Balancing Cognitive Effort and AI Assistance: an AI-assisted Sensemaking Framework for Synchronous Communication

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Abstract

Sensemaking in real-time team meetings is challenging due to the highly synchronous and rapid exchange of verbal information. Building external representations, such as shared meeting notes, is cognitively demanding and burdensome. While introducing AI could offload the time and effort when people build external representation in meetings, it also takes away the beneficial cognitive engagement in this process. This paper presents an AI-assisted sensemaking framework that balances AI assistance with cognitive effort in synchronous communication scenarios. The framework aims to understand cognitive effort in different sensemaking stages (representation creation and representation interpretation) when AI aids the process. The paper emphasizes the importance of providing desirable AI assistance and interactivity that can maintain user cognitive engagement in understanding and decision-making. AI should be used to facilitate cognitive processes beneficial to people's interpretation of context rather than replacing human thinking. The framework guides the design of responsible AI-assisted sensemaking tools, ensuring AI application enhances efficiency and preserves human engagement.

Keywords: Sensemaking, Synchronous Communication, AI-assistance Level, Cognitive Effort

Sensemaking has been studied in a variety of contexts, including but not limited to search and information retrieval (Paul and Morris 2011; Suh et al. 2023; Morris, Lombardo, and Wigdor 2010), information visualization(Suh et al. 2023), and literature discovery (Chang et al. 2023). However, real-time sensemaking of collaborative conversations poses unique challenges due to the highly synchronous, linear, and rapid exchange of verbal information (Deshpande, Vries, and van Leeuwen 2005). People frequently struggle to keep track and make sense of the content, leading to miscommunication, failure of grounding, and lower work efficiency(Beers et al. 2006). To address this challenge, people usually build external representations to present the linear verbal conversation in a form that is manipulable in the external environment, e.g., keeping a shared meeting note that reflects verbal communication accurately in synchronous communication, which effectively enhances cognitive engagement and supports sensemaking (Goyal, Leshed, and Fussell 2013; Kirsh 2010).

However, building an external representation is cognitively demanding. AI-assisted methods, including live transcript (Chen et al. 2023), automatic meeting notes (Asthana et al. 2023), and on-the-fly visuals (Liu et al. 2023), were proposed to assist with creating external representation to reduce the burdensome manual work. While AI has the potential to ease the load of generating external representation, further challenges arise when AI is used to facilitate the sensemaking of collaborative conversations. There is a desirable amount of cognitive effort people need to spend in understanding the content through ideating, creating, and modifying the external representation. However, when AI takes over this work, it could inadvertently impair the sensemaking process.

How much AI should be introduced to assist with external representation generation (i.e., creating shared meeting notes to facilitate sensemaking)? How should AI be designed to assist sensemaking in meetings while not taking away desirable cognitive engagement from users?

This paper introduces an AI-assisted sensemaking framework for synchronous communication that articulates a balance between AI assistance and cognitive efforts. This framework provides a lens to decipher the level of cognitive effort involved in the different stages of sensemaking when AI is utilized to facilitate the process during synchronous team communication.

Sensemaking in meetings

We contextualize the sensemaking process in meetings with “shared notes” as the external representations people are creating using the four sensemaking stages proposed by Russell et.al (Russell et al. 1993).:

- **The search for representations** involves identifying what information to include in the external representation (e.g., a note) and the type of representation (e.g., a diagram, a list, or a mind map) that would best facilitate understanding and collaboration.
- **The instantiate representations** involve the actual creation of the external representation. Participants contribute their knowledge, which is then captured and integrated into a visual or textual format and at the granularity defined in the search for representation stage.

- As the meeting progresses, the **shift representations** involve adapting the representation in real-time to reflect new insights and changes in direction, ensuring that it remains relevant and useful as the conversation evolves.
- In the final stage, which is **consuming encodons**, participants use the shared representation to guide their understanding and decision-making. They may refer to it to summarize key points and clarify complex relationships. After the meeting, the representation can serve as a reference for follow-up tasks or as a record of the discussion.

Since the search for, instantiating, and shifting representations are an iterated process of creating and refining a representation, we categorize the three stages as **"representation creation",** and accordingly, the final stage of consuming encodons is categorized as **"representation interpretation."** In synchronous team meetings, the process of representation creation (search for, instantiate, and shift representations) and representation interpretation (consuming encodons) is frequently iterated, reflecting the dynamic nature of the conversation. Participants in meetings need to consume encodons almost in real time. The ability to quickly adapt and integrate new information into the external representation is crucial for maintaining alignment and driving decision-making in these fast-paced environments.

