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The "Architectures" of Successful Remote Collaborative Problem Solving: Exploring Commitment in Dyadic Interaction

Johanna Pöysä-Tarhonen, University of Jyväskylä, johanna.poysa-tarhonen@jyu.fi
Nafisa Awwal, University of Melbourne, n.awwal@unimelb.edu.au

Abstract: During successful collaborative problem solving (CPS), participants are expected not only to share and process information to solve the task, but also to show responsiveness and commitment to their partners. Accordingly, this exploratory study aims, via two contrasting cases, to acquire a preliminary understanding of how commitments and successful CPS come together in remote, dyadic interaction. To do so, the study relies on objective and subjective measures and combines group with individual levels of analysis on log files and cued interviews. The results revealed how commitments were interrelated with efficient coordination of interactions during CPS. Coordinated, well-communicated problem-solving trails, in turn, resulted in positive outcomes regarding the problem-solution. Thus, if commitments can reduce uncertainty of the partner's actions, required in efficient coordination, to focus on the "anatomy" of commitments can provide us with a better understanding of what may (dis)favour successful CPS to take place in this context.

Introduction

This paper explores how commitment and successful, remote collaborative problem solving (CPS) processes come together in dyadic interactions. Focusing on commitment during CPS is motivated by the expectations that commitment can facilitate successful joint actions of multiple actors; e.g., by increasing the motivation to contribute to shared goals and reducing the uncertainty often related to fulfilment of these goals (e.g., Michael & Salice, 2017; Pacherie, 2013). Additionally, as successful socio-cognitive exchanges of CPS (e.g., Avry et al., 2020; Graesser et al., 2018; Scoular et al., 2017; Zwiecki et al., 2020) are not given but require learning and careful training, in order to guide a learner to become more competent participant in CPS, a broader understanding of the "architectures" of social relationships (e.g., Perret-Clermont, 2015) regarding CPS is essential.

Definitions of CPS routinely point out that for a dyad or group, there is a shared goal to be accomplished through problem solving and that a single participant cannot solve the problem alone (Graesser et al., 2020). Earlier studies have shown that for successful CPS to occur, participants need to intentionally organise themselves to a coordinated activity (Barron, 2000); coordination referring to "the process of ordering of entities (events, behaviours, and actions) in time, simultaneously or sequentially" (Baker, 2015, p. 461). Moreover, in successful CPS, problem solvers are expected not only to share and process information to solve the joint task, but also, in real-time interaction, to show responsiveness and commitment to their partners (e.g., Avry et al., 2020).

In conventional definitions, commitments are thought to arise verbally through speech acts of promising or making agreements (i.e., as explicit commitments): "If one social partner intentionally communicates to another that he intends to do X, and the other acknowledges this, then they have common knowledge about this interaction, and the first partner is committed to do X" (see Siposova et al., 2018, p. 192). Yet, the readiness to be jointly committed can also be expressed without explicit verbal statements (such as "I promise to do X" or "I will do X"), but more implicitly via expectations and motivations (Michael et al., 2016b), slight nuances of verbal communication (Michael & Salice, 2017), or even nonverbally (Siposova et al., 2018). Thus, together with verbal agreements, there are many situational factors that can give rise to a sense of commitment not recognised directly by the conventional definitions (Michael & Salice, 2017; Michael et al., 2016b).

Accordingly, Michael et al. (2016b, see also Michael & Salice, 2017) have proposed a minimal structure in which commitment and a sense of commitment can arise, which includes (a) a situation where there exists an outcome that an actor needs to achieve, or which is the goal of action that the actor is currently performing or intends to perform; and (b) in this situation, the external contribution of a second actor is crucial to bringing about the goal. This situation may elicit a sense of commitment on the part of one or two actors, or *w*hen both actors desire to reach the goal, the commitment is mutual. What is seen as critical for commitments to arise is that the goal of action is defined primarily in an agent-neutral manner (Michael et al., 2016b); that is, the goal or the outcome is instructed to be brought about in the most efficient way irrespective of whose goal it is (see also Butterfill, 2012).

