A Review of How Team Creativity is Affected by the Design of Communication Tools

Yan Xia and Yue Chen(✉)

East China University of Science and Technology, Shanghai 200237, China
chenyue@ecust.edu.cn

Abstract. Team creativity can be strongly affected by communication. With the trend of online collaboration, the design of communication tools increasingly affects different creative processes of teams working online. To clarify this effect, this study took the perspective of affordances and reviewed 54 papers to map the needs of teams, the design of communication tools, and the effects of tools on creativity in different creative stages. First, we summarized teams' requirements for communication tools in different stages. Second, we identified key affordances with relevant features. Third, we discussed how these affordances could affect communication and team creativity in different stages and built a mapping of creative teams' needs and communication tools. The mapping can provide insights for both designing communication tools for creative teams and expanding the current team creativity theories to fit the online context and new communication technologies.

Keywords: Communication · Communication Tools · Team Creativity · Creative Process · Online Collaboration

1 Introduction

Team creativity is critical to success in today's rapidly changing business landscape. Though individual creativity is usually defined as a cognitive process, team creativity results from the interplay of many cognitive, social, and motivational factors [1, 2]. Team creativity can be generally promoted by effective collaboration among team members [3]. Through collaboration, communication, and information exchange, team members can bring different knowledge, skills, experiences, and perspectives to create more diverse, novel, and useful ideas [4].

In recent decades, these co-creative processes have been shifting online, and this trend has been accelerated by the COVID-19 pandemic. Increasing teams work online and use various communication tools or applications, including instant messaging, video conferencing, and social media, to facilitate team collaboration and creative performance. Some of them have even been added with functions specifically to support creativity, such as Mural in Microsoft Teams and the Post-it notes on whiteboards in Meta Workrooms. The design of these communication technologies can strongly affect teams' creative processes and performance.

P.-L. P. Rau (Ed.): HCII 2023, LNCS 14023, pp. 297–314, 2023.
https://doi.org/10.1007/978-3-031-35939-2_22

Currently, these communication tools provide various functions and features to support behaviors of team members, such as task-oriented discussion (e.g., idea generation or evaluation), social-oriented or informal talk, and meta-cognitive behaviors (e.g., task management and updates) [5, 6]. The effect of different behaviors on team creativity can vary in different stages of creative processes. A creative process consists of problem identification, ideation, and evaluation [7, 8]. For example, in the early ideation stage, others' ideas may inspire a motivated team member but make an unmotivated member social loafing. Therefore, team members may have different needs for communication and require different functions or features of communication tools in different stages.

However, it is unclear what design features of communication tools team members need in different stages and how these features affect team creativity. Practitioners and researchers have designed various features and explored how these specific features affected social interaction and creativity [10]. However, these results are fragmented and some features may be hard to generalize across communication tools. In addition, these tools increasingly adopt new interactive technologies, such as virtual reality and conversational agents. It is also hard to generalize the findings of previous specific features to the new ones. Designers need a more holistic and general understanding of how the design of tools affects team creativity.

Therefore, this study abstracts specific design features of communication tools and maps them with team creativity from the perspective of affordances. Affordances can be defined as the action possibilities offered by a product [9]. Researchers used the concept of affordance and developed a theoretical framework to map user needs, affordances, and design features of social media [11]. This mapping could help designers to choose or develop innovative interactive features of specific affordances based on the needs of social media users. This study adopted a similar perspective and answers the following research questions:

RQ1. What are the main tasks of team members and the requirements of communication technologies in the different stages of creative processes?

RQ2. What affordances and features are provided by the communication tools used in creative teams?

RQ3. How do the affordances of communication technologies affect communication and team creativity in the different creative processes?

2 Method

This study conducted a literature review. First, we systematically searched two research databases: Scopus and Web of Science. Search phrases include "online collaboration", "collaborative creativity", "team creativity", "creativity support tools" and "collaborative creativity support tools". Second, we preliminary selected relevant papers based on their titles and abstracts. This step resulted in 235 publications. Then, all the publications were screened to find those that focused on the collaborating and communicating processes, tool design, and team creativity. In addition, we manually added some other articles and book chapters in this field that may contribute to answering our research questions from other resources. Finally, we reviewed the full text of 54 publicans. Based on these articles, we mapped the affordances and features of communication tools, as well as

the communication module of collaborative creativity support tools, and examined the effect of these features on team communication and creativity.

3 Results

3.1 Main Tasks and Requirements of Every Creative Process Stage

In previous studies, creative process models are predominantly represented in the form of a linear sequence of stages [12].

Zeng et al. summarized the creative process by a four-stage model: analysis, ideation, evaluation, and implementation [7]. Since our study focuses on online communication**,** and the implementation stage is usually offline, we mainly discuss the first three stages which include more information sharing and communicating process. Similarly, Reiter-Palmon and Leone proposed the three core stages of the team creative process: problem construction, idea generation, idea evaluation and selection [8]. Varieties of creative process models have been proposed, and usually divided the whole creative process into four or three parts.

Analysis/Problem Construction. Generally, the first part of the creative process includes two major sub-processes: problem finding and problem formulating [13, 14]. Instead of routine, presented problems, the creative process involves ill-defined, discovered problems, which makes the analysis (or problem construction) phase indispensable.

