub type within a meeting, we calculated individual tendencies to exhibit hub type-specific actions. These tendencies were expressed as the ratio of hub type-specific actions over the total number of utterances for any given team member. These hub tendencies were then correlated to local network measures, i.e. local efficiency, nodal strength, participation coefficient, betweenness centrality, and within-module degree.

Local efficiency reflects a node's integratory capacity at a local level, for example within a module (Figure 3). The **participation coefficient** indicates a node's tendency to link to nodes outside of its own module (subnetwork), instead of nodes inside its own module. Thereby, it measures the diversity of connections that extend beyond a node's own module (Acharya et al., 2022). The centrality of a node's position in the entire network can also be measured, for instance through **betweenness centrality**. As touched upon before, non-connected nodes exchange information through shortest paths that run through other nodes. Betweenness centrality represents the number of shortest paths in the network that pass through a specific node, and thereby indicates the centrality (i.e. importance) of a node in a network (Sporns, 2018). Betweenness centrality is often used to determine whether a given node is a **hub**. Hubs are highly connected nodes in the network, i.e. featuring a high number of connections (high **degree**) with high/heavy/strong weights (high **nodal strength**), that are

thought to be key integrators of information in the brain, and often are connected to each other, thereby forming a so-called rich club (Bassett & Sporns, 2017; van den Heuvel & Sporns, 2011, 2013). Although the meaning of hubs within the context of communication is undefined up until now, hubs may fulfill similar roles within meetomes, as they likely have a more profound impact on communication patterns and general meeting structure than non-hubs. Hubs may fulfill various roles within a meeting, and thereby fundamentally impact translational processes in the meeting as a whole.

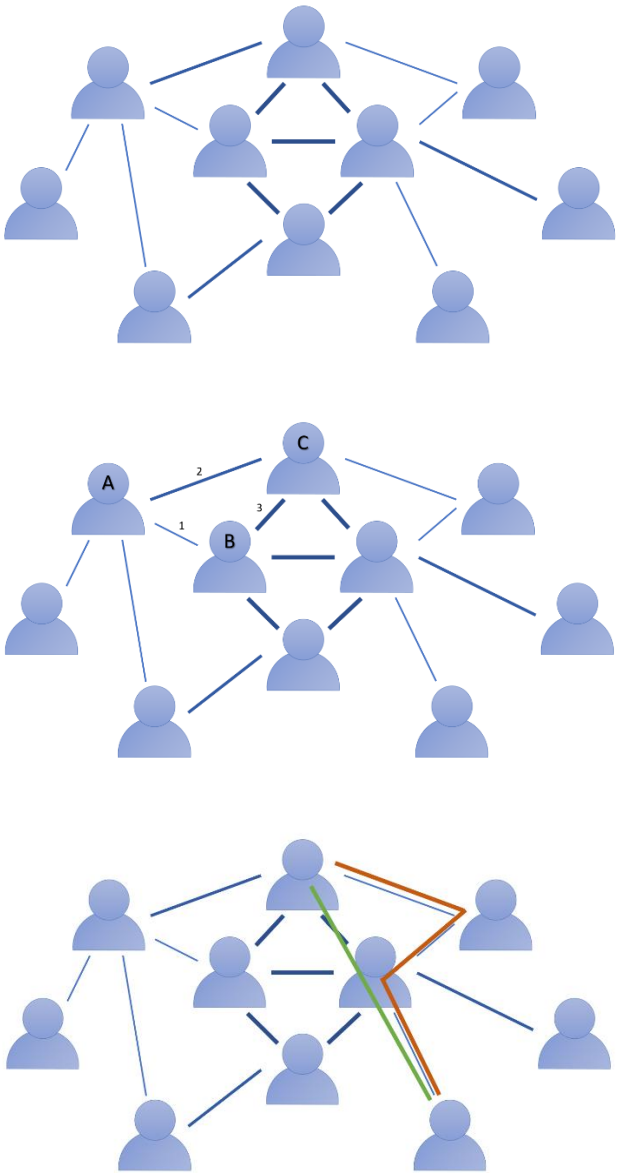
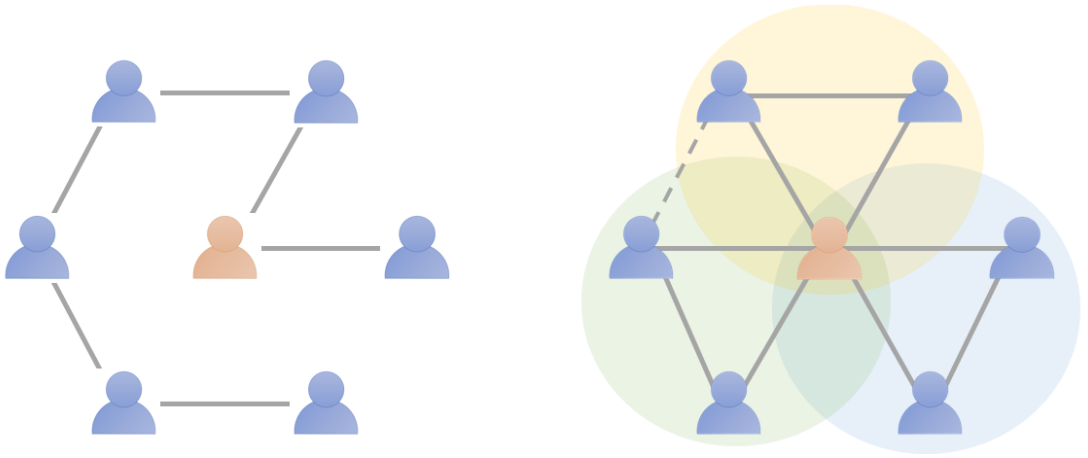


