Hybrid Teamwork: Consideration of Teamwork Concepts to Reach Naturalistic Interaction between Humans and Conversational Agents

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Abstract. Hybrid teamwork between humans and conversational agents (CA) is a promising approach to augment humans' thinking and problem solving during task work. To realize a natural interaction, it is inevitable to consider research insights from human-centric disciplines for the design of CAs, as human team members have underlying assumptions regarding team work that need to be addressed to achieve valuable outcomes in hybrid teamwork settings. In this paper, we conducted a systematic literature review to consolidate past research on considered teamwork-specific psychological concepts for the design of CAs. The in-depth analysis of 19 publications demonstrates that, both, studies with a conceptual focus and CA instantiations, are primarily concerned with task-related teamwork concepts, while mostly disregarding relationship-related concepts. The results are discussed and implications for future research are identified.

Keywords: Hybrid teamwork, conversational agent, interaction design, team research, literature review.

1 Introduction

Incremental technological improvements in artificial intelligence (AI), machine learning (ML) and natural language processing (NLP) will in near future enable human-machine collaboration for diverse knowledge intensive work tasks [1, 2]. This hybrid teamwork is in line with the concept of intelligence augmentation (IA), which emphasizes a machine's facilitation of human thinking and problem solving [3]. Augmentation can help balance humans' bounded rationality in finding solutions, debias judgements, reduce noise in decision-making and foster creative task performance [4]. The realization of human-machine collaboration will encompass joint, interactive and dynamic task accomplishment through inter alia technology-generated advices (e.g. insights and predictions), which rely on vast amounts of data and thereby qualify as criteria for human workers' decision making [1]. Moreover, teamwork between humans and machines will entail and allow the delegation and allocation of (sub-)tasks to one another [5, 6].

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Due to progressive NLP capacities, collaborative work in hybrid team settings could take place via natural language (written or spoken) [1]. In this vein, AI-powered conversational agents are a phenomenon that is increasingly addressed in scientific literature [7–9]. A CA is a software system, which is capable of autonomously interacting with humans via natural language [10]. In a hybrid team, which consists of a CA and at least one human member, the artificial entity could take over the roles of a facilitator, peer or expert [1, 7, 11]. As human collaboration for joint task work significantly depends on communication [12, 13] and the usage of natural language by artificial interlocutors enhances humans' expectations of a natural interaction with machines [14], the design of CAs should satisfy users' underlying assumptions for human teamwork. Therefore, to naturally and effectively collaborate with humans and comply with their tendency to anthropomorphize machines' behavior [15, 16], CAs require a cognitive model to, on the one hand, execute pre-defined team-relevant behaviors such as planning or goal specification. On the other hand, due to the dynamic nature of teamwork, CAs should be able to anticipate and flexibly react to changing subtasks with associated goals and human team members' intentions and actions [9, 17]. In addition, CAs need to behave in a transparent and predictable way and comply with human norms, while utilizing human communication principles [18–20].

The described progressive technological advancements can be exploited to reach naturalistic hybrid teamwork settings with CAs, but need to be complemented with knowledge on teamwork. Accordingly, the design of human-CA interaction should be guided by human-centered approaches [8, 9, 21–23]. It should be informed with findings from team research (cognitive psychology), which focuses on communication processes, action sequences in and psychological aspects of small groups, to strengthen CAs' capacity for teamwork and socialness in settings of shared task accomplishment [1, 7, 19, 24]. In order to make insights from teamwork research accessible and usable for the growing number of IS researchers designing CAs, a twofold objective is pursued in this paper. First, teamwork concepts that have so far been included in CA designs are systematized. Second, aspects of teamwork, which have been proven to be essential in team research are identified and presented. A systematic literature review is conducted to address the following research question: *Which teamwork-specific psychological concepts have so far been considered for the design of conversational agents for hybrid teamwork?*

The remainder of this paper is structured as follows: Section 2 covers the theoretical background and introduces established teamwork concepts. In section 3, the method of the systematic literature review is introduced. Subsequently, in section 4 the results of the review are presented and integrated. In Section 5, the findings are discussed and implications for future research are defined. Section 6 concludes with limitations of the study at hand and an outlook.

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2 Theoretical Background

2.1 Teamwork Research

The essential principle of human teamwork is the integration of individuals' efforts to achieve a shared goal [11]. Accordingly, extensive research has focused on several team outcomes (e.g. effectiveness, productivity) to investigate teams' abilities to reach their objectives and accomplish tasks [25–27]. These team outcomes are particularly influenced by team processes and emergent states [26–28].