During online collaboration, especially cross-border collaboration or interdisciplinary collaboration, individuals are likely to have different backgrounds, which makes them tend to represent the problem in very different ways [15]. On the one hand, different representations of the problem facilitate a more complex and complete understanding of the problem, which can lead to better team creative performance [13]. On the other hand, the representational gaps (rGaps) between team members may disrupt team agreement regarding a solution when not resolved and can lead to the provoke of conflict [63]. Conflicts are inevitable during team collaborative processes, and there are constructive or destructive conflicts [16, 17]. If managed appropriately, constructive conflict can result in the integration of different perspectives, help to identify shortcomings in the discussion of the group and lead to better team creative performance [13]. Team members can also bridge and integrate the different problem representations and potential by discussing the different goals and ways to construct the problem, which can lead to increased creative performance [13].

Open-minded discussions facilitate team members to freely express their views, listen and understand opposing ones, and then integrate them to promote constructive conflict [18]. However, in online circumstances, the lack of support for nonverbal communication, including facial expressions and body language, often leads to misunderstandings, which aggravate destructive conflict, and detriment team creative performance. A survey found that in about two-thirds of the reported misunderstandings, the problem occurred because of the tone of the message and other nonverbal cues, and open communication was used to resolve it [19]. Therefore, it's necessary for teams that work collaboratively online to adapt communication tools that facilitate non-verbal communication which

allows team members to express their opinions and share their knowledge adequately and accurately.

In conclusion, during this stage, communication tools are required for:

1. Rich modalities: Enhancing the sharing of non-verbal information to reduce destructive conflicts caused by rGaps and misunderstandings, and support effective communication;
2. Enough responding time: Leaving team members enough time to analyze the problem before responding;
3. Support for rehearsing: Allowing careful crafting of messages (or other types of information), to make it more accurate and understandable for problem integration.

Ideation/Idea Generation. Ideation is defined as idea generation via divergent thinking without evaluation (which involves more reverse thinking) [20]. During this stage, the main purpose is to generate enough novel and appropriate ideas, which is essential for creative performance. In this case, team diversity may contribute to the production of more creative ideas, as team members can provide unique and diverse viewpoints [13].

However, teams are likely to fail to capitalize on their diversity in knowledge and ideas, which may be partly caused by the lack of information sharing [8], which can be caused by certain team dynamics phenomena, such as evaluation apprehension, or concerns about being socially accepted, which inhibit the quality of knowledge sharing [21]. On the contrary, teams with enabling dynamics can support open, respectful, and consistent communication, in which members felt comfortable expressing their viewpoints, and were encouraged to share divergent perspectives [22]. In this case, the action and quality of knowledge sharing can be improved by encouraging certain enabling dynamics, including collaboration, and both open and continuous communication [22].

Besides, exposure to other members' ideas and evaluation apprehension can lead to productivity deficits in the number and categories of ideas, although the novelty of ideas was not affected [23]. Ways of alleviating negative impacts of evaluation apprehension include decreasing team members' stress related to response time management [24], making them feel their ideas are taken seriously and valued by others, especially those in positions of authority [22], and eliminating their feelings of embarrassment and uneasiness by providing different online user-identity revelation modes [25].

While reducing harmful team phenomena like evaluation apprehension can be beneficial to knowledge sharing, thus promoting idea generation during the creative process, it is proposed that knowing how to engage in a knowledge behavior may also facilitate productive knowledge sharing. When team members do not intend to hide their knowledge, the facilitating conditions make it easier for them to perform the knowledge-sharing act [26].

Based on the above findings, during the ideation stage, we concluded several aspects of the main requirements for communication tools for better communication and team creativity:

4. Support for positive interaction and feedback: Alleviating the phenomenon that affects the quality of information sharing, such as evaluation apprehension, can be very helpful. This can be achieved by adding interactive affordance that encourages positive feedback, commonly the like button. Embedding flexible and versatile capabilities of

communication tools by allowing users to use virtual backgrounds and self-image, nicknames, and choose not to be identified [25] can also help to solve the problem.
5. Ease of use: Secondly, provide facilitating conditions that enable team members to record and share their ideas at ease by improving usability, especially features that facilitate users' perceived ease of use, commonly intuitive user interfaces, and rich media channels.
6. Support for continuous communication: Open, respectful, and consistent communication will make team members more likely to share their ideas.
7. Support for simultaneous communication: Allowing team members to share their ideas at the same time.

Evaluation/Idea Evaluation and Selection. Generating ideas alone may not be enough to ensure the implementation of effective and innovative solutions: the team must actively and effectively evaluate the ideas before implementing the solutions. Make unbiased and accurate judgments on the merit of ideas generated. The evaluation stage involves convergent thinking whereby one analyzes, refines, and selects ideas generated [7], and required team members to make unbiased and accurate judgments on the merit of the ideas [13].

An effective evaluation process includes a combination of intuitively analyzing the ideas and then rationally considering the resulting intuition in making the final decision. Both the accuracy of quality and originality are considered during evaluation [27]. When teams assessed solution originality more accurately, they were more likely to be accurate in selecting an optimal solution that was truly creative, while teams that were more accurate in assessing solution quality were more likely to accurately select a solution that was high in quality alone [27]. Teams will consider both the specified evaluation criteria and the explicit solution selection instructions when selecting ideas and solutions [28, 29].