Suitably, to investigate commitment during successful CPS, the digital CPS environment and the tasks employed in this study (see Assessment and Teaching of 21st Century Skills [ATC21S], http://www.atc21s.org; e.g., Care et al., 2016) are expected to meet the requirements of the minimal structure of situations of commitments

and a sense of commitment to arise (Michael et al., 2016b). In the ATC21S environment, student dyads interact remotely to solve shared, open-ended problems with impersonal goals. Most CPS tasks implement an overall structure—an asymmetry of resources—which imposes the need for collaboration and requires participants to pool their knowledge, information, and resources (Scoular et al., 2017). Thus, each individual action is only effective if the other action is also performed, and to successfully solve a task requires both the participants' commitment to the task and commitment to their partner (see Hesse et al., 2015; Scoular et al., 2017).

However, the ATC21S environment does not provide preselected solution paths for the participants but allows the flexibility of movements, which can result in a great variability in how the participants proceed through the tasks (Scoular et al., 2017). When the partners lack definite problem solving strategies, the solution paths can be more random and involve both significant and insignificant activities regarding their relevance to the task completion (Vista et al., 2016). The possible moments of confusion can be challenging, as they require the dyad to develop diverse strategies to clarify the uncertainties and to understand and accept the combined impact of their refined intentions and actions to reach the shared goal (Barron, 2000; see also Michael & Pacherie, 2015). Yet, commitments, if credible, are seen to have the potential to reduce uncertainties in joint actions (Michael & Pacherie, 2015; Michael & Salice, 2017; Pacherie, 2013). This is important regarding successful CPS, as in joint actions, uncertainties can undermine the mutual predictability required for efficient coordination to take place (Michael & Pacherie, 2015).

Consequently, the aim of this explorative study is, via two contrasting cases, to look more closely into (1) how commitments and successful CPS processes come together in remote dyadic interaction (i.e., how interactional events of the log files are related to each other in terms of the speech acts of promising or making agreements; to the appearance of the task-specific CPS elements in these events; and the significance of CPS events in this regard); and (2) what can lead the participants to act committed and expect the others do the same. The strategy of interrelating two contrasting cases (e.g., Baškarada, 2014; Flick, 2004), based on different perspectives as objective and subjective measures of the remote CPS processes in dyads (i.e., as log files, cued retrospective reporting CRR interviews), is chosen as it is expected to make the process qualities and components related to commitment and its role in successful CPS more salient and open.

Methods

Participants and study set-up

The two contrasting cases were drawn from a study of ten student dyads recruited from an initial teacher education programme in a Finnish university. In the data gathering situation, the dyads focused in this paper were working in two separate cognitive labs, and while completing the CPS tasks, their eye movements were recorded with desktop eye trackers (screen-based; SensoMotoric Instruments [SMI] RED 250 Mobile). These data as eye gaze video exports were used as a stimulus in the cued retrospective reporting (CRR) interviews (van Gog et al., 2005). The log files from the CPS environment were automatically generated.