Figure 2. Example of a meetome. (A) Nodes correspond to team members, and edges correspond to their respective interactions, which can vary in interaction partner and in interaction strength. (B) Interaction strength, i.e. edge weight, depends on the number of shared interactions between two interaction partners. For instance, there are more interactions between B and C than between A and B, so the weight of the edge connecting B and C is higher than that of the edge connecting A and B. (C) Although there are multiple paths from node A to node B in the network (i.e. red), the shortest path (green) is the most informative with respect to efficiency of information transfer within the network.



Globally:		**Globally:**	
Low modularity	no submodules present in the graph	High modularity	3 submodules (yellow, green, blue)
Low efficiency	long average distance between nodes (1-6)	High global efficiency	short average distance between nodes (< 2)
Locally (red node):		**Locally (red node):**	
Low degree	only connects to 1 other node	High degree	connects to 6 other nodes
Low local efficiency	only receives input from 1 node	High local efficiency	integrates input from all other nodes
Low betweenness centrality	only few shortest paths through red node	High betweenness centrality	almost all shortest paths through red node

Figure 3. Network topology and corresponding network measures. On the left, even though the red node is centrally placed in the network, it cannot be considered a hub, as it does not integrate information from multiple nodes and clusters of nodes. On the right, the red node integrates information from many surrounding nodes, and is a crucial gatekeeper for inter-module communication. Therefore, on the right, the red node can be considered a hub.

Results

Conversation analytic hub type classification

Based on exploration of 11 transcribed research meetings, we have constructed six clusters of recurring and coherent interaction patterns, which we termed hub types. It was found that all important utterances could be characterized as one of the actions listed in Table 1, indicating that this provides a close to complete classification of actions and roles that are relevant for translational science, or at least in the context of these specific research meetings. The following sections provide a detailed description of each hub type.

The most prominent hub is the **chair**. This person is typically the group leader, and can easily be recognized as the one that takes charge of the agenda, decides which topics are discussed, and determines who gets the turn to speak. Interestingly, the chair will notice when people get interrupted or talked over, and (re-)allocate the turn to the previous speaker. Hereby, the chair pursues equivalent importance of all group members in the discussion, which is important to facilitate information exchange / interaction between disciplines. Further, the chair occasionally quizzes the group and delegates tasks. But most importantly, the chair encourages and compliments team members on their performance, while keeping the group oriented toward long term goals and the bigger picture. Thereby, the chair is an important determinant for the atmosphere within the research meeting. Fitting with this characterization is the fact that we noticed that the chair often jokes, particularly after exhibiting behavior that could be interpreted by other team members as bossy or hostile. The main goal of the chair is to produce high-quality research that is innovative and of high scientific relevance. To bring out the best in each of the team members, especially in terms of stimulating input from different perspectives and disciplines, the chair must maintain a balance between a stimulating research environment and a safe space in which every team member can comfortably express themselves and their ideas. The chair is arguably the most important determinant for the group's translational capacity.