Team processes involve team members' interactions through verbal, behavioral and cognitive activities during task work [27, 29]. The investigations of teams' interactions have been led by the emergence of the fundamental theoretical framework by Marks et al. [29], as the concepts have been continuously verified [27, 30]. The authors developed a taxonomy of team processes with three different categories referring to different temporal phases and corresponding activities, which are defined in Table 1.

Table 1. Definition of activities for team processes [29]

Focus	*Cat.*	*Activities*	*Definition*
Task	Transition	Mission analysis & planning	Identify tasks, consider team resources and environmental conditions
		Goal specification	Identify and prioritize (sub-) goals
		Strategy formulation	Develop sequence of actions
	Action	Monitoring progress	Monitor task process and communicate status to team members
		Systems monitoring	Monitor team resources and environmental conditions
		Team monitoring & backup behavior	Support team members (1) with feedback, (2) through taking over activities or (3) through taking over a task
		Coordination	Coordinate time and sequence of interdependent actions
Relationship	Interpersonal	Conflict management	Prevent team conflicts by establishing conditions, resolve task and interpersonal conflicts
		Motivation & confidence building	Establish and maintain confidence, motivation and cohesion among team members
		Affect management	Manage emotions relevant for task execution (e.g. frustration)

Note. Category (Cat.).

Transition processes occur in the beginning of teamwork and include the steps of mission analysis, goal specification, strategy formulation and planning. Action processes refer to activities to accomplish team goals by coordinating actions, monitoring progress, systems and the team. Lastly, interpersonal processes span over each phase of teamwork and refer to conflict, affect and motivation management as well as confidence building. The transition and action processes are considered to be task-focused comprising behaviors directed at reaching joint goals (e.g. monitoring

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progress) [25, 27–29, 31]. The interpersonal processes are relationship-focused actions (e.g. encourage motivation) [25, 27, 29].

The concept of emergent states, introduced by Marks et al. [29], denotes teams' cognitive and affective states, which arise through and change in relation to team processes [26, 29, 30] (see Figure 1). Spanning almost two decades of research, various team level constructs have been investigated. In accordance to Mathieu et al. [27], a sample of the most intensively studied emergent state concepts in team research are presented in Table 2 with corresponding definitions [11, 30]. As with team processes, emergent states have also been distinguished into task- and relationship-related states [25]. Task-related states reflect how individuals' actions influence or provoke cognition and attitudes about task work (e.g. team confidence), whereas relationship-related states represent the team members' feelings about the nature of teamwork (e.g. trust) [27, 32].

Table 2. Definition of cognitive and affective emergent states

Focus	*Cat.*	*Emergent state*	*Definition*
Task	Cognitive	Shared mental models	Mental representations about the team task, resources, roles and responsibilities that are shared among team members [30, 33]
		Transactive memory systems	"Shared understanding of which member knows what as well as a structure that allows for storage, retrieval, and communication of that knowledge at the team-level" [30]
		Team Confidence	Comprises efficacy and potency beliefs and reflects teams' perception to accomplish a specific and a range of tasks across contexts [30, 34]
Relationship	Affective	Cohesion	"Shared attraction or bonding among team members that is grounded in social- or task-based aspects of team membership, and that drives team members to remain together" [30]
		Team trust	"Shared psychological state among team members comprising willingness to accept vulnerability based on positive expectations of a specific other or others" [35]
		Affective tone	"consistent or homogeneous affective reactions within a group" [36]
		Psychological safety	"A shared belief that the team is safe for interpersonal risk taking" [11]

Note. Category (Cat.).

As depicted in Figure 1, both, team processes and emergent states unfold over time during task work. The transition and action processes constitute crucial building blocks with varying time spans and depending on the task are repeatedly executed for subordinate tasks to accomplish the task.