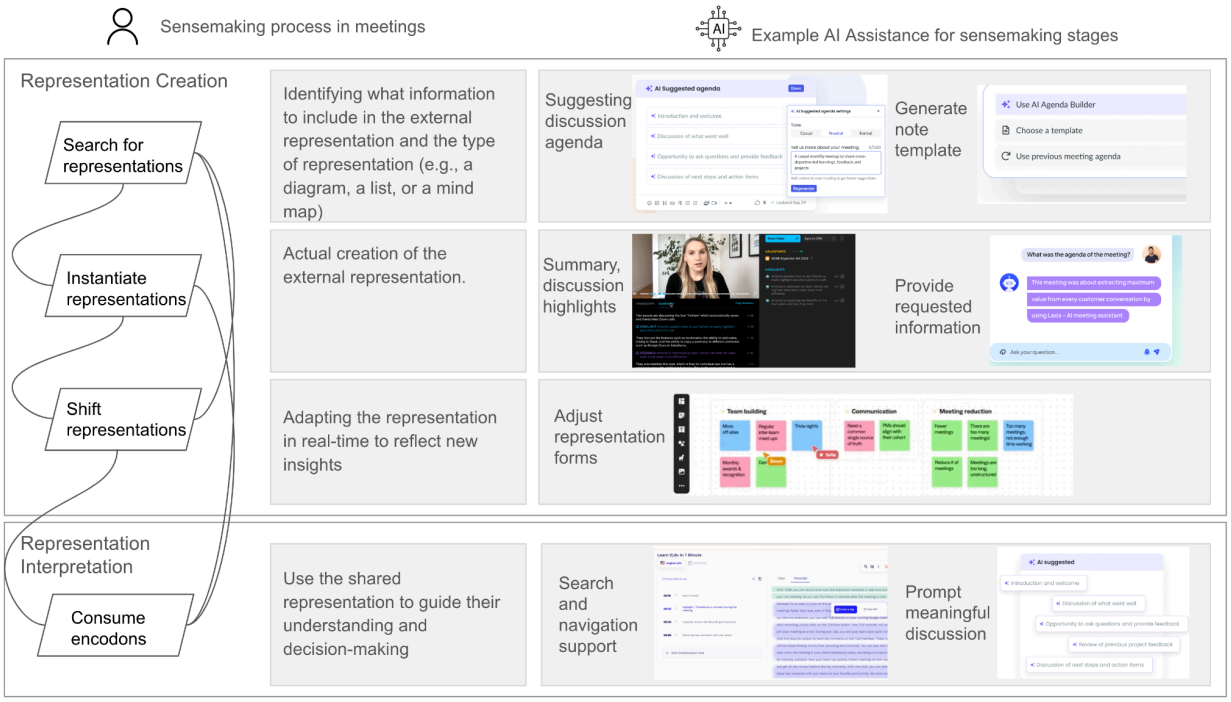
Next, we briefly present how AI has been applied to support the representation creation and representation interpretation process in current practice. For representation creation during meetings, AI tools could assist in capturing and organizing discussions as they unfold. For example, Clickup[1] assists with the search for representation stages by generating meeting agenda templates to set clear expectations on what information to note down in the meeting notes. Webex Assistant[2] listens, transcribes, and categorizes key points into structured notes, assisting with the representation instantiation. For dynamically shifting representations, MURAL[3] uses AI to rearrange ideas in real-time as the discussion evolves to help sensemaking. On the interpretation side, tools like Otter.ai [4]go beyond simple transcription by analyzing the content of the meeting in real-time and highlighting key points, questions, and action items to aid understanding.