Excerpt 1. Example of the Chair

After a long discussion that emerged following someone's research presentation, the chair makes a move to close the subject.

Jeremy: "Okay Marianne. We have had quite some discussion within the group, and also among the department, which is very nice I think because with that you perfect your research. Do you have enough input to go on?"

In addition, two hub types are characterized by asking a lot of questions, but the way in which they do so is fundamentally different. On the one hand, we have characterized the **clarifier**; this person asks a lot of open questions that invite the speaker to clarify or expand on a subject. In our data, the role of clarifier is fulfilled by the highest number of individual team members throughout the meetings. Team members typically take on this role when they do not fully understand the topic under discussion, or when they are curious to know more. This is usually the case for members that do not share the same background as the speaker, and therefore the clarifier showcases typical interdisciplinary behavior. The clarifier orients to the knowledge of the speaker, and aims to increase their own understanding of the subject. In doing so, they create a window of opportunity for the rest of the group to ask any questions they have, or to provide their own view on the matter. Additionally, clarifiers provide natural 'checkpoints' to summarize the information shared thus far, and to ensure that the group can continue forward in the discussion on the same level of understanding. This deepens the collective understanding of the topic under discussion. Thereby, the borders between disciplines within the research group can begin to fade and the multidisciplinary team can progress more readily to an interdisciplinary approach.

Excerpt 2. Example of the Clarifier

Simone asks a clarifying question after a presentation on a new type of treatment for leukemia. Here she orients to the knowledge of the other. Furthermore, by asking this question, one of the most important aspects of this new research is highlighted, making it an effective clarifying question.

Simone: "And, do you think that, how, kind of, how much more effective [than chemo-treatment] would this [treatment] be, you think, or would you not know?"

On the other hand, we identified the **skeptic**, someone with a skeptical attitude who poses challenging questions. These questions are not meant to further their own understanding of the subject matter, but are rather asked with the intention to test the speaker on their knowledge of the subject, the validity of their research methods and underlying assumptions, and the scientific relevance and implications of the results. The skeptic approaches newly presented information from their own (sizable) knowledge base, which they use to measure the quality of the presented research. Although these actions may challenge the credibility of the speaker and occasionally catch them off guard, thereby posing a potential threat to perceived psychological safety, they can be beneficial for translation. This is the case, as they evoke discussion and critical thinking among all present team members, and thereby ensure high quality of research output.

Excerpt 3. Example of the Skeptic

After a colleague has presented their research, the skeptic intervenes by saying that some of the terms used can be interpreted in many ways and asks for a specific definition.

Ben: "You use a lot of container concepts hè. Lesion is a typical container concept. Of course, a lot is packed in there, but the question remains, what do you mean with lesion?"

Fourthly, it was observed that some people acted as an **expert**. Whenever a speaker struggles to satisfactorily answer a question, or when there is general confusion on the state of affairs during a meeting, the expert intervenes. In such cases, the expert explains the topic and answers the question under discussion, so as to dissolve the confusion and commotion. Notably, the expert is not specifically asked for their input; they decide to intervene on their own accord, confident that they have the expertise needed to resolve the issue at hand, because it concerns a research area that they are specialized in. The expert hub may correct others or even criticize their statements, and does so in a very matter-of-fact way. Like the skeptic, the expert orients toward their own knowledge, but rather than testing the presenter, the expert aims to support the presenter and to resolve uncertainty. Interestingly, we observed that the rest of the group acknowledges the expert's superior knowledge by accepting their explanation as the definitive answer to the question at hand. Therefore, experts often close off conversation topics and allow space for new topics to emerge in the meeting, all while teaching the group more about the subject under discussion.

Excerpt 4. Example of the Expert

When Stacy is explaining how she can calculate Z-scores for her research, Lorie, in an expert-role, steps in to slightly correct Stacy to prevent confusion for the group. Later, she even asks Stacy to explain what the pros and cons are of the two methods, to ensure that these are also clear for the rest of the group.

Stacy: So, the local method uses regressions, and the clinical method is, well, is it's its whole own thing.
Lorie: Well, it's just, they both generally use regressions, but here we often use local control measures. […]
Stacy: Yeah, so solely to just make a choice [regarding] which method we will use to do this, I got the correlation coefficient-
Lorie: And could you maybe still explain the pros and cons of each method? Because I am still not sure if everybody has a clear picture of the difference.