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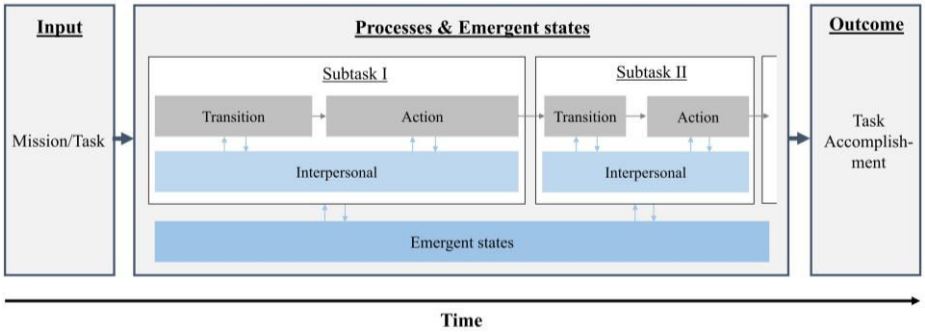

Figure 1. Temporal relationship of team processes and emergent states (adapt. [29])

Activities relating to interpersonal processes are performed to positively affect team functioning. In addition, emergent states evolve through task work and in turn have an impact on the different team-specific verbal, behavioral and cognitive activities.

2.2 Hybrid Teamwork with CAs

Following Seeber et al. and Bittner et al. [1, 7, 9], CAs are intelligent autonomous machines, which are capable of joining human teams. In accordance with the established work team definition by Kozlowski and Bell [11], we conceptualize these hybrid teams to comprise at least two members with one CA and at least one human member. So far, CAs can take over three roles in a hybrid team [7]: (1) a facilitator supports users' achievement of a task with directive behavior, (2) a peer makes contributions or challenges other members' comments and is a full member of the hybrid team, (3) an expert has a special expertise to supplement task work upon request.

To achieve natural interactions between humans and CAs for interdependent hybrid teamwork, a human-centric CA design should incorporate insights from human team research about factors, which enhance the effectiveness of teamwork. This application of transdisciplinary knowledge from cognitive psychology to design software-based systems is in line with the established "Computers as Social Actors" (CASA) paradigm. CASA bases on the social response theory, which proposes that individuals treat computers with social cues as social actors and apply social rules and norms of human-human interaction and associated expectations during human-computer-interaction [37, 38]. Multiple studies showed that humans mindlessly react to artificial entities with social cues (e.g. use of natural language, interactivity) by showing social reactions and behavior [14, 38, 39]. Consequently, due to the humanlike characteristics of CAs, individuals unintentionally apply social conventions, which are specific to the artificial interlocutors' cues and the social context. Hence, for effective hybrid teamwork, CAs need an understanding of fundamental sequences of task- and relationship-focused team processes and emergent states to affect the outcomes of shared tasks.

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3 Research Method

A systematic literature review following the principles of vom Brocke et al. [40], Webster and Watson [41] and Cooper [42] was conducted to identify, assess and interpret existing research findings, which are relevant to answer the posed research question and derive implications for future research. The review process was structured along the five steps proposed by vom Brocke et al. [40].

In a first step, Cooper's taxonomy [42] was applied to determine the scope of the review. The focus was set on research outcomes, methods, applications and theories by integrating literature and identifying central issues to espouse a position. The conceptually organized literature addresses general scholars. In the second step, central definitions (Section 1) and key concepts were derived (Section 2).

To conduct the literature search process, in step three, domain relevant databases were selected: Web of Science, ScienceDirect, IEEE Xplore, ACM DL and EBSCO. For the construction of the search string, keywords, terms and synonyms for CAs and team work were identified by undertaking an initial search in the databases [43]. Subsequently, the literature search was conducted with the following search string: *(("conversational" OR "virtual" OR "digital") AND ("agent*" OR "assistant*") OR "chatbot*" OR "chatterbot*") AND ("team*" OR "team work" OR "hybrid team" OR "collabor*" OR "coop*"))*. The search string was applied to titles, keywords and abstracts and restricted to peer reviewed English literature. In total, the search process comprised two screening phases (see Table 3).

Table 3. Procedure of the literature search process

Database	*Search results*		*First screening*		*Second screening & Backward search*	
	n	*%*	*n*	*%*	*n*	*%*
Web of Science	235	29	27	29	6	35
IEEE Xplore	169	21	29	31	2	12
ACM DL	249	31	24	25	7	41
EBSCO	62	8	8	8	1	6
ScienceDirect	86	11	7	7	1	6
Total papers	**801**	**100**	**95**	**100**	**17(2)**	**100**