However, studies have found that teams do not always evaluate ideas very accurately and tend to emphasize the quality of an idea over originality [13]. Ways of overcoming this problem include generating a guideline detailing the team's evaluation criteria. This creates a shared framework that supports the team evaluation and selection process, and integrates different ideas and problem representations into the final choice of ideas [13].

To support efficient idea evaluation, communication tools are expected to have the capacity of:

8. Cognitive support: Being able to collect and organize the idea manually or automatically;
9. Easy access: Providing easy access for users to the ideas generated and collected, such as shared documents and group files. Functions that allow quick access to certain ideas, such as tags, likes, or marks may also be helpful;
10. Opinion collection: It's necessary to facilitate team members' interactions and efficiently collect feedback for ideas through certain design functions, such as opinion polls and votes.

3.2 Affordances and Features of Communication Tools

Communication Tools for Creativity. During the team creative process, teams adapted various tools for communication including tools specialized for communication (High

synchronicity: IM, video conferencing applications, etc. Low synchronicity: e-mail, etc.), more comprehensive systems (such as enterprise social networking tools, social applications, collaborative creative support tools, etc.), and collaborative creative support system that support highly professional tasks that require specific functions (such as collaborative systems for architecture design, or game development).

The past few years have seen the growing adoption of more complex and comprehensive collaboration support tools, including enterprise social networking (ESN tools, also known as enterprise 2.0), by organizations in an attempt to foster better team communication and collaboration [35, 58]. Compared to Web 1.0 tools such as e-mail, ESN platforms are considered more capable of facilitating effective and efficient team communication and collaboration [36]. A study showed that companies that adapted social media tools for team communication achieved around twice as much innovation as companies that did not [37]. The challenges of using ESN tools in agile virtual teams include language, unbalanced activity, and finding the right ESN workspace structure [38]. Even with a language barrier, tools with face-to-face communication functions were the most recognized media for supporting team communication and enhancing team cooperation [39].

In the field of design, collaborative design technologies are used to support a team of designers to jointly work on a design project either remotely or co-located. During the design process, team members are likely to focus on shared design representations including sketches, drawings, and models, therefore the important features of collaborative design technologies are the types of digital media for design representation, the types of interactions for creating, modifying, and exchanging the shared design works [40].

Relevant Theories

The Creativity Support Index (CSI). CSI is designed for helping researchers and designers evaluate the capacity of creativity support provided by a system, or interface [31]. The CSI measures six dimensions of creativity support: Results Worth Effort, Expressiveness, Enjoyment, Exploration, Immersion, and Collaboration. Users can rate each factor from 1 (highly disagree) to 10 (highly agree) After rating, the factors would be ranked through pairwise comparisons.

Media Richness Theory (MRT). MRT suggests that various types of media differ in their capacity to convey messages and cues. Face-to-face interaction is considered to be the richest medium, while written documents, statements, newsletters, reports, or posters are placed as less rich communication channels. In the middle of the continuum are video conferencing, telephones, IM, and e-mails [31]. A rich medium is especially useful for non-routine, difficult-to-understand messages, and has the immediacy of feedback and dialogue, the use of both verbal and nonverbal cues as well as natural language (gestures, eye contact, and tone of voice), which makes it easier to solve problems and reduce misunderstanding or misinterpretation during communication [34]. Previous research on social media used for teamwork has found that in general, rich communication channels are considered more effective for team communication, and are capable to promote creativity and innovation [35].

Media Synchronicity Theory (MST). MST defines five media capabilities: transmission velocity, parallelism, symbol sets, rehearsability, and reprocessability [43]. Transmission velocity and more natural symbol sets (physical, visual, and verbal) have a positive impact on the tool's synchronicity, whereas parallelism, reprocessability, and rehearsability all have a negative impact [43].

Affordances and Features. Depending on the configuration of affordance, communication technologies will vary in their features and provide functions, which make them fit for different communication scenarios, and ultimately have different effects on communication and team creativity. The fit between the features of the media and the needs of the task influence how users adopt and use them [64]. Practitioners and researchers have designed various features and explored how these specific features affected communication and creativity [9], however, these results are fragmented and some features may be hard to generalize across communication tools.

To help generalize the affordances from various features that may influence communication and team creativity, we referred to MRT, MST, and CSI. Based on these theories, we abstracted affordances from features provided by various communication tools as well as collaborative creativity support tools (see Table 1).

Table 1. Affordance and features of communication tools

Affordance	Definition	Features
Transmission velocity	The speed at which a medium can transfer a message from a sender to an intended receiver	Live preview, instant messaging, etc.
Parallelism	The number of simultaneous communications that can occur through a medium	Group chat, group sending, etc.
Modality richness	The number of ways in which information can be encoded for communication	Emojis, voice messaging, video chat, etc.
Rehearsability	The extent to which the media enables the sender to rehearse a message before sending it	Message editing before sending
Data Persistence	The extent to which the medium enables a message to be reexamined or processed again, during decoding, either within the context of the communication event or after the event has passed	Chat history, group files, etc.
Accessibility	Accessibility refers to the extent to which information can be accessed or extracted easily from the system	A mobile version of the tool, etc.

3.3 The Effects of Affordances of Communication Technologies on Communication and Team Creativity

Transmission Velocity. Transmission velocity refers to the speed at which a medium can transfer a message from a sender to an intended receiver, and can notably support synchronicity not only because it improves behavior coordination, but also because the shared focus exists between individuals working together [44]. Collaborative creativity support tools have offered multiple functions that support the affordance of transmission velocity and synchronicity, such as instant messaging and a live preview of others' work.