We have also observed a few instances of the **connector** hub type. This hub type's main aim is to connect, in the broadest sense of the word. For instance, connectors tend to involve others into the conversation, and may even explicitly invite them to provide their input. Further, the connector might come up with metaphors or innovative ways of understanding certain phenomena. The connector also draws parallels between different studies, for example by comparing methods, pointing out similarities or dissimilarities between conceptual frameworks, and by relating research findings to previous literature. Connectors point out striking aspects of a story and associate them to other work or other encounters that they have experienced. Thereby, the connector can facilitate the exchange of information between disciplines, and thereby an interdisciplinary way of working. We even observed one instance where a connector proposed to bring a team member in contact with an acquaintance of theirs, and suggested they collaborated on a topic that they were both doing work on. All in all, this person has a very direct and explicit role in building the bridges that are required for interdisciplinary teamwork to occur. However, connector-like actions were least frequently observed in our analyzed meetings.

Excerpt 5. Example of the Connector Hub

Will is discussing some of the results of his research. Here the connector, Leonard, jumps in, to propose a possible conclusion of some of his results. Will's answer showcases that Leonard remark has provided him with new insights into his research.

Leonard: So, since that isn't the case, you could say that the immunization doesn't have an effect on the status of your synapses.
Will: Ehm… Yeah, yeah, I'd never thought of it like ehh… Yeah, never really thought about it, but yeah, maybe yes.

Finally, we have observed a few instances of what we call the **practical Joe**. This person is very solution-oriented, and has some similarities to the expert, as they are both clearly knowledgeable on the subject and intend to help the speaker. However, whereas the expert helps to clarify a topic or a problem, the practical Joe proactively proposes a concrete solution to the issue being proposed. The practical Joe is typically 'activated' when the speaker proposes a problem or explicitly asks the group for feedback or how to continue. They will then step forward to explain concisely how the speaker should approach the problem that they have raised, and occasionally literally reassure them that it will be okay. The practical Joe's suggestion need not be accepted as the go-to answer by the rest of the group, as the practical Joe just focuses on helping out the speaker, and is only interested in their response to their proposed solution. The practical Joe offers help in the form of advice ('I would…'), tools ('I have a script that does that…'), or proposing step-by-step solutions ('If you do X, you can then do Y and thereby achieve Z'). Another important function of the practical Joe is to reassure the speaker that their problem can be fixed, and that they will be helped. So besides making research practice more efficient, the practical Joe can contribute to a sense of trust and solidarity in the group, increasing psychological safety.

Excerpt 6. Example of the Practical Joe

After someone has suggested Marianne could use a specific technique to map her results, she signifies that she does not fully understand how to do that yet. Here, the Practical Joe, in this case Will, steps in to offer practical help. With Marianne's acceptance the topic is closed, and hence does not need to take up valuable group discussion time anymore.

Marianne: What do you do then?
Will: We can have a look at it at it this afternoon.
Marianne: Okay, nice.

Just as hub types are not necessarily restricted to one person, people are not necessarily bound to one hub type, but are dynamic in the roles they take on, among other things depending on their affinity with the topic under discussion or their respective relationship to the speaker (e.g. supervisor). However, we did notice that most team members show a preference for a specific hub type. Also important to bear in mind is that hub type-specific actions do not necessarily contribute to the meeting in a positive way. For example, when the critical questions of the skeptic become too many or too detail-focused, they may slow down the conversation and consume precious meeting time over relatively irrelevant details. Or conversely, the connector might draw a connection that is not relevant for the majority of the group or distracts from important core topics.

Inter-rater agreement

To ensure reproducibility of our conversation analytic method as described above, we evaluated inter-rater agreement by means of the ICC. Two raters classified each of 605 utterances of a random dataset as containing an implied action that may be important for translation, or not. We calculated the ICC using a two-way mixed effects model, for the raters are fixed and the data (utterances) are random. This yielded a 'strict' ICC of 0.765 (95% CI 0.736-0.791). After consultation, i.e. discussing the reasons behind marking utterances as important, and their attributed meaning and consequences, the ICC increased to 0.966 (95% CI = 0.962-0.971). Strikingly, before conferring with one another there was a 100% consensus on the action implied in the utterance that was found important by either one of the raters. Thus, our hub classification also rendered 100% consensus on the hub type as which utterances were labeled.