In the first phase, the search delivered 801 publications. By excluding irrelevant, unavailable literature and duplicates, 95 publications remained after reviewing titles and abstracts. Literature was excluded, if it had a focus on (1) robots (e.g. manufacturing machines), (2) pure technological characteristics of or approaches to develop CAs, (3) visual representations of CAs (e.g. gestures, eye gazing), (4) other forms of interaction than natural language (written or spoken), (5) communication specific prerequisites for CAs (e.g. repair acts, modality) or (6) knowledge and response training of CAs. In the second screening phase, publications for the in-depth analysis were selected by examining the full texts of the previously identified articles. 17 publications were identified by assigning them to three content-related categories:

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teamwork concepts, CA role and scope. The categories teamwork concepts and CA role were derived deductively. With regard to teamwork concepts, we differentiated between task- and relationship-focus of team processes and emergent states [25–27]. To determine whether publications deal with team processes or emergent states, behaviors and states from human teamwork literature were utilized (see Section 2.1) [26, 27, 29, 31]. By referring to the classification of Bittner et al. [7], the roles of CAs (peer, expert, facilitator) were assessed. The category scope was developed inductively by assessing whether the authors either focused on pure conceptual aspects or CA instantiations. Furthermore, following the approach of Webster and Watson [41], a backward search was applied and delivered two additional publications. Therefore, a final number of 19 publications was considered for the analysis.

In step four, the identified literature was analyzed and synthesized (see Section 4). As a final step, the findings were utilized to derive implications for future research.

4 Results

Following Webster and Watson [41], identified publications addressing teamwork-specific psychological concepts for the design of CAs are structured with a concept matrix to summarize and analyze the relevant findings. In total, 19 papers were selected, which either focus on general conceptual aspects or CA instantiations. The literature structuring process revealed that the articles at hand cover different teamwork concepts dealing with task or relationship aspects and CA artefacts, which serve different roles. In the following subsections, the results are described in detail.

4.1 Conceptual Aspects for CAs

Four publications are concerned with conceptual design aspects of CAs by referring to teamwork concepts. Due to their focus, these articles do not refer to specific CA roles.

Task-focus: Team Processes. With reference to task-focused concepts, two behaviors relating to team processes are specified for artificial agents to reach an effective and a natural form of hybrid teamwork: (1) commit to teamwork by aligning goals to shared objectives and (2) monitor own and collective progress towards shared goals to coordinate interdependent actions [17, 44]. These requirements can be considered as fundamental activities of transition and action processes (coordination, monitoring progress) [29]. In more detail, Castelfranchi [45] addresses the team process of coordinating actions for hybrid teamwork. The author expounds the necessity for artificial agents to coordinate actions with human team members to efficiently exploit knowledge and task-relevant capacities of the individual actors. The proposed central concepts are goal delegation and goal adoption. Depending on a joint task and a corresponding plan, an artificial agent needs to adopt delegated sub-tasks that coincide with the collective's intention to complete a task. Nevertheless, to

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be considered collaborative, the agent should anticipate flawed plans and proactively modify and align (sub-) goals to the overarching objective.

Task-focus: Emergent States. Klein et al. [17] and Bernard [44] propose that artificial agents should be capable of establishing a mutual understanding by sharing information with members, which is consistent with the concept of shared mental models [27, 32]. To achieve this state, Azevedo et al. [46] point out that artificial agents should explain their actions, decisions and the perceived reactions of the human team members.

Relationship-focus: Emergent States. The work of Azevedo et al. [46] indicates that trust between human and artificial team members needs to be established to improve joint task work. The development of this emergent state is dependent on the artificial agent's ability to convey its understanding of the emotional influence of its actions and decisions on the human team member, which in turn elevates mutual understanding.

4.2 Instantiated CAs

Fifteen reviewed publications cover thirteen CA instantiations for hybrid teamwork, as Kumar and Rosé [47, 48] and Kumar et al. [49] report on the same setup.

CA Role. With respect to the different roles, two CA instantiations refer to the role of a facilitator. The instantiated agents proactively tutor, guide and instruct users to achieve a predefined goal or execute a specific task [47–50]. Furthermore, CAs serving the role of a peer were examined in five studies. In accordance to their role, these CAs behave and communicate in the manner of an autonomous team member and are capable of coordinating actions, specifying goals with a human member and monitoring task progress [51–53]. Furthermore, the CAs are capable of proactively managing conflicts and creating shared mental models [54, 55]. Lastly, six studies investigated CAs in the role of an expert, which act predominately reactive. These CAs update and elicit task-relevant information from team members, inform human individuals about the workload state or provide information about conflicting work states [56–61].