On the one hand, faster transmission velocity allows fast information transmission, continuous communication, and quick feedback, and reduce the cognitive effort of team members to interpret information [30, 41, 43], which may be particularly suitable for the idea generation stage for its focus on generating and sharing enough creative ideas. On the other hand, collaboration technologies with low synchronicity allow participants to take more time between the messages, which may help with better analyzing the content of messages [43]. This can be utilized during the stage of problem construction and idea evaluation, which involves more analysis behaviors, and simultaneous interaction is not necessary [30].

During the collaborative creative process, such as game development, live preview is a very popular and helpful feature associated with high transmission velocity. It enables team members to keep up with what other team members are working on, and be instantly aware of progress and updates their partners made during the collaborative creative process [51]. This can foster group awareness [52] and enhance collaboration [64], which ultimately promotes team creative performance.

Other than that, technologies with high transmission velocity, such as IM, enable near real-time communication [30, 54]. The continuous real-time feedback during communication helps to narrow its users' focus on the activity of messaging and makes them easier to concentrate on the content, which brings about flow for team members [54, 59]. Communication technology users' flow comes from both interaction with the technology and social interactions with communication partners and has a significant indirect influence on perceived expected creativity through exploratory behavior and positive affect [54].

To sum up, communication technologies with high transmission velocity facilitate continuous real-time communication and feedback, which not only improve efficiency, but also help users better concentrate on the idea-exchanging content during communication, and bring about flow to make them feel more creative. For collaborative creative support tools, features like live preview serve as a way of communication to let team members know others' progress and update, which promotes creativity by fostering group awareness and collaboration. However, technologies with relatively low transmission velocity are not necessarily ineffective for team creativity, for the ample time it allows for analyzing the information, which may be helpful for the problem construct and idea evaluation stage of the creative process.

Parallelism. Technologies with a high level of parallelism are capable for multiple simultaneous communications [43], which enhance the efficiency of social interactions among users and have an insignificant effect on information capital, and ultimately

positively influence team creative performance [9]. Besides, a high parallelism media allows user to seek feedback from different resources simultaneously, which enables a high level of feedback resources for users and facilitate high level of creativity [53].

However, simultaneous communications can lead to multiple unrelated discussion topics from different persons at the same time, and lower shared focus [43]. Studies have found that such a communication process may damage cohesion among team members [43, 60]. Also, parallelism can create an environment where users get exposure to a variety of ideas from other team members. Although being exposed to common or moderately creative ideas was effective in improving creativity [61], during the second half of the group's idea generation, this can reduce the number and type of ideas generated by the groups [23], and have a negative impact on team creative performance.

Modality Richness. Modality richness is evaluated by the number of cues a media can provide in transmitting information [46]. Technologies with rich modality facilitate convey and converge of information [44], which allows effective communication. Rich communication channels are still preferred. According to a survey, business professionals view richer (involving more vocal and nonverbal cues), traditional communication channels as the most effective for team communication [35].

Previous studies have found that technology with rich modalities, such as video conferencing, can help users get to know about the state of other team members and make them feel more connected with each other by offering social cues, both auditory and visual [46]. This promotes certain social processes, such as the establishment of trust, increases collective efficiency [46–48], and further support effective communication [42]. Other than that, the feeling of connection fostered by rich communication cues can also promote the activity of information sharing, including the exchanging of novel information and ideas [49], which is essential for creativity during the idea generation and evaluation stage.

On top of that, non-verbal cues, such as facial expressions, reduce uncertainty and misinterpretation during communication [19, 46], which can be helpful throughout the whole creative process, especially the problem construction stage for its need to integrate different problem representations [13].

In collaborative tasks that are highly visual, modality richness plays an even more important role in improving the tool's capacity to support creativity. An experimental study showed that teams communicating through rich modalities, like video conferencing, generated more useful creative ideas and perceived better collaboration than teams communicating by chatting, and this was especially evident about the share of excellent ideas [50]. Since for creativity, it is usually not the average performance, but the positive outliers that can lead to success [62], this provides another perspective for understanding the positive effect of modality richness on creativity.

Finally, some people suggested that text chat may be more disruptive than a richer modality of communication (e.g., voice chat) during a collaborative working process [51] since it can only convey information when people stop their work to send messages, while voice chat allows communicating and working at the same time. However, for the communication process alone, this may be a minor consideration.

Rehearsablity. Previous studies defined rehearsability as the extent to which the media enables the sender to rehearse a message before sending it [43]. For instance, e-mail,

instant messaging, and social media applications allow for the drafting of messages before sending them [44]. And after sending out, it can leave enough time for responding, allowing the receivers to think carefully about how to respond, compared to media like telephone calls and video chat. This may facilitate a better representation and understanding of the message, which is beneficial for the problem construct and idea evaluation stage. Besides, studies have shown that rehearsability has significant and positive effects on information capital, which further supports team creativity [9].

Furthermore, during the communication process, the mentioned affordances of transmission velocity, parallelism, and modality richness can facilitate more efficient communication and sometimes better creativity performance, but may also lead to greater damage when mistakenly releasing important or misleading information, for their capability to support information transmission [43], thus emphasized the importance rehearsability during the creative process, as well as other communication circumstances.