[1] https://clickup.com/

[2] https://help.webex.com/en-us/article/ygksov/Webex-Assistant-for-meetings

[3] https://www.mural.co/ai

[4] https://otter.ai/

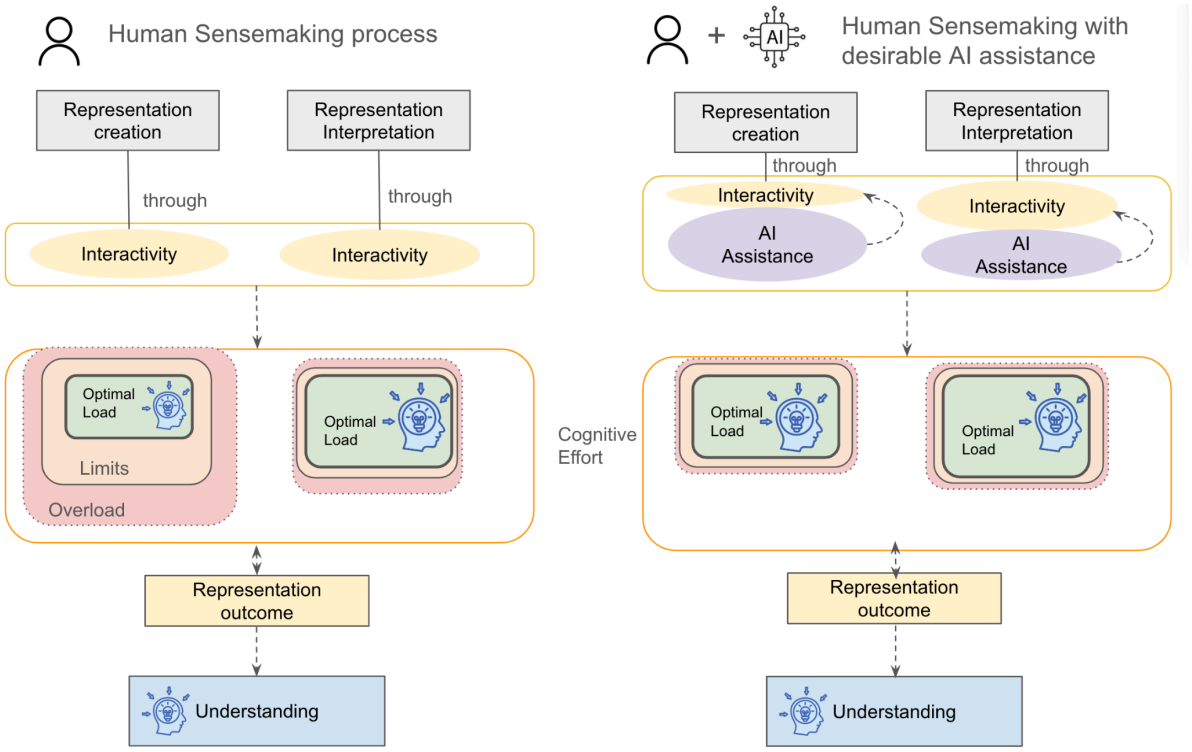


AI-assisted Sensemaking Framework for Synchronous Communication:

Without AI assistance, users are deeply involved in the sensemaking process through both cognitive engagement and interaction. In the **representation creation** stages, users spend considerable cognitive effort and interaction in identifying relevant information, creating and organizing the external representation, and adapting it as the discussion evolves. In the **representation interpretation** stage, users expend cognitive effort in understanding and analyzing the shared representation.

When AI is introduced, it has the potential to reduce the cognitive effort required in the representation creation stages by automating tasks such as identifying relevant information, capturing key points, and updating the representation. However, this reduction in cognitive effort during creation might lead to challenges in the representation interpretation stage.

To design desirable AI assistance in the sensemaking process during meetings, our framework discusses the nuanced interplay between AI assistance, interactivity, and cognitive effort of sensemaking in synchronous communication. The goal is to find a balance that maximizes the benefits of AI in reducing the manual burden of representation creation while ensuring that users remain sufficiently engaged to effectively interpret and make sense of the representation.



1. **The level of AI assistance (A):** This factor considers the extent to which AI is involved in helping with sensemaking and the distribution of work between humans and AI in each sensemaking stage. The level of AI assistance can be quantified based on the level of automation and support AI provides.
2. **Interactivity (I):** In the context of external representations, interactivity allows users to manipulate, explore, and experiment with the information, thereby enhancing their understanding and ability to make sense of complex data (Kirsh 2010). Incorporating AI assistance into this process adds another layer of interactivity, where users interact with both the external representations and the AI system. In this work, Interactivity (I) is thus conceptualized as a two-dimensional construct that includes:
    a. **Interactivity with External Representations:** This aspect involves the engagement of individuals with the external representations (e.g., notes, diagrams) they create or use to make sense of information, including the interaction in both the representation creation and representation interpretation process.
    b. **Interactivity with AI:** In the context of AI-assisted sensemaking, this aspect refers to the level of interaction between the user and the AI system. It includes **expressing intent** to the AI (e.g., specifying what kind of assistance is needed) and **evaluating the AI's output** (e.g., assessing the AI-generated artifacts).
3. **The outcome of the external representation (O):** The outcome of these external representations is influenced by both the level of AI assistance and interactivity. Specifically, we detail the quality of the outcome external representation by considering the following aspects:
    a. Completeness: The extent to which the external representation captures all relevant aspects of the conversation or discussion.

b. Accuracy: The degree to which the external representation accurately reflects the content and nuances of the conversation.
c. Readability: The ease with which the users can read and understand the external representation.

