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# CROSS-TIMESCALE EXPERIENCE EVALUATION FRAMEWORK FOR PRODUCTIVE TEAMING

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## ABSTRACT

This paper presents the initial concept for an evaluation framework to systematically evaluate productive teaming (PT). We consider PT as adaptive human-machine interactions between human users and augmented technical production systems. Also, human-to-human communication as part of a hybrid team with multiple human actors is considered, as well as human-human and human-machine communication for remote and mixed remote- and co-located teams. The evaluation comprises objective, performance-related success indicators, behavioral metadata, and measures of human experience. In particular, it considers affective, attentional and intentional states of human team members, their influence on interaction dynamics in the team, and researches appropriate strategies to satisfyingly adjust dysfunctional dynamics, using concepts of companion technology. The timescales under consideration span from seconds to several minutes, with selected studies targeting hour-long interactions and longer-term effects such as effort and fatigue. Two example PT scenarios will be discussed in more detail. To enable generalization and a systematic evaluation, the scenarios' use cases will be decomposed into more general modules of interaction.

***Index Terms*** – Productive Teaming, user evaluation, experience, team member states, interaction dynamics.

## 1. INTRODUCTION

A human-centric interactive communication for productive teaming may be characterized by interaction turns and their temporal evolution, both during a more dynamic adaptation phase and for the case of a mostly adapted interaction scenario. Building on the concept of turns [15][9], an analysis of the communication may focus on interaction state analysis. Here, turn-taking and roles have been considered as factors that influence success in human-robot teaming, however, there are contradicting outcomes, e.g., specialized robot roles leading to exclusion in human-robot teaming [18]. Also, to achieve efficiency and satisfaction in human-robot teams, Gombolay et al. [19] suggested that human-robot shared decision-making may favor the perception of human and robotic teammates to the human counterpart. Considering a state model also for longer-term processes, different adaptation mechanisms and "impairments" thereof can be assumed.
Here, the impacts due to interaction processes happening at shorter timescales, the impact due to states related with emotions and mood and due to longer-term socio-demographic influencing factors are considered in the proposed conceptual evaluation framework.

Perceptions, interactions and experiences across all timescales are driven by the "states and traits" (e.g., [16]) of the human and machine interactants (programmed in case of the machines). Here, both cognitive constructs of "trust" and "acceptance" are assumed to be in a bijective relation with the interactions, influencing these interactions and being influenced by them.

## 2. TIMESCALES OF INFORMATION PROCESSING AND EXCHANGE

How is information processed and exchanged between cooperative partners? Before we can answer this question, it is critical to first address the timescale at which information might be processed and knowledge be created.

Levels of human cognition and action can be defined in terms of the timescales that it takes for decisive activity to be generated from information processing [1]. At the level of neural processing (i.e., biological band; $10^{-4}$-$10^{-2}$ secs), the human brain can respond instinctively to salient stimulation. At the cognitive band ($10^{-1}$-$10^{1}$ secs), human actors could perform deliberate acts and operations to process information in working memory for long-term storage or to generate new knowledge. Such knowledge could be directed towards the completion of goal-defined tasks at the rational band ($10^{2}$-$10^{4}$ secs), which would generate longer-term implications at the social band ($10^{5}$-$10^{7}$ secs) for learning and cultural norms. Delineating information processing and actions with regards to timescales is a critical prerequisite to understanding how the outcomes of human actions at a given timescale (e.g., deliberate acts) could influence one's likely repertoire of actions and perceived affordances at a different timescale (e.g., trust and risky behavior).

For instance, a study [13] that investigated the role of *in situ* displays to provide montage assembly instructions found correspondence between experiential self-reports of lower cognitive loads (rational band) that were commensurate with EEG/ERP activity that indicated less working memory load (biological/cognitive band). The interesting finding, however, was that certain individuals reflected that they felt like the "robot" in such an instance (social band) after the study was completed. Conversely, users of a system that allegedly adapted task difficulty to real-time user states from their implicit physiological activity (biological band) self-reported greater confidence in their performance (rational band) that was commensurate with actual performance relative to use of a non-adaptive system [14]. However, both systems were identical and the effectiveness of the "adaptive system" was a placebo effect. More interestingly, users of the placebo system demonstrated reduced trust after using it, but still demonstrated a willingness to use it (social band). This bears implications to the deployment of systems that can sense, interpret, and adapt to human activity.

## 3. AFFECTIVE AND INTENTIONAL STATES OF TEAM MEMBERS, AND DYNAMIC STRATEGIES FOR APPROPRIATE SITUATED ACTIONS

Relevant user states for action coordination depend on the personal state of human team members. Here, relevant dispositions [2] and timing factors and their disruption [3] for action coordination have been identified. Multimodal observations of affective and attentional states, their change and team dynamics lead to a construction of a user-adaptive interfacing in the spirit of companion technology [4]. This type of interaction comes with models of team dynamics, in particular, shared mental models (for the area of cognitions) about the expected success of the team as well as communication and cooperation strategies (behavior), which allows also for a joint approach in hybrid teams to adapt and define strategies of action and planning [5]. For the modeling of the dynamics, different modeling methods are envisaged that are, for example, based on RNNs (Recurrent Neural Networks) and/or BERT (Bidirectional Encoder Representations from Transformers) (e.g., [17]), which allow for identifying both positive and negative strategies for interactive-cooperative, dialog-based clarification of possible conflicts with natural language. This may appear in situated and remote settings [6,7]. Structured discourse representations and flexible dialogue models implement policies for choosing the means/strategies for coordination and alignment of artificial and human team members which all appear as peers [8].