However, the reprocessing ability may delay message transmission and synchronized communication, and hinder cohesion and collaboration [9, 43], which can have a negative effect on team creativity. Therefore, it's necessary to find a balance between the crafting of a message and the time it takes.

Data Persistence. Previous studies used the term reprocessability to describe the extent to which the medium enables a message to be re-examined or processed again [43]. In our study, we refer to the definition of reprocessability, and use the phrase data persistence to describe the extent to which a medium can retain the information generated and shared during communication, including messages, images, files, etc.

In collaborative creative works, reprocessability is an indispensable affordance. Some collaborative support tool provides access to previous working versions, which facilitate team members to easily backtrack to a certain working version, and would be extremely helpful for correcting mistakes during collaborative creative works, for example, fixing bugs in collaborative game development [51].

Like parallelism, reprocessability also has an insignificant effect on information capital, which positively influences user creative performance [9].

During the creative process, it has been proved that ideas and solutions from previous "ideation" sessions can substantially stimulate users' creativity, and facilitate elaborate past knowledge for them to solve new creative problems [55]. Features, such as chat history, meeting records, and shared group files can provide team members easy access to review and reprocess these ideas and solutions, and benefit from the past information, therefore promoting team creative performance.

Last but not least, tools with high data persistence can highlight members' contributions, and thus increase motivation during the collaborative creative process [56], leading to better team creativity.

Accessibility. Apart from the mentioned affordances, accessibility is also a necessary affordance in the team creative process. Accessibility refers to the extent to which information can be accessed or extracted easily from the system, or the medium [57]. Accessibility has a positive effect on the system satisfaction of users, for a collaborative creativity support tool, such as an enterprise mobile application that provides users with simple features and functionalities that help them to work on creative tasks easily, accessibility

is positively associated with task-technology fit, which improves user's perceived job performance and job creativity, making it a better creativity-supporting system [57, 58] (Table 2).

Table 2. Effect of different affordances on communication and team creativity

Affordance	Effect on communication	Effect on team creativity	Requirements
Transmission velocity	Allows fast information transmission and continuous communication [43]	1 Foster group awareness [52] and enhance collaboration [51] 2 Allows continuous communication and quick feedback, reducing the cognitive effort of team members to interpret information [43] 3 Bring about flow for team members, which has a significant indirect influence on perceived expected creativity through exploratory behavior and positive effect [54] 4 Media with low synchronicity allows sufficient time to process feedback information [43], which improves the effect of feedback information and improves creativity [53]	2-, 6+,
Parallelism	Allow users to send group messages and provide them with the access of knowing whether a message has been read [44]	1 Parallelism has an insignificant effect on information capital, which positively influences user creative performance [9] 2 Enable users to seek feedback from different persons simultaneously, enabling a high level of feedback source variety and facilitating relatively high level of creativity [53]	7+

(*continued*)

Table 2. (*continued*)

Affordance	Effect on communication	Effect on team creativity	Requirements
Modality richness	Facilitate convey and converge of information [44]	1 Promote social processes, such as the establishment of trust, and increase collective efficiency [46–48], enabling more time for creative work 2 Help team members to feel more connected, hence promoting information sharing and communication of novel information and ideas [49] 3 Reduce the uncertainty and misinterpretation during communication [46], facilitate idea integration 4 Facilitate collaboration, especially the sharing of excellent ideas, and improve team collaborative creativity performance [50] 5 Text chat may be more disruptive than richer modality (e.g. Voice chat) during collaborative work [51]	1+, 4+,10+

(*continued*)

Table 2. (*continued*)

Affordance	Effect on communication	Effect on team creativity	Requirements
Rehearsability	Leaves enough time for responding, allowing the receivers to think carefully about what to respond [43]	1 Contribute to communication performance by allowing senders and receivers enough time to think before communicating [44] 2 Have significant and positive effects on information capital and support team creativity [9] 3 However, the reprocessing ability may delay message transmission and synchronized communication, and hinder cohesion and collaboration [9, 43]	2+ , 3+
Data Persistence	Allows individuals to revisit messages to support information processing [43]	1 A previous working version can facilitate members easily backtrack to that working version and would be extremely helpful for correcting mistakes during collaborative creative works [51] 2 Reprocessability has an insignificant effect on information capital which positively influences user creative performance [9] 3 Facilitate users to elaborate on past knowledge to solve new creative problems [55] 4 Tools with high data persistence highlight members' contributions, and thus increase motivation during the collaborative creative process [56]	2+, 8+, 9+

(*continued*)

Table 2. (*continued*)

Affordance	Effect on communication	Effect on team creativity	Requirements
Accessibility	Allow the information to be accessed and retrieved by users more easily [57]	1 System accessibility is positively associated with task-technology fit, which improves users' perceived job performance and job creativity, making it a better creativity-supporting system [57, 58] 2 Tools with high accessibility facilitate users' accessing and retrieving information from it more easily [57]	4+, 5+, 8+, 9+

4 Conclusion

With the widespread adoption of communication tools in creative teams working online, it is important to clarify how the design of communication tools affects team creativity. This study reviewed 54 papers to map the needs of teams, the design of communication tools, and the effects of tools on creativity in different creativity stages. First, we summarized teams' requirements for communication tools in different stages. Second, we identified key affordances with example features, including transmission velocity, parallelism, modality richness, rehearsability, data persistence, and accessibility. Third, we summarized empirical studies and discussed how these affordances could affect communication and team creativity in different stages.