Network analysis

We found that both global and local network measures correlated with the proportions of hub-specific utterances in the meeting. A strong chair-like presence, i.e. high relative proportion of chair utterances, was associated with higher modularity in the meetome (r = .814, p = .049). However, none of the hub type proportions correlated significantly with global efficiency.

On an individual level, skeptic utterances were associated with higher local efficiency (r = .342, p = .030) and higher nodal strength (r = 0.400, p = 0.033). Connector hub utterances were associated with higher local efficiency (r = .366, p = .012), as well as with higher within-module degree (r = .369, p = .012) and higher betweenness centrality (r = .338, p = .036). Practical utterances were associated with a higher within-module degree (r = .350, p = .024) and higher betweenness centrality (r = .410, p = .003).

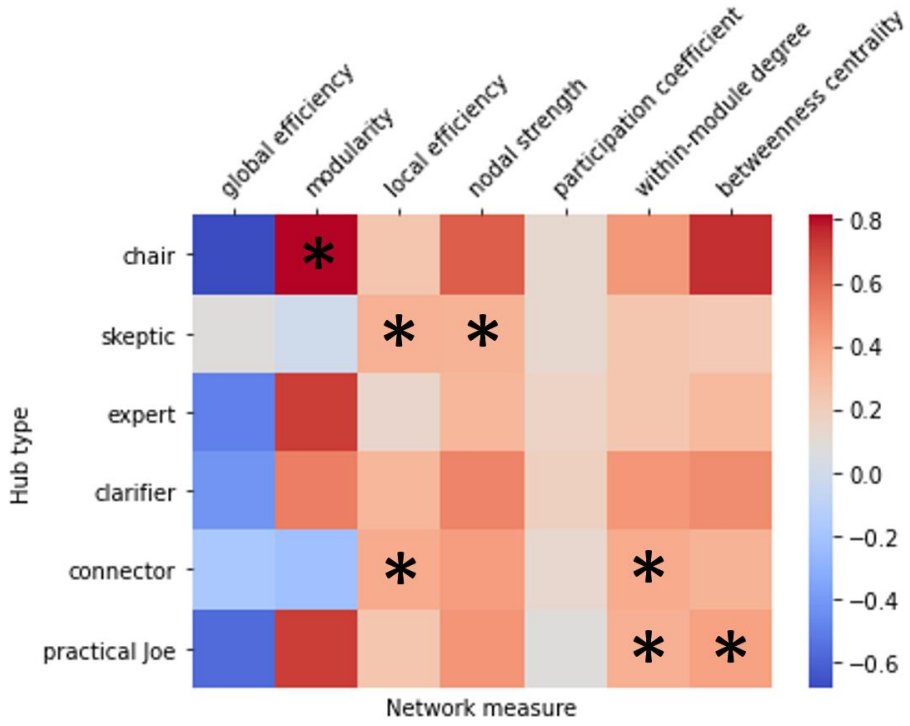


Figure 4. Correlations between network measures and relative proportions of hub proportions. Important to note is that for global measures, hub proportions were calculated per meeting, however, for local measures, hub proportions were calculated per person.

Correlations to meeting evaluations

Correlating meeting evaluations to the roles that people fulfilled during the meeting (incl. weight indicating frequency of hub role activity). It appears plausible that people would rate a meeting as more interesting, educational or fun when they were able to fulfill their preferred role. The correlations that we found between the relative prevalence of each hub type and the outcomes of an evaluative questionnaire are presented in Figure 5. Although there appeared to be some trends in the correlations, none of the items was significantly correlated to preferred hubness.