Digital CPS environment and task

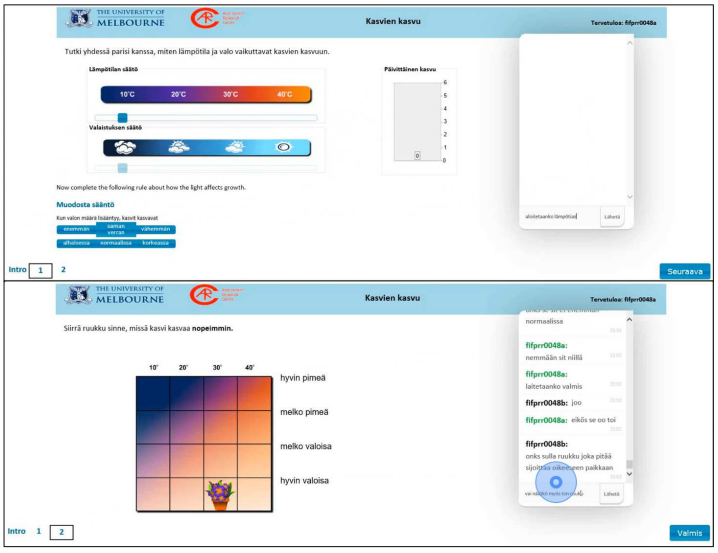
When exploring CPS processes, the study takes the unique properties of the digital, game-like CPS assessment environment ATC21S (e.g., Care et al., 2016; Scoular et al., 2017) as its point of departure. The CPS tasks of the ATC21S environment have been designed for dyads following a comprehensive CPS framework by Hesse et al. (2015, see also Care et al., 2016; Scoular & Care, 2020; Scoular et al., 2017). The framework covers both social and cognitive elements of the CPS construct and amalgamates theoretical knowledge from social psychology and problem solving. The framework involves three main strands of social elements (i.e., participation, perspective taking, and social regulation) and two main strands of cognitive elements (i.e., task regulation and knowledge building), which are all further divided into sub-elements (19 elements in total; Hesse et al., 2015). In the environment, the defined problem space is presented through a graphical user interface, which enables users to interact with the problem environment and with their collaborating partner (Vista et al., 2016). As a game-like (e.g., Squire et al., 2003), dual interaction space (Zemel & Koschmann, 2013), the environment encompasses a chat property as a free-form, synchronous interface and a space with actionable artefacts that have either a symmetrical or asymmetrical outlook for the individuals. In a symmetrical task, stimulus content and actionable artefacts are equal for the partners, whereas in an asymmetrical task, the dyad is given a unique subset of resources for problem solving. Alternatively, the screen view can be identical, while the ability to move certain objects or scroll the bars is divided between the partners. The success of one student depends on the behaviour of the other and the reactions offered (Care et al., 2016).

The task, focused on in this paper, is one of the ATC21S tasks named Plant Growth (Figure 1) (Awwal et al., 2015; Scoular et al., 2017). The task has asymmetric resources for the participants and is presented in two

levels (Pages 1 and 2). On the first level (Page 1, Figure 1), each of two participants (Students A and B) can control only one of the resources (temperature or light density) to manipulate the daily growth of plants. In the screen view, students can view the choices made by their partners (without access to their partners' controls) and the effect of their selections on plant growth. They are required to observe if there is a consistent pattern of growth based on variations in light (very dark, quite dark, quite bright, and very bright) and temperature (10, 20, 30, and 40) when applied together or in isolation. Participants are then asked a question regarding the mechanism of their partners' control, which requires an exchange of information with their partners. The task is thus divided into processes in which, following initial exploration, problem solvers are required to go through stages to collect information, identify patterns, form rules, test rules, generalise rules, and test hypotheses (Awwal et al., 2015). On the second level (Page 2, Figure 1), the aim is to assess under which conditions the plant grows fastest or slowest and to apply their understanding of the conditions to position the plant on the grid provided. The first level operates as an exploration space for participants to learn and understand the problem space and the game mechanics. The second level, in turn, tests whether participants understand the rules and can apply their learning in a different context (Awwal et al., 2015).

Figure 1

Screen Captures from the Plant Growth Task (Pages 1 and 2)



Note. Student A Views (in Finnish)

Data

To better understand commitment and successful remote CPS processes in dyads, the current paper relied on both objective (i.e., observations of interaction) and subjective measures (i.e., participants' experiences of interaction). The *objective* measures were based on the information embedded in automatically generated log files from the CPS environment. The log files consisted of time-stamped information of the participants' actions as movements of artefacts and the communication stream via a free-form chat interface (Care et al., 2015). The log file from the collaborative session included data on the collaborating team, the record index in the database, task and page, activity events, and details of any onscreen activities along with the corresponding time.