This study provides a holistic mapping of creative teams' needs and communication tools. Many team creativity theories were developed for face-to-face teams, and thus the role of communication tools is often missing. The mapping in this study connected the psychological theories of team creativity (such as stage models and IPO models) with the design theories of communication tools (such as media richness theory). It provides a potential approach to refining or modifying the theories of team creativity in online contexts with the consideration of new communicational technologies.

This study also provides practical design implications. Designers could develop guidelines based on the mapping for the design of effective communication tools for creative teams working online. Since the mapping abstracted design features as affordances, it could be used to face the ever-changing new technologies. Note that as a limitation of this study, this preliminary mapping was developed by two researchers. Therefore, future research is needed to evaluate or refine the mapping empirically.

For researchers, future studies in HCI can identify the psychological and technical needs motivating the use of specific communication tool functions based on affordances. And for practical design of tools, this study facilitates designers improving communication tools for more creative and commercially competitive use.

References

1. Paletz, S.B., Schunn, C.D.: A social-cognitive framework of multidisciplinary team innovation. Top. Cogn. Sci. **2**(1), 73–95 (2010)
2. Paulus, P.B., Brown, V.R.: Toward more creative and innovative group idea generation: a cognitive-social-motivational perspective of brainstorming. Soc. Pers. Psychol. Compass **1**(1), 248–265 (2007)
3. Hargadon, A.B.: How Breakthroughs Happen: The Surprising Truth About How Companies Innovate. Harvard Business School Press, Boston (2003)
4. Sawyer, R.K., DeZutter, S.: Distributed creativity: how collective creations emerge from collaboration. Psychol. Aesthet. Creat. Arts **3**(2), 81 (2009)
5. Mäntymäki, M., Riemer, K.: Enterprise social networking: a knowledge management perspective. Int. J. Inf. Manage. **36**(6), 1042–1052 (2016)
6. Coursey, L.E., Williams, B.C., Kenworthy, J.B., Paulus, P.B., Doboli, S.: Divergent and convergent group creativity in an asynchronous online environment. J. Creative Behav. **54**(2) (2020)
7. Zeng, L., Proctor, R.W., Salvendy, G.: Creativity in ergonomic design: a supplemental value-adding source for product and service development. Hum. Factors **52**(4), 503–525 (2010)
8. Reiter-Palmon, R., Forthmann, B., Barbot, B.: Scoring divergent thinking tests: a review and systematic framework. Psychol. Aesthet. Creat. Arts **13**(2), 144 (2019)
9. Wu, Y.-L., Li, E.Y., Chang, W.-L.: Nurturing user creative performance in social media networks: an integration of habit of use with social capital and information exchange theories. Internet Res. **26**, 869–900 (2016). https://doi.org/10.1108/IntR-10-2014-0239
10. Norman, D.: The Design of Everyday Things. Basic Books (1988)
11. Karahanna, E., Xu, S.X., Xu, Y., Zhang, N.A.: The needs – affordances – features perspective for the use of social media. MIS Q. **42**(3), 737–756 (2018)
12. Howard, T.J., Culley, S.J., Dekoninck, E.: Describing the creative design process by the integration of engineering design and cognitive psychology literature. Des. Stud. **29**, 160–180 (2008)
13. Isaksen, S.G., Treffinger, D.J.: Celebrating 50 years of reflective practice: versions of creative problem solving. J. Creative Behav. **38**, 75–101 (2004)
14. Lubart, T.I.: Models of the creative process: past, present and future. Creativity Res. J. **13**, 295–308 (2000–2001)
15. Reiter-Palmon, R., Leone, S.: Facilitating creativity in interdisciplinary design teams using cognitive processes: a review. Proc. Inst. Mech. Eng. C J. Mech. Eng. Sci. **233**(2), 385–394 (2019). https://doi.org/10.1177/0954406217753236
16. Dreu, C.D., Gelfand, M.J.: The Psychology of Conflict and Conflict Management in Organizations. Lawrence Erlbaum Associates (2008)
17. Deutsch, M., Coleman, P.T., Marcus, E. (eds.): The Handbook of Conflict Resolution: Theory and Practice. Jossey-Bass, San Francisco (2014)
18. Tjosvold, D., Wong, A.S.H., Feng Chen, N.Y.: Constructively managing conflicts in organizations. Ann. Rev. Organ. Psychol. Organ. Behav. **1**(1), 545–568 (2014). https://doi.org/10.1146/annurev-orgpsych-031413-091306