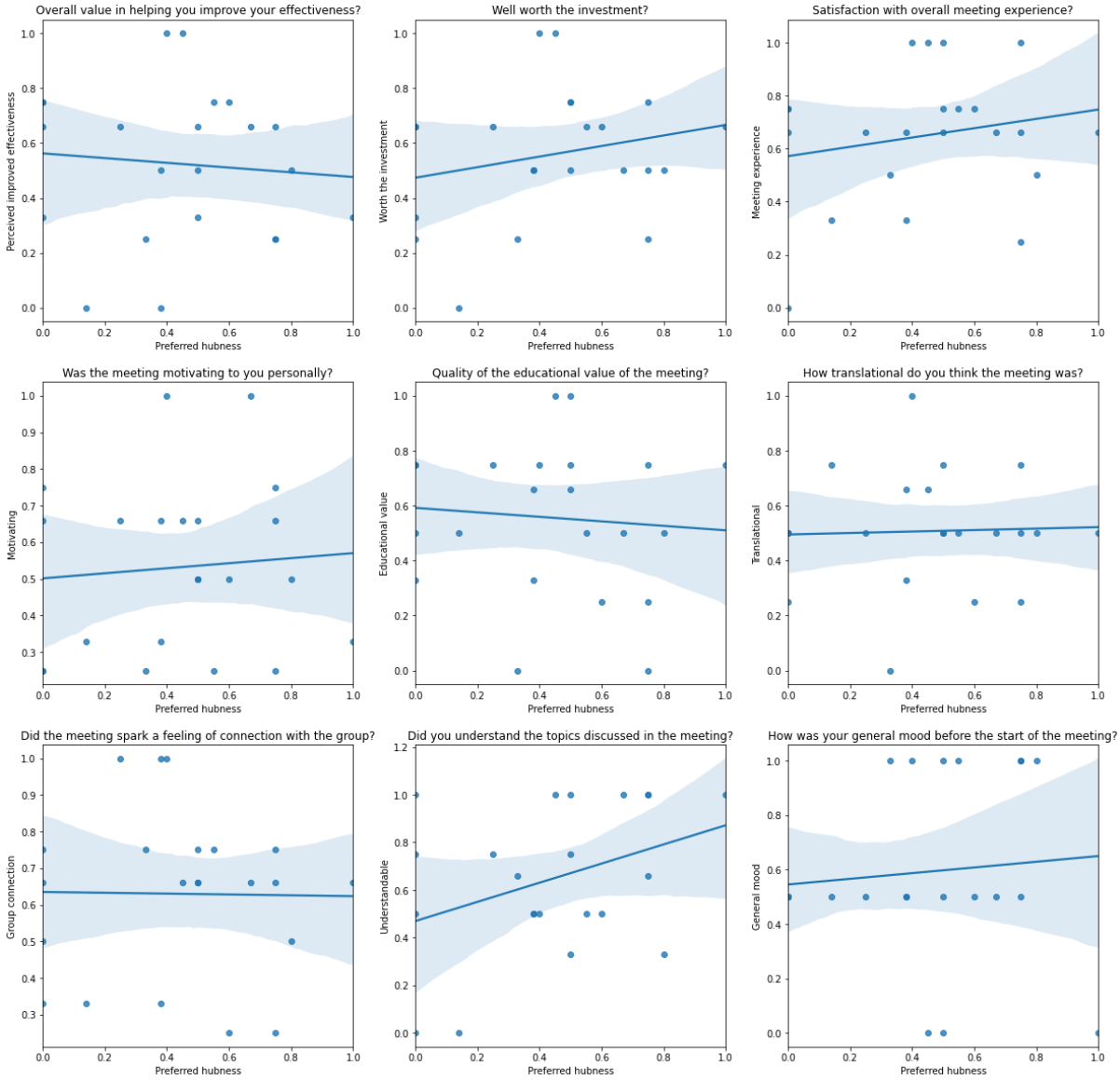


Figure 5. Correlations of preferred hubness to meeting evaluations. Preferred hubness reflects the extent to which team members showcased actions that were typical for their hub type of preference.

Discussion

Based on the communication patterns that we consistently observed in our dataset, we described six hub types, each with a specific set of typical actions, providing a fingerprint of communicative behavior throughout the research meetings. These roles were the chair, the connector, the clarifier, the expert, the critic, and the practical Joe. These hub types provide a reference framework of actions and behaviors in small research groups that contribute to translation at the root of scientific collaboration and innovation.

Further, we propose a methodological framework to analyze the translational capacity of research meetings, and to extract the ways in which translational science occurs in natural language in research settings. Our methodology provides a standardized way to characterize hub roles in any research meeting. In future studies, this may help to evaluate or predict a team's performance and translational capacity.

Some important remarks should be made concerning the results we described here. First, hub types are not necessarily restricted to one team member; multiple team members may very well take on the same type of hub role within the same meeting. Similarly, people are not necessarily bound to one hub type, but are dynamic in the role they take on. This may depend on their affinity with the topic under discussion or their respective relationship to the speaker (e.g. supervisor), among other things. Thus, in future analyses, it would be interesting to investigate whether hub flexibility, i.e. readily switching between hub roles throughout a meeting, could improve meeting outcomes.