Task-focus: Team Processes. Various verbal, behavioral and cognitive activities could be identified in the CA configurations, which pertain to the categories transition, action and interpersonal. The CA, with a restricted dialogue capability, by Harbers and Neerincx [57] incorporates the action process behaviors of team monitoring and backup behavior. In line with this concept, the CA assists team members in finding support (taking over specific activities) by notifying other members that workers with a high workload need support completing their (sub-) task. The CA by Lopez et al. [52] is equipped with a knowledge representation about the task, the team and itself. Due to this technological architecture, the CA is able to reactively respond to human team members' oral questions about current plans to accomplish goals. In addition, the abilities of proactively initiating a joint goal definition process and actively monitoring task progress by asking and informing other team members, the CA executes the action process behaviors of coordination and monitoring progress. In a similar vein, Toxtli et al. [58] developed a CA, which

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supports team members in keeping track of and coordinating shared tasks. Utilizing natural language in a team chat, TaskBot can delegate tasks to other members on demand, create plans for execution and monitor whether the assignee has completed the task. Sayme, a CA designed by Paikari et al. [61], helps to coordinate team members' interdependent task work by proactively notifying members of a software developer team in a one-to-one chat when the same file is opened or a method is changed by two workers to avoid code conflicts. Similarly, Traum et al. [53] implemented a training scenario in which the embedded CA is able to coordinate joint actions by engaging in dialogues with human team members about plans and team roles. Moreover, Trinh et al. [50] integrated functionalities for the CA to plan the task and assess human team members' progress towards goal accomplishment. In the same way, Aesop, the CA by Meo et al. [51], is capable of monitoring task progress during interactively creating a movie with a user. With its representation of task goals (e.g. character creation), the CA can proactively prompt the user when information is missing.

Task-focus: Emergent States. Two studies address the concept of shared mental models. The CA by Fan and Yen [56], interacts individually with members to update information concerning their acts and beliefs, which in turn are relayed to continuously update shared mental models for the team. In extension to this, Hanna and Richards [55] found out that CAs with an agreeable personality positively affect the development of shared mental models.

Table 4. Teamwork concept matrix

	Teamwork concepts																
Publications	**Task-focus**										**Relationship-focus**						
	Team processes							Emergent states			Team processes			Emergent states			
	Transition			Action				Cognitive			Interpersonal			Affective			
	MA & P	GS	SF	MP	SM	TM & BB	C	SMM	TMS	TC	CM	MB & CB	AM	CO	TT	AT	PS
[17] *				X			X	X									
[44] *				X			X	X									
[45] *				X			X										
[46] *								X							X		
∑*	-	-	-	3	-	-	3	3	-	-	-	-	-	-	1	-	-
[50]	X			X								X					
[53]							X										
[52]		X		X			X										
[47–49]												X					
[57]						X											

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[56]								X									
[58]				X			X										
[61]				X			X										
[51]				X													
[55]								X									
[54]											X						
[59]																X	
[60]														X			
∑	1	1	-	8	-	1	7	5	-	-	1	2	-	1	1	1	-
Legend	**MA & P**: Mission analysis & planning **GS**: Goal specification **SF**: Strategy formulation			**MP**: Monitoring progress **SM**: Systems monitoring **TM & BB**: Team monitoring & backup behavior **C**: Coordination				**SMM**: Shared mental models **TMS**: Transactive memory system **TC**: Team confidence			**CM**: Conflict management **MB & CB**: Motivation & confidence building **AM**: Affect management			**CO**: Cohesion **TT**: Team trust **AF**: Affective tone **PS**: Psychological safety			

Note. * = *conceptual publications.*

Relationship-focus: Team Processes. Three of the reviewed CAs entail configurations, which refer to relationship-focused team processes. Kumar et al. [49] and Kumar and Rosé [47, 48] applied team research insights to implement an interaction strategy for the CA, which builds up users' motivation and confidence by expressing approving (reward, satisfaction, passive acceptance) statements during tutoring. In the same way, the CA developed by Trinh et al. [50] utilizes a conversation strategy to induce motivation by animating users to reconsider their work. Lastly, Kuramoto et al. [54] developed a CA, which is capable of managing conflicts during triangular chat interactions with an employee and a customer. By establishing sympathy with an angry customer, the CA suppresses an anger-filled atmosphere.