19. Edwards, R., Bybee, B.T., Frost, J.K., Harvey, A.J., Navarro, M.: That's not what I meant: how misunderstanding is related to channel and perspective-taking. J. Lang. Soc. Psychol. **36**, 188–210 (2017). https://doi.org/10.1177/0261927X16662968
20. Basadur, M.: Managing the creative process in organizations. In: Runco, M.A. (ed.) Problem Finding, Problem Solving, and Creativity, pp. 237–268. Ablex, Norwood (1994)
21. Bordia, P., Irmer, B.E., Abusah, D.: Differences in sharing knowledge interpersonally and via databases: the role of evaluation apprehension and perceived benefits. Eur. J. Work Organ. Psy. **15**, 262–280 (2006)
22. Rosso, B.D.: Creativity and constraints: exploring the role of constraints in the creative processes of research and development teams. Organ. Stud. **35**, 551–585 (2014). https://doi.org/10.1177/0170840613517600
23. Zhou, X., Zhai, H.-K., Delidabieke, B., Zeng, H., Cui, Y.-X., Cao, X.: Exposure to ideas, evaluation apprehension, and incubation intervals in collaborative idea generation. Front. Psychol. **10**, 1459 (2019). https://doi.org/10.3389/fpsyg.2019.01459
24. Mehmood, F., Mahzoon, H., Yoshikawa, Y., Ishiguro, H.: An interactive response strategy involving a robot avatar in a video conference system for reducing the stress of response time management in communication. Presented at the 2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN), Vancouver, BC, Canada (2021). https://doi.org/10.1109/RO-MAN50785.2021.9515503
25. Yu, F.Y., Liu, Y.H.: Creating a psychologically safe online space for a student-generated questions learning activity via different identity revelation modes. Br. J. Edu. Technol. **40**, 1109–1123 (2009). https://doi.org/10.1111/j.1467-8535.2008.00905.x
26. Serenko, A., Bontis, N.: Understanding counterproductive knowledge behavior: antecedents and consequences of intra-organizational knowledge hiding (2016)
27. Kennel, V., Reiter-Palmon, R., de Vreede, T., de Vreede, G.: Creativity in teams: an examination of team accuracy in the idea evaluation and selection process. In: 2013 46th Hawaii International Conference on System Sciences, pp. 630–639. IEEE, Wailea, HI, USA (2013). https://doi.org/10.1109/HICSS.2013.153
28. Runco, M.A., Illies, J.J., Eisenman, R.: Creativity, originality, and appropriateness: what do explicit instructions tell us about their relationships? J. Creative Behav. **39**, 137–148 (2005)
29. Runco, M.A., Illies, J.J., Reiter-Palmon, R.: Explicit instructions to be creative and original: a comparison of strategies and criteria as targets with three types of divergent thinking tests. Korean J. Thinking Problem Solving **15**, 5–15 (2005)
30. Sundaravej, T., Mirchandani, D., Lederer, A.: Synchronous collaboration technology use in teamwork. In: 2015 48th Hawaii International Conference on System Sciences, pp. 216–225. IEEE, HI, USA (2015). https://doi.org/10.1109/HICSS.2015.35
31. Cherry, E., Latulipe, C.: Quantifying the creativity support of digital tools through the creativity support index. ACM Trans. Comput. Hum. Interact. **21**, 1–25 (2014). https://doi.org/10.1145/2617588
32. Cherry, E., Latulipe, C., Fung, R., Terry, M.: Creativity factor evaluation: towards a standardized survey metric for creativity support (2009). https://doi.org/10.1145/1640233.1640255
33. Lee, Y.: Dynamics of symmetrical communication within organizations: the impacts of channel usage of CEO, managers, and peers. Int. J. Bus. Commun. **59**, 3–21 (2022). https://doi.org/10.1177/2329488418803661
34. Ean, L.C.: Face-to-face versus computer-mediated communication: exploring employees' preference of effective employee communication channel **1** (2010)
35. Cardon, P.W., Marshall, B.: The hype and reality of social media use for work collaboration and team communication. Int. J. Bus. Commun. **52**, 273–293 (2015). https://doi.org/10.1177/2329488414525446