The *subjective* measures were acquired via cued retrospective reporting (CRR) interviews (e.g., van Gog et al., 2005) of the individual participants. During CRR participants are invited to verbalise their thought processes during the task performance, retrospectively based on a cue or cues of their performance (van Gog et al., 2005). In this study, the CRR interviews were cued with eye gaze video exports as scan path visualisations, computed from the eye-tracking data (e.g., Blignaut, 2009) with eye-tracking software SMI BeGaze. In the scan path visualisations, the gaze positions and eye events are plotted on a stimulus video, based on the gaze coordinates and duration. To guarantee the accuracy of the CRR data, interviews were conducted within a two-day time span from the recorded CPS sessions. The videotaped interviews were transcribed for the analysis.

Data analysis

As a *preliminary* phase, to capture the general features of dyadic interaction during CPS, contributing to commitment, quantitative summaries of the CPS activities were created. The summaries included the

quantification of the total number of dyadic activities captured from the automatically generated log files (including chats and actions) and calculating the total time spent on the task. In the *actual* analysis, the focus was on how commitments and successful CPS processes came together in remote, dyadic interactions and what could lead the participants to act committed. Thus, the focus was on how interactional events of the log files (i.e., chats and actions) were related to each other in terms of commitments, what was the appearance of the task-specific elements of CPS in the interactional events, and what was the significance of these events regarding successful CPS. The CRR reports were, in turn, analysed for individual participants' verbal references to commitment. To do so, a qualitative coding procedure was applied, which included the following phases: In the *first* phase, the activities that were associated with explicit commitments (i.e., promising and making agreements) as verbal references or moving of artefacts, were they related to (a) initiative (i.e., commitments) or (b) responsive actions or chats (i.e., accepted commitments) were identified from the log file data (e.g., Siposova et al., 2018). In the *second* phase, to contextualise these coded events, the process qualities of CPS interaction regarding the CPS elements, as defined in the CPS framework (i.e., Hesse et al., 2015) were also identified from these data. That was, to detect the behavioural indicators of the task-specific CPS elements (see Table 1) from the log file data (i.e., Hesse et al., 2015), such as interaction, responsibility initiative, responsiveness and more. *Simultaneously*, due to the lack of preselected solution paths in the ATC21S environment (Scoular et al., 2017), these interactional events of CPS were also analysed in accordance with whether the events were significant or insignificant in their relevance to task completion (Vista et al., 2016). Significant events in CPS are those where dyadic interactions are coordinated and have a considerable positive effect on the progress towards the resolution of the problem. Any explicit commitments shown through an initiation would generally be followed by a responsive act (i.e., chats or actions). Insignificant events are an indication of less coordinated CPS interactions. Dyads generally do not systematically coordinate or respond to their partners and are often seen to work in isolation, the consequences of which are most often damaging to their progress or in reaching a committed situation for reliance on one another. Moreover, in the *third* phase, the verbal references to commitments, be they explicit or implicit (i.e., verbalised motivations and expectations, expressions of trust, and more), were identified from the CRR interview data transcriptions of the individual participants. *Finally*, to form an inclusive picture of the CPS interactions of dyads, all three phases of the actual analysis were combined into episodes of the CPS processes, building on the log file data, and notated with the evidence from the different phases of the analysis as well as different perspectives (i.e., dyad and individual levels). In this paper, the contrasting cases are exemplified via brief representative examples (Tables 2 and 3), drawn from the full episodes of the CPS processes in dyads.

Table 1
The Task-Specific Elements Regarding the CPS Construct (Plant Growth Task)

Skills	Behaviour	An example of data captured for assessment
Interaction	Interacting with partner.	Presence of chat during actions and processes.
Responsibility Initiative	Taking responsibility for progress for parts of the group task.	Realising the need to move to subsequent pages of the task, communicating with partner.
Responsiveness	Responding to contributions of others.	Responding to partner's specific queries before proceeding with other activities.
Collecting information	Recognising the need for more information.	Undertaking activities with relevant and available resources.
Systematicity	Implementing possible solutions to a problem.	Trial of different combinations of light density and temperature options in search of plausible conditions.
Solution	Answering correctly.	Placement of the plant in the correct position on the grid by Student A and B, respectively, as per the conditions given.