Group dynamics and expectation patterns are integral in determining team member's roles. For example, if no one dares to make a critical comment about questionable research, then this role is reserved for the boldest team member present. Moreover, the uptake of certain utterances by the rest of the group determines the validity and the impact of an utterance. For example, in the case of the expert, if the utterance results in consensus and closure, it was

successful, but if the rest of the team does not accept the utterance as the final answer, then a new discussion emerges and possibly more confusion is created.

Despite the dynamic nature of hub types, we noticed that most team members show a preference for a specific hub type and will take on the opportunity to fulfill that role in most cases. This may explain why the meeting evaluations obtained for all team members were very heterogeneous; ratings on all survey items ranged from very bad to very good within every meeting. Therefore we hypothesized that if team members are able to occupy their preferred niche in the meeting, then they might rate the meeting more positively. However, our correlation analyses showed that the extent to which a person occupies their preferred niche only correlates with the extent that that person understood the topics under discussion. This indicates that occupying one's preferred role within a meeting does not necessarily make that meeting more enjoyable for that person.

Not only do team members show a preference for one specific hub type, there are also clear individual differences between the ways in which team members fulfill a certain hub role. For instance, one team member typically preferred the clarifier role, but occasionally acted as an expert. In cases where the PhD candidate that they supervised was presenting and was confronted with critical and harsh questions, they would take on the expert role in such a way that they could defend their student. Such an instance occurred twice, and we did not see any other team member use the expert role in this way. Therefore, it is important to keep in mind the individual differences that add on to this crude classification of people's actions and contributions to the meeting.

Roles were very much dependent on the topic under discussion and the patterns of hierarchy and group dynamics. For instance, when there was a pressed or tense atmosphere, often only senior members would speak. Then, after someone made a joke, the atmosphere was

lightened and then, more junior members would join in again. However, this trend was not apparent enough to include in the model proposed here.

Considering the extensiveness of the dataset, the agreement between two independent raters on the hub classification per utterance was remarkably high. This showcases that it was clear to the raters which utterances positively contributed to a meeting and which actions they implied. Thus, our proposed method is consistent enough to systematically and reliably analyze any new transcript. This method may be used in future research to further investigate translational communication, to adapt our classification to specific types of research teams, or alternatively, as an evaluation tool for individual research teams to explore how translation occurs within their research meetings.

Although previous research on the translational approach within research teams is scarce, various studies have used qualitative approaches and systematic literature searches to identify factors that are crucial for effective interdisciplinary teamwork (Lorenzetti et al., 2022; Nancarrow et al., 2013; Salas et al., 2005; Tkachenko & Ardichvili, 2020). The factors identified in these studies are remarkably similar, and relate to the hub types identified here in various ways. First, effective teams need a supportive, encouraging and facilitating leader who listens to team members and establishes a clear vision for the team (Lorenzetti et al., 2022; Salas et al., 2005; Tkachenko & Ardichvili, 2020). Thus, chairs aiming to implement a translational approach should possess these qualities. In addition, the chair should ensure that the team composition is balanced in terms of knowledge, skills and seniority (Nancarrow et al., 2013; Tkachenko & Ardichvili, 2020). If most team members share the same background, then team members' marginal knowledge is largely redundant and the team is not diverse enough to effectively recombine expertise, thus interdisciplinarity cannot be achieved. Conversely, if the team members have very little expertise in common, team members will not possess the shared knowledge necessary to absorb and make use of one another's expertise (Vestal & Mesmer-

Magnus, 2020). In teams with diverse backgrounds, experts are crucial to establish a common ground of knowledge.

Further, a psychologically safe environment should be fostered in which there is mutual trust and solidarity, openness and appreciation of contributions, and shared values and goals that facilitate a team-oriented mindset (Lorenzetti et al., 2022; Salas et al., 2005; Tkachenko & Ardichvili, 2020). Whereas the chair is mostly responsible for aligning values amongst team members, hub types other than the chair can significantly contribute to a safe environment, for example by asking open questions and accepting answers without judgment (clarifier), and by reassuring the speaker and offering support (practical Joe). Another important factor that contributes to a safe environment is team members' capacity for adaptivity, and their willingness to be flexible and help each other out (Salas et al., 2005). This is reflected in various hub actions, for example through bridging knowledge and sparking discussion to come up with answers or solutions (connector, clarifier), or directly offering one's own help in reaching a solution (practical Joe). Closely related to this are communication strategies that promote effective team processes (Nancarrow et al., 2013; Salas et al., 2005). This involves closed-loop communication so that team members are sure to get an appropriate answer to any questions they have. Further, it involves remaining up to date of team members' respective tasks to facilitate mutual performance monitoring and readily intervening (Salas et al., 2005). This is again mostly facilitated by the chair, although other senior members in the team may also help.