4. **Cognitive effort (C):** the cognitive effort experienced during the sensemaking process. Individuals should engage and spend a desirable cognitive effort to make sense of the discussion. However, too much cognitive effort leads to extraneous cognitive load, which can compromise the effectiveness of the sensemaking process (Plass, Moreno, and Brünken 2010). The interactivity between users and the external representation requires individuals to distribute their attention from the discussion, which might add to cognitive effort. The interaction between humans and AI can either relieve or add more cognitive effort, depending on the context. For instance, AI assistance simplifying note-taking or providing relevant insights can reduce cognitive load. Conversely, AI assistance that is inaccurate or requires frequent corrections can increase cognitive load. The quality of the external representation also plays a role in determining the cognitive effort. A well-structured and clear representation can reduce cognitive load by making it easier to understand and process the information.
5. **Understanding (U):** we use the term "understanding" (U) to represent the outcome of the sensemaking process. Understanding in this paper refers to the user's comprehension and internalization of the meeting content, facilitated by the external representations created through sensemaking. The goal of AI assistance in this context is to maximize this understanding (U) by finding the right balance between external representation outcome (O), interactivity (I), and cognitive burden (B) across the different sensemaking stages.

$$U = w_1 O + w_2 I - w_3 B - w_4 (I \times B)$$

$$O = f(I, A)$$

Where:

- $I \times B$ captures the interaction between interactivity and cognitive burden. This is especially important as it recognizes that a high cognitive burden can negate the benefits of interactivity, emphasizing the need for a balanced approach to AI assistance in the sensemaking process.
- w_1 w_2 w_3 w_4 - Weight Coefficients are the factors that adjust the impact of each variable on understanding. These coefficients need to be empirically determined.

The application of this framework could reveal the nuanced roles that AI can play in the sensemaking of real-time conversations (As shown in Appendix). In particular, we want to draw attention to the AI assistance dilemma when people are engaged in sensemaking. When AI provides assistance to sensemaking, it may result in undesirable outcomes where it takes away the desirable cognitive efforts people want to spend in order to support their understanding and decision making. AI should be used to facilitate cognitive processes beneficial to people's interpretation of context rather than replacing human thinking. Moreover, the design of interactivity also affects the ability of AI to be effectively utilized to promote cognition and sensemaking. By proposing this framework, we hope to guide the design of future responsible AI-assisted sensemaking tools, ensuring that the application of AI not only enhances efficiency but also safeguards human engagement.

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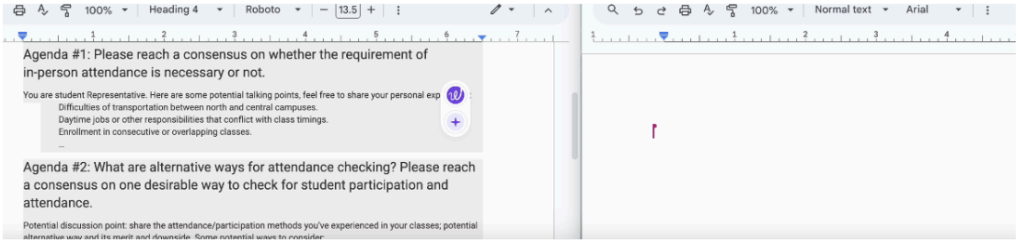
Appendix: Analysis of meeting scenarios with different levels of AI support using the framework

The analysis of how this framework can be applied to support designing and evaluating AI-assisted meeting note-taking design is based on several studies we ran before (Chen et al. 2023).