## 4. EXAMPLE PRODUCTIVE TEAMING INVESTIGATION SCENARIOS

The above-mentioned concepts of timescales, affective and intentional user states and strategy finding processes can best be investigated in two productive teaming scenarios.

The first scenario is designed to focus on *decomposing the addressed interactions in a modular manner*. An initial set of according evaluation measures and the methods for their assessment form dependent variables. The technical set up for the adaptive machine instances and associated interaction scenarios will be realized with AR and VR technology. This scenario also comprises setting up research frameworks for signal- and metadata-acquisition. Building on related work [10], means for capturing questionnaire-type subjective data, attention-, interaction- and communication-related behavioral data and task performance information are realized within a framework for a reproducible research data management.

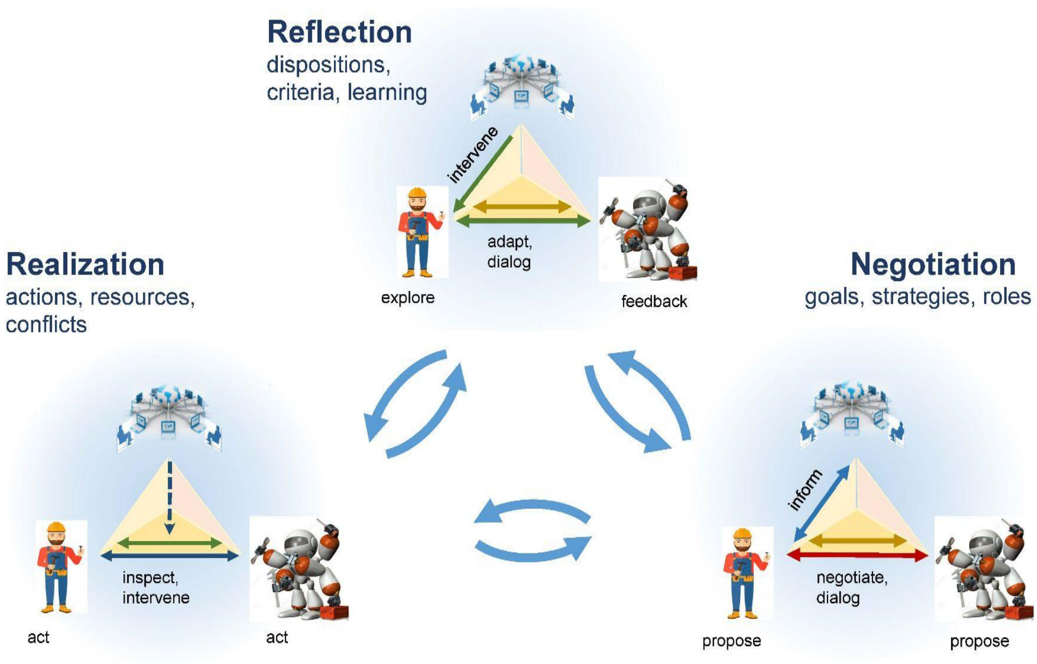


*Fig. 1: Levels of cooperation in productive teams*

The second scenario focuses on *experience prediction and interaction adaptation through empirical user studies*. Best suitable success and quality-of-experience indicators (key performance, key quality) are identified in this framework, building, e.g., on [20], along with the relevant affective and intentional user states. The outcome is (meta-)data about communication states, attention, emotional responses and experience, as well as socio-demographic aspects and cognitive constructs representing the teaming process. Algorithms for performance-indicator and experience prediction are implemented in interaction models based on observable data, which allow for a response and interaction management system of the machine-type team member.

Both scenarios are based on the hypothesis that in functioning productive teams there must be sufficient coordination on three interacting *levels of cooperation* [11] and that different coordinative or communicative mechanisms can be used for this (see Figure 1): At the realization level, the operational implementation of separate or joint actions must be coordinated (e.g. through observation, feedback or intervention); at the negotiation level, the objective or larger implementation plan must be coordinated with strategies and role assignments (e.g. by proposing or negotiating based on new information); Finally, on a reflection level, the process itself can be coordinated, if necessary with an alternative choice, according to changeable criteria and dispositions [12].

## 5. CONCLUSION

We have presented a framework for conceptualizing and evaluating human-centric interactive communication for productive teaming, through interaction state analysis. Perceptions, interactions and experiences across all timescales can be investigated in two dedicated frameworks, where dialogic interactions and cognitive constructs are cornerstones of productive teaming solution findings and strategy adaptations.

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