Results: Two contrasting cases

The preliminary phase of analysis on the log file data showed substantial differences in terms of the general characteristics of CPS interaction of the two dyads (hereafter Dyad 1 and Dyad 2). Accordingly, the quantitative summaries of the total number of activities completed during the Plant Growth task showed that, when comparing the activities of Dyads 1 and 2, Dyad 1 had remarkably more actions (manipulating artefacts) than Dyad 2, both in terms of the light and temperature inputs (64.7% of the number of light input actions and 79.7% of the temperature input actions), whereas the number of chats (i.e., 'Type message') was more equal in the dyads (Dyad 1 wrote 55% of the total number of messages).

Equally, the actual analysis of both the objective and subjective measures of the CPS processes (i.e., log files and CRR interviews) showed discrepancies in the quality regarding the actualisation of the CPS process concerning all the aspects of analysis, such as how the interactional events of the log files (i.e., chats and actions) were related to each other in terms of explicit commitments, the appearance of the task-specific elements of CPS during the task completion, and the significance of these activities. Furthermore, as subjective measures, the CRR

interviews shed more light on the agreements made between partners and how they expressed trust in their partners (Dyad 2), for example. Taken together, the quality of the various aspects came together and was visible in the two diverse, contrasting solution paths of the two dyads, named here as 'Low coordination condition of CPS' (Dyad 1) and 'High coordination condition of CPS' (Dyad 2).

Next, based on the outcomes of the analysis, a brief depiction as an observational summary (Barron, 2000) of the CPS process characteristics of each pair is provided. The depictions are followed by brief excerpts from the CPS interaction of the two dyads (it is not possible to portray the full event here), in which the notions of the different phases and aspects of the analysis are embedded in and accompanied with the CRR data captions of the individual students (Tables 2 and 3). The excerpts showcase how commitments, primarily explicit such as making promises and agreements, came into existence (or did not) and were related to highly coordinated conditions and to successful CPS in this context; whereas in less coordinated conditions and a less successful CPS process, commitments, such as promises and agreements, were rare or missing (e.g., Michael & Salice, 2017; Michael et al., 2016a,b; Siposova et al., 2018).

Low coordination condition of CPS (Dyad 1)

As visible in the excerpt (Table 2), Dyad 1 set out plans for solving the task (here, Student A was more active) but did not systematically coordinate their actions in accordance with the plans, and explicit commitments, such as promises and agreements, were not made (Michael & Salice, 2017; Michael et al., 2016b; Siposova et al., 2018). Even though they did more trials than Dyad 2 and spent more time on the task, they were, to a large extent, repeating similar, insignificant activities without acknowledging the solution path (for example, see lines 195, 197, and 201). It seems that they did not fully comprehend the task, and even when reaching the solution, it seems that they did not at first recognise it. In the excerpt, only a few task-specific CPS elements can be observed (here, "action" as the largest category, followed by "collecting information" by Student A," perseverance" by Student A, and "interaction"; see Hesse et al., 2015). In the CRR quote (in Table 2) from Dyad 1 (Students A and B), it is observed that during their CPS process, their interactions had been mostly uncoordinated. They set out without a clear conception of the given instructions for the task and did not coordinate well on what each of them could view. Consequently, their actions were not synchronised with the other's or in relation to the plan they had made. Thus, their report during the interview suggests that they commenced the task without a comprehensive picture of the problem or a plan on how to collaborate.