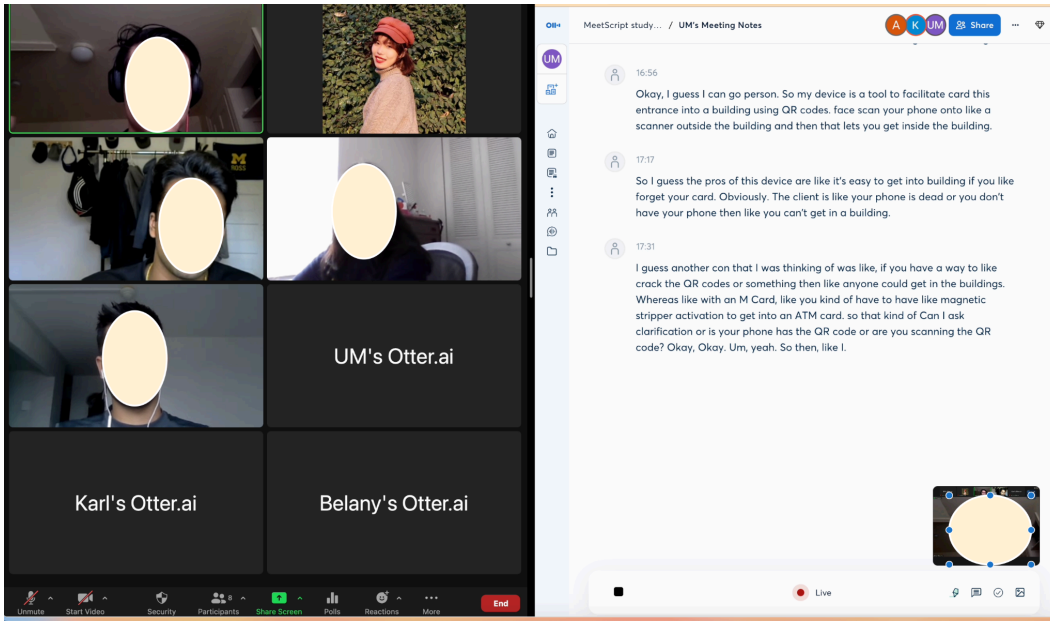
We first describe 5 online meeting scenarios with different levels of AI support. These scenarios either describe business-as-usual online meetings or scenarios where people receive AI assistance on note-taking during meetings.

1. **Zoom Meeting with Manual Notes:** This is a business-as-usual meeting scenario where users have meetings over Zoom and have the option to take notes manually, either privately or collaboratively, using tools like Google Docs, OneNote, or Notion. The notes typically capture key ideas in a linear order, and some meetings may have a dedicated note-taker for more professional representation.



Zoom Meeting with AI Transcription: AI provides real-time transcriptions as external representations, presented as closed captions or in chronological order with speaker differentiation, and is used as a shared reference during or after the meeting. It is common

practice for online meetings to have real-time transcripts using services such as otter.ai.



2. **MeetScript :** MeetScript offers real-time interactive transcripts, visualizing discussions in a chat-like interface and allowing collaborative annotations. It also gradually hides extraneous content to retain essential information.

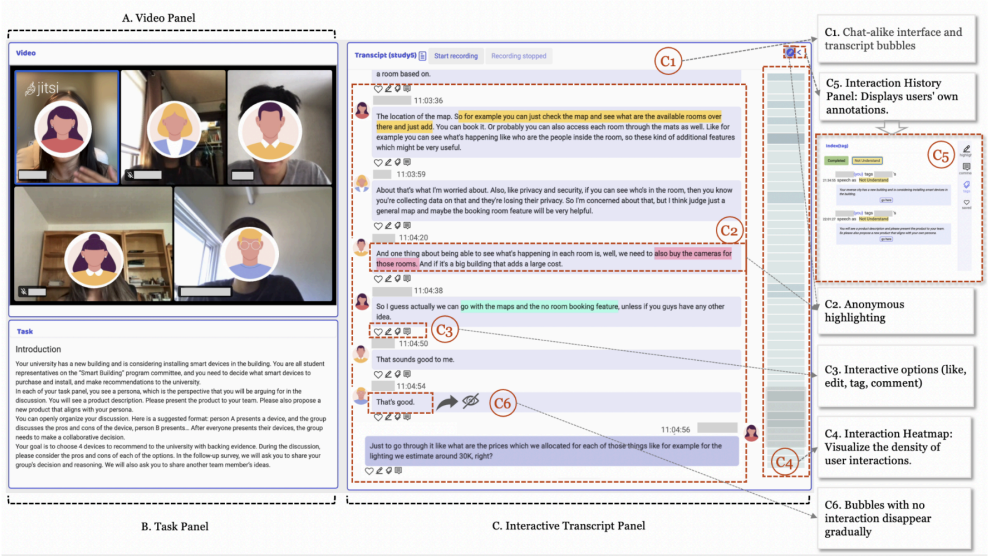


Fig. 1. **MeetScript User Interface.** MeetScript supports group video meetings through (A) a Video Panel and (C) an Interactive Transcript Panel. Users' conversations are transcribed in real-time and displayed in a chat-alike interface through transcript bubbles (C1). Users have a suite of options to interact and contribute to the conversation unobtrusively through the transcript. Users can highlight (C2), like, edit, tag, and comment on each transcript bubble (C3). To help users process the most essential information, transcript bubbles without user interaction gradually disappear over time (C6). Users can navigate the transcript using the Interaction Heatmap (C4) and Interaction History Panel (C5).