Previously, an 'organization joker' has been described as an assumed social position that propagates humor within the workplace. This has been described to relieve tension and to (temporarily) subvert hierarchical patterns, among other things (Plester, 2015; Plester & Orams, 2008). In our meetings, we noticed that the chair occasionally used humor to lighten the atmosphere from time to time, but this was not to such an extent that our CA method characterized it as an independent hub type. Strikingly, in absence of the usual chair, the team

member who takes over the chair role shows even more pronounced 'joker activity'. Thus, although the joker effect may not impact translational processes directly, the role of the joker certainly is important for group dynamics and warrants further investigation.

By identifying hub types and describing the specific actions that characterize them, we provide examples of behaviors that increase the translational capacity of research meetings and thereby of research groups. Although some behaviors are tightly bound to certain personality types or levels of expertise, we also present some behaviors that can be learned. Thereby, we show that any research group can adopt a translational approach through these actions, given that team leaders and/or other senior members actively teach and encourage their team members to take on a translational attitude.

Our study presents some limitations which should be taken into account while interpreting the results. First, we used meeting recordings from one research team. This limits the generalizability of our results to other teams that may operate in different ways and therefore feature different mechanisms underlying translation. Moreover, since we adopted a manual approach to transcribe and analyze the data, the volume of our CA data is limited (~10 hours). This is because manual replay and transcription of the recordings yielded much more accurate transcripts, also taking into account soft and subtle utterances such as 'yes' and 'okay', as well as interpretation of tone of voice. These seemingly tiny details were of crucial importance to our goal, namely to characterize the actions expressed in speech and the uptake of those actions by the rest of the group. We were therefore unable to find automated voice recognition and transcription software that was capable of reaching those standards. Still, after analyzing only a few (2-3) transcripts, we were able to extract the most striking and robust communication patterns and to combine these into classification of hub types. This classification remained relatively stable while analyzing the remaining meetings, indicating that the data volume that we used was already sufficient to recognize distinct and robust communication patterns.

In addition, each meeting covered up to six different topics. Therefore, it is plausible that team members switched between hub types as the meeting progressed toward new topics. This could also be regarded as a characteristic of various team members; some members will demonstrate higher 'hub flexibility', i.e. a higher capacity for switching between hub types, than others. This flexibility may be related to the 'translational attitude' that team members should strive towards in order to achieve effective interdisciplinary teamwork, however in this study we did not look further into hub flexibility.

The multitude of topics under discussion in each meeting may also affect meeting evaluations, in the sense that one topic may appeal to a particular team member more than others. However, we limited evaluations to one survey per meeting to limit complexity of our results. This may partially explain why meeting evaluations showed enormous variation; each meeting received evaluations ranging from the lowest to the highest possible ranking on each questionnaire item.

Notably, each meeting consists of a different set of present members, and this can subtly alter group dynamics across meetings. Therefore, for optimal results of our proposed systematic method to analyze translation, group composition should be as stable as possible between meetings.

Future research into translational processes within research teams should thus use larger datasets, perhaps facilitated with the help of appropriate and effective automatic analysis tools; apply our methodology to other research teams to estimate generalizability of our results; and incorporate dynamic features of meetings, such as topics discussed, members present and hub flexibility. This will likely uncover more interesting findings about team members' participation, role assignment and contentment about the meeting. By uncovering the communication mechanisms that support translation within research meetings, we can establish evidence-based research practice to optimally support interdisciplinary research teams.

Conclusion

Interdisciplinary teamwork relies on translational processes. By focusing on actions implied in naturally occurring speech, this study identified coherent communication patterns within research teams that facilitate translational processes to occur. The roles that we defined contributed to translational research in different ways, and correlated well with turn-taking topology of the meetomes or meeting networks. The methodology and classification model presented here can function as a tool for evaluation of translational processes within interdisciplinary research teams, and as a framework to be expanded upon in future research.

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