36. Turban, E., Liang, T.-P., Wu, S.P.J.: A framework for adopting collaboration 2.0 tools for virtual group decision making. Group Decis. Negot. **20**, 137–154 (2011). https://doi.org/10.1007/s10726-010-9215-5
37. Hinchcliffe, D., Kim, P.: Social Business by Design. Jossey-Bass, San Francisco (2012)
38. Stray, V., Moe, N.B., Noroozi, M.: Slack me if you can! using enterprise social networking tools in virtual agile teams. In: 2019 ACM/IEEE 14th International Conference on Global Software Engineering (ICGSE), pp. 111–121. IEEE, Montreal, QC, Canada (2019). https://doi.org/10.1109/ICGSE.2019.00031
39. Garbajosa, J., Yagüe, A., Gonzalez, E.: Communication in agile global software development: an exploratory study. In: Meersman, R., et al. (eds.) OTM 2014. LNCS, vol. 8842, pp. 408–417. Springer, Heidelberg (2014). https://doi.org/10.1007/978-3-662-45550-0_41
40. Gu, N., Kim, M.J., Maher, M.L.: Technological advancements in synchronous collaboration: the effect of 3D virtual worlds and tangible user interfaces on architectural design. Autom. Constr. **20**, 270–278 (2011). https://doi.org/10.1016/j.autcon.2010.10.004
41. Kratzer, J., Leenders, R., Van Engelen, J.M.L.: The social network among engineering design teams and their creativity: a case study among teams in two product development programs. Int. J. Project Manage. **28**, 428–436 (2010). https://doi.org/10.1016/j.ijproman.2009.09.007
42. Maier, A.M., Kreimeyer, M., Hepperle, C., Eckert, C.M., Lindemann, U., Clarkson, P.J.: Exploration of correlations between factors influencing communication in complex product development. Concurr. Eng. **16**, 37–59 (2008). https://doi.org/10.1177/1063293X07084638
43. Dennis, F.: Valacich: media, tasks, and communication processes: a theory of media synchronicity. MIS Q. **32**, 575 (2008). https://doi.org/10.2307/25148857
44. Wang, W.Y.C., Pauleen, D.J., Zhang, T.: How social media applications affect B2B communication and improve business performance in SMEs. Ind. Mark. Manage. **54**, 4–14 (2016). https://doi.org/10.1016/j.indmarman.2015.12.004
45. Hopkins, M.: Collaborative composing in middle and high school chamber music ensembles. Am. String Teacher. **69**, 47–53 (2019). https://doi.org/10.1177/0003131318816084
46. Reiter-Palmon, R., Kramer, W., Allen, J.A., Murugavel, V.R., Leone, S.A.: Creativity in virtual teams: a review and agenda for future research. creativity. Theor. Res. Appl. **8**, 165–188 (2021). https://doi.org/10.2478/ctra-2021-0011
47. Staples, D.S., Webster, J.: Exploring the effects of trust, task interdependence and virtualness on knowledge sharing in teams. Inf. Syst. J. **18**, 617–640 (2008). https://doi.org/10.1111/j.1365-2575.2007.00244.x
48. Bos, N., Gergle, D., Olson, J.S., Olson, G.M.: Being there versus seeing there: trust via video. In: Tremaine, M.M. (ed.) Extended Abstracts on Human Factors in Computing Systems, pp. 291–292 (2001). https://doi.org/10.1145/634067.634240
49. Hogg, M.A., Reid, S.A.: Social identity, self-categorization, and the communication of group norms. Commun. Theory **16**(1), 7–30 (2006). https://doi.org/10.1111/j.1468-2885.2006.00003.x
50. Grözinger, N., Irlenbusch, B., Laske, K., Schröder, M.: Innovation and communication media in virtual teams – an experimental study. J. Econ. Behav. Organ. **180**, 201–218 (2020). https://doi.org/10.1016/j.jebo.2020.09.009
51. Hossain, Md.Y., Zaman, L.: NCCollab: collaborative behavior tree authoring in game development. Multimed Tools Appl. **82**, 4671–4708 (2023). https://doi.org/10.1007/s11042-022-12307-2
52. Hilliges, O., Terrenghi, L., Boring, S., Kim, D., Richter, H., Butz, A.: Designing for collaborative creative problem solving. In: Proceedings of the 6th ACM SIGCHI Conference on Creativity & Cognition - C&C 2007, p. 137. ACM Press, Washington, DC, USA (2007). https://doi.org/10.1145/1254960.1254980

53. Sijbom, R.B.L., Anseel, F., Crommelinck, M., De Beuckelaer, A., De Stobbeleir, K.E.M.: Why seeking feedback from diverse sources may not be sufficient for stimulating creativity: the role of performance dynamism and creative time pressure. J. Organ. Behav. **39**, 355–368 (2018). https://doi.org/10.1002/job.2235
54. Zaman, M., Anandarajan, M., Dai, Q.: Experiencing flow with instant messaging and its facilitating role on creative behaviors. Comput. Hum. Behav. **26**, 1009–1018 (2010). https://doi.org/10.1016/j.chb.2010.03.001
55. Sielis, G.A., Mettouris, C., Papadopoulos, G.A., Tzanavari, A., Dols, R.M.G., Siebers, Q.: A context aware recommender system for creativity support tools. J. Univ. Comput. Sci. **17**(12), 1743–1763 (2011)
56. Chen, Y., Wu, M., Gao, Q.: Online communication for team creativity in tech companies: barriers and tool design. In: Rau, P.-L.P. (ed.) Cross-Cultural Design. Applications in Business, Communication, Health, Well-being, and Inclusiveness, pp. 13–28. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-06050-2_2
57. Wixom, B.H., Todd, P.A.: A theoretical integration of user satisfaction and technology acceptance. Inf. Syst. Res. **16**(1), 85–102 (2005)
58. Chung, S., Lee, K.Y., Choi, J.: Exploring digital creativity in the workspace: the role of enterprise mobile applications on perceived job performance and creativity. Comput. Hum. Behav. **42**, 93–109 (2015). https://doi.org/10.1016/j.chb.2014.03.055
59. Bakker, A.B.: Flow among music teachers and their students: the crossover of peak experiences. J. Vocat. Behav. **66**, 26–44 (2005)
60. Simpson, J.: Conversational floors in synchronous TextBased CMC discourse. Discourse Stud. **7**, 337–361 (2005)
61. Fink, A., et al.: Stimulating creativity via the exposure to other people's ideas. Hum. Brain Mapp. **33**, 2603–2610 (2012). https://doi.org/10.1002/hbm.21387
62. Girotra, K., Terwiesch, C., Ulrich, K.T.: Idea generation and the quality of the best idea. Manag. Sci. **56**(4), 591–605 (2010)
63. Cronin, M.A., Weingart, L.R.: Representational gaps, information processing, and conflict in functionally diverse teams. AMR **32**, 761–773 (2007). https://doi.org/10.5465/amr.2007.25275511
64. Dennis, A.R., Wixom, B.H., Vandenberg, R.J.: Understanding fit and appropriation effects in group support systems via meta-analysis. MIS Q. **25**(2), 167–193 (2001)