3. **MeetMap:** MeetMap is an AI-assisted dialogue mapping system for real-time sensemaking during online meetings. It transcribes and summarizes participants' speech into nodes, with which

users can arrange and link on a Map Canvas to create dialogue maps. AI also generates draft maps for further user edits.

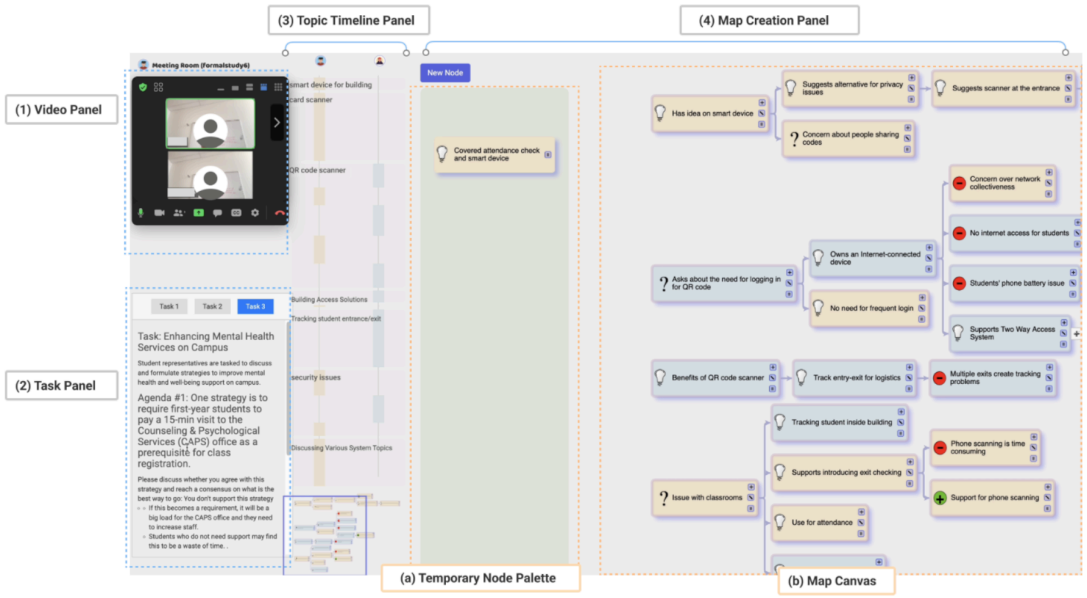
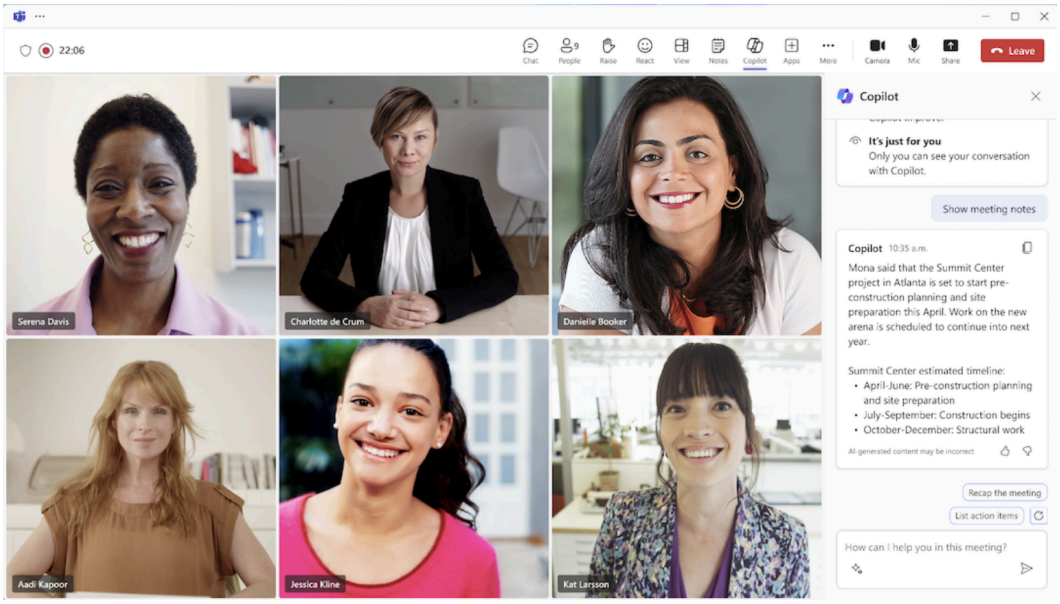