Relationship-focus: Emergent States. Two reviewed studies focused on affective states provoked by CAs. Portela and Granell-Canut [59] showed that CAs can positively impact users' emotional engagement utilizing text messages by touching personal topics, showing empathetic signs, keeping the context and conversations open. This behavior can be utilized to induce an affective tone. The cohesion in a hybrid team working on an information-seeking task and the collaborative experience can be improved by the CA's ability to infer members' need for an information search [60].

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5 Discussion and Future Research

As technological advancements pave the way for naturalistic hybrid teamwork between humans and CAs via natural language [1, 9], a human-centered approach is required for the design of CAs. Therefore, the aim of the paper at hand was to make teamwork-specific psychological concepts from team research accessible and usable for IS researchers to design human-centric CAs. For this reason, we systematically reviewed literature on heretofore proposed and utilized concepts for the design and implementation of CAs.

We discovered that the majority of identified publications (13/19) deal with task-related teamwork concepts. More specifically, behaviors are addressed, which are relevant during (action team processes) and prior (transition team processes) to joint task work. Concerning behaviors during task accomplishment, previous investigations show that CAs need a representation of shared plans to flexibly align their goals during task execution [17, 44, 52, 53]. Generally, the artificial team member should act proactively in order to coordinate collective actions and monitor progress towards common task objectives [45, 61]. For coordination purposes, the CA should be capable of detecting flawed plans and present proposals for an alternative course of action accordingly [45]. In addition, to monitor progress of task processes, CAs have to engage in dialogues with individuals to ask and inform other team members about dynamically changing task and workload states [57]. This request for information from individuals by the CA can also serve to monitor the team by relaying relevant disclosures to other members [57]. Referring to the preparation of teamwork (transition team processes), CAs accomplish to identify (sub-) goals by actively initiating goal definition processes with the human team member [52]. At this stage, the CA needs to create a representation of an initial plan and its corresponding goals to warrant successful task execution [50]. Apart from these behaviors, the task-focused emergent state of shared mental models has been previously realized with CAs. This concept can be established by the CA's capability to share task-relevant information [17, 44], describe perceived effects of its own behavior on others and transparently explain its motives for behavior and decisions during teamwork [46]. Furthermore, the development of shared mental models can be positively affected by CA's agreeable personality [55].

A small number of reviewed publications (6/19) cover relationship-related teamwork concepts for CA design. To account for socio-emotional aspects, CAs can positively affect members' motivation levels by encouraging them to reflect on and approving contributions [47–50]. In addition, CAs can assist to resolve conflicts by detecting anger and establishing sympathy between two actors [54]. Regarding relationship-related emergent states, CAs are capable of increasing human team member's emotional engagement by being empathic and personal [59]. Moreover, the transmission of the CA's understanding of the influence of its actions on team members' emotions increases trust [46].

Overall, a small number of previous publications dealt with teamwork concepts in connection with human-centered design approaches for CAs. The reviewed publications show that currently task-related team processes and emergent states are

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considered to a greater extent than those with a relationship focus. Furthermore, behaviors referring to the preparation of teamwork (transition) and emergent states in general are focused on restrictedly. For the CA instantiations, we observed that none of the CAs incorporate more than three different teamwork concepts, which indicates that CAs do not yet provide full support for teamwork. To expand this research endeavor, we propose general implications for future research. First, the conceptually covered teamwork concepts should be expanded to the described team processes and emergent states to comprehensively inform the design of CAs. More specifically, multiple task-related behaviors should be included by simultaneously considering their temporal sequence (see Figure 1) to allow for flexible hybrid teamwork. Second, the conditions for an efficient delegation and allocation of tasks between humans and CAs should be examined. Third, proposed relationship-related behaviors for joint task work in team research literature should be adopted and intensively examined to account for socio-emotional aspects during teamwork. Fourth, the extension of emergent states to achieve elevated hybrid teamwork outcomes should be pursued.

6 Conclusion

This paper covers the current state of research on the application of teamwork-specific psychological concepts and presents knowledge-enriching insights from team research for the design of CAs for hybrid teamwork. Although the conducted literature review contributes to an increased understanding regarding this issue, the results are restricted to articles in the field of information technology, as databases in the domain of human sciences (e.g. PsycINFO) have largely been neglected. Nevertheless, the derived insights constitute a basis for future research and are highly relevant for designers of CAs in science and practice. Overall, the approach of applying well established findings regarding human teamwork is promising to achieve human-centric designs of CAs for hybrid teamwork settings.

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