Fig. 1. **MeetMap User Interface**. MeetMap allows users to create dialogue maps collaboratively in real-time during online meetings through (1) a VIDEO PANEL and (2) a TASK PANEL, which displays the meeting agenda; (3) a TOPIC TIMELINE PANEL, which shows turn exchanges and conversation topics chronologically; (4) a MAP CREATION PANEL, which includes two parts: a) A TEMPORARY NODE PALETTE which presents nodes that summarize users' speech by AI, arranged in chronological order; b) A MAP CANVAS enable collaboratively work to create and refine a dialogue map using nodes.

4. **AI Companions/Copilots:** In this scenario, users interact with AI through chat to generate content aligned with current LLM tools.



Next, we analyze how AI assistance, cognitive effort, and interactivity vary across the 5 scenarios and the interplay of these factors with people's understanding of the conversations and the quality of the notes people are taking.

1. Zoom Meeting with Manual Notes:

- AI Assistance (A): There is no AI assistance, as notes are taken manually. Users have full autonomy in creating external representations.
- Interactivity (I): There is high interactivity between humans and the external representation (notes). However, there is no interactivity between humans and AI.
- Outcome of the external representation (O): The externalization is manual notes. Ideally, user-generated external representations should accurately reflect the content deemed essential by the user. However, prior work indicates that the quality of such notes is inconsistent and often lacks completeness. Many users believe they have understood the discourse and decide not to record it, which impacts further discussions due to their limited working memory.
- Cognitive Effort (C): The cognitive effort during the "representation creation" stage is high, as participants need to actively listen, process information, and take notes during highly synchronous communication. However, the cognitive effort during the "representation interpretation" stage is relatively low, as users are already familiar with the content of the notes they have created
- Understanding (U): The level of understanding is highly influenced by how people engage with the "representation creation" process. If critical content that should be recorded to aid sensemaking is not perceived and captured by users, the overall understanding level in this scenario is comparatively low. Conversely, if someone is an expert in note-taking and creates highly organized and complete notes, the understanding level should be high. This is because they benefit from both the "representation creation" process and the ease of understanding the notes, along with relatively low cognitive effort during the "representation interpretation" stage.

2. Zoom Meeting with AI Transcription:

- AI Assistance (A): AI provides real-time transcription, which users can choose to read. We consider this to be lower-level assistance since AI doesn’t actively support users’ sensemaking processes.
- Interactivity (I): As the transcript is linear and participants have limited ability to manipulate or annotate it in real-time, our studies have shown that users had almost no interactivity with either AI or the external representation, limiting their interpretation and use.
- The outcome of the external representation (O): The externalization in this scenario is real-time transcript, and we didn’t take account into the scenario where the user also take manual notes while getting a transcript from AI. while the transcript records the conversation completely, the readability of the transcript is really low.
- Cognitive Effort (C): Compared with manual notes, users almost have no cognitive effort in “representation creation” if they don’t create other representations than the transcription generated by AI. The AI-generated transcript helps users catch up and lower the cognitive burden in real-time listening, especially when they fall behind in the conversation or face language barriers. However, the cognitive effort in “representation interpretation” is really high since users

face challenges in making sense of the transcript and finding the relative content, and they would not use the transcript as a reference for further discussion and decision-making.
- Understanding (U): The role of external representation (AI transcript) is limited in enhancing sensemaking, as it provides little support for the active interpretation and manipulation of information. The final understanding is even lower than when people take notes manually.

3. MeetScript:
- AI Assistance (A): Meetscript provides moderate AI assistance in the "representation creation" phase, which not only transcribes the conversation but also chunks it into readable pieces and visualizes it in a chat-alike interface to improve readability. AI also assists with "shift representation" by hiding the extraneous turn based on user interaction with the note.
- Interactivity (I): The interactivity between humans and the external representation is high as MeetScript offers social annotation features that enable users to actively engage with the transcript and collaboratively make sense of the dialogue. AI assistance affords higher interactivity between the users and the external representation. In particular, in contrast with traditional transcription services, the external representation quality is more readable, increasing users' interaction with it.
- Outcome of the External Representation (O): The externalization of this scenario is reduced transcript with user annotations. Compared with AI's first two conditions, the quality of the external representation is enhanced by the ability to highlight and annotate key points, but the lack of control over the final form and structure of the transcript may limit its effectiveness in reflecting the process and structure of the discussion.
- Cognitive Effort (C): The tool reduces the burden of understanding the verbose AI-generated transcripts by allowing users to focus on critical parts of the discussion, which helps reduce the cognitive effort in "representation interpretation." However, since the representation co-creation process between the user and AI requires a lot of interactivity in user annotation, it still requires a moderate cognitive effort during "representation creation."
- Understanding (U): The understanding level is improved compared to both full transcripts and manual notes, as users can focus on essential points and actively engage with the content through annotations with moderate cognitive effort. However, the understanding of back-and-forth conversations may be hindered by the transcript flow.

4. MeetMap:
- AI Assistance (A): MeetMap provides a high level of AI assistance in "representation creation," using LLM models to chunk dialogue into short summaries and block-based summaries for constructing dialogue maps. Besides, it also provides some assistance in "representation interpretation" since it is designed to present the note in a visual structure with a concise summary and notation schema.
- Interactivity (I): The interactivity between humans and the external representation is high, as users interact with the map interface to construct dialogue maps based on AI-provided summary nodes. Although it lacks interaction design on how users express intention to AI, e.g., specifying the granularity and the timing of the summary node, users interact with AI-generated content frequently.

- Outcome of the External Representation (O): The representation in this scenario is a structured dialogue map. As the dialogue maps provide a structured and logical representation of the conversation, the quality of the external representation is relatively high compared with all three conditions listed above, aiding in sensemaking and decision-making.
- Cognitive Effort (C): The cognitive effort in MeetMap is moderate, as users are more involved in "representation creation" through connecting the AI-generated nodes or modifying the AI-generated map, compared with the creation effort required in MeetScript. However, compared with manual notes, users spend less cognitive effort in typing and filling in the content that they want to use in the dialogue map. The cognitive load in "representation interpretation" is also lower since users create the structure themselves.
- Understanding (U): Since users' cognitive effort is desirable in this condition, focusing on activities with higher-order thinking rather than mechanical work, and people receive some AI assistance while also still interacting activity to create the representation to make sense of the conversation, the understanding level is improved compared to prior conditions.

Teams Copilot:

- AI Assistance (A): The AI assistance varies based on user initiation. If users ask for more information with chat, the AI assistance should be high as Teams Copilot could provide real-time assistance such as summarizing discussions, suggesting action items, and providing relevant information through chatting with users. In this scenario, AI will not provide the assistance proactively.
- Interactivity (I): The interactivity between the user and AI is high since users can interact with the AI assistant by expressing their intent explicitly, through typing or other direct manipulation interaction. However, there is almost no interactivity between the user and the external representation since users just read AI-generated answers but do not further edit or organize them.
- Outcome of the External Representation (O): The representation in this scenario is the AI-generated answer shown in the chat history. The quality of external representations depends on whether users express their intent accurately and concretely and also depends on the performance of AI. From our observation, if users type a very concrete question, e.g., "Please summarize the mentioned shortcoming of the latest version of the product, as discussed by xxx under topic xxx", AI could provide an accurate answer. However, the answer is usually long, which might reduce the overall quality of the representation outcome.
- Cognitive Effort (C): Cognitive effort is required when users initiate a question since they need to phrase and type the question to AI; this means users spend some cognitive effort in "search for representation." There is almost no cognitive effort needed in both instantiate and shift representation. The cognitive effort in interpretation is related to the outcome of the external representation, e.g., if the AI provides some information that hasn't been mentioned in this meeting, users need to put more effort into identifying the error from the AI result.
- Understanding (U): When users interact with the AI properly, the understanding level is high since the AI assistant helps users stay on track. However, when users interact with the AI assistant too often, they will focus on interacting with AI rather than making sense of and listening to the conversation.

Scenario	AI Assistance (A)	Interactivity (I)	Outcome of the External Representation (O)	Cognitive Effort (C)	Understanding (U)
Zoom Meeting with Manual Notes	None	High with external representation	High quality but often lacks completeness	High in creation, low in interpretation	High if notes are organized and complete
Zoom Meeting with AI Transcription	Low	Low	Complete but low readability	Low in creation, high in interpretation	Lower than manual notes
MeetScript	Moderate	High with external representation	Enhanced by annotations	Moderate in creation	Improved compared to transcripts and manual notes
MeetMap	High	High with external representation	High quality, structured representation	Moderate, focused on higher-order thinking	Improved compared to prior conditions
Teams Copilot	Varies based on user initiation	High with AI, low with external representation	Depends on user queries and AI performance	Required during question initiation	High when users interact effectively with AI