Table 2

Excerpt from the Full Problem Solving Episode of Dyad 1

Logfile data:

Line	Student	Activity		Time	Relation of Interactional Events (Initiating-Responding)	Observable Subskill	Sign/Insignificant activities
193	**A**	**Type message**	**But try still those other points**	23.52.37	initiating	Perseverance: A	
194	**A**	**Type message**	**Set that 2**	23.52.40		Interaction	
195	B	Light input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.43	responding	Action	Significant: 193-195
196	A	Temperature input	temp: "10 degrees"; light: "quite dark"; growth: 1mm	23.52.43	initiating	Action	
197	A	Temperature input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.45		Action	Insignificant:195, 197
198	B	Light input	temp: "20 degrees"; light: "quite bright"; growth: 3mm	23.52.46	initiating	Action	
199	A	Temperature input	temp: "10 degrees"; light: "quite bright"; growth: 1mm	23.52.49	initiating	Action	
200	B	Light input	temp: "10 degrees"; light: "quite dark"; growth: 1mm	23.52.50	initiating	Action	Insignificant:196, 200
201	A	Temperature input	temp: "20 degrees"; light: "quite dark"; growth: 2mm	23.52.51	initiating	Action	Insignificant:195, 197,201
202	A	Temperature input	temp: "30 degrees"; light: "quite dark"; growth: 3mm	23.52.53		Action	

Cued Retrospective Reporting (CRR) Interviews:

Student A:
'Then **I** at least **had fully forgot at this point that we might have the different things** there although **there might just be some discussion about it in the beginning**, or in a way so that there can be same or different stuff, so then the **initial assumption was that the same things are actually displayed to both**, the same things. Or one somehow thought that also the question is the same at this point when we were still starting to solve this.'

Student B:
'Er, so that I **didn't realise it at first that it's sort of different, for both of us**. So we noticed it together only at some point, we had proceeded quite far already with this and then **we realised that (oops) I cannot do like it**. That we have a different question. So we realised this fairly quickly that we have different controls. But **we discovered then only later that we didn't have the same question**, after all, what we were looking for. So that we **needed to collaborate differently** from the first one.'

High coordination condition of CPS (Dyad 2)

Over the course of solving the CPS process, as is also visible in the excerpt (Table 3), students constantly interacted by sharing information to build a mutual understanding of the problem space. They set out a plan that covered all the combinations of light and temperature inputs and retried them, proceeded systematically with the trials, and made explicit, mutual commitments to coordinate the actions (Gilbert, 2009; Michael & Pacherie, 2015). Regarding the task, they defined a hypothesis, tested it, reported the trials, and searched for the relationships between the information achieved via testing. By communicating with one another, they could develop an understanding of the relationships between the two controls as well as remarking on the variations in the growth chart. Even though they spent less time on the task and did fewer trials (i.e., the total number of temperature or light inputs is lower than that of Dyad 1), their activities consisted of a larger number of significant activities regarding the efficient solution path. The students demonstrated a high level of tolerance for the ambiguity of the task in which there was a lack of definition surrounding the most efficient solution path (see Scoular et al., 2017), and from their CPS process traces, all the task-specific CPS skills could be identified (i.e., "interaction", "responsibility initiative", "responsiveness", "collects information", "systematicity", and "solution"). Dyad 2, as noted in their CRR quotes (Table 3), started with an understanding of what was required of them as they guided each other through the CPS process. From the beginning, they progressed systematically by sharing information about their instructions, screen view, and understanding of the problem. They were well coordinated in all their CPS interactions, demonstrating explicit commitment to their dyadic activities, which resulted mostly in significant events during the CPS process. In short, their CRR reports suggested that they commenced the task with a shared understanding and plan on how to proceed, evidenced through their coordinated CPS interactions and well communicated symptomatic trials, and resulting in good progress and positive outcomes for the group in finding a resolution to the problem.

Table 3

Excerpt from the Full Problem Solving Episode of Dyad 2

Logfile data:

Line	Student	Activity		Time	Relation of interactional events (Initiating-Responding)	Observable subskill	Sign/Insignificant activities
519	**B**	**Type message**	**30**	01.08.37	initiating	Audience awareness: B	Significant: 519-523
520	**A**	**Type message**	**Shall we put 30c**	01.08.41	initiating	Goal setting: A	Significant: 520-529
521	A	Temperature input	temp: "30 degrees"; light: "very dark"; growth: 1mm	01.08.47	responding	Action	Significant: 521
522	**B**	**Type message**	**Yes**	01.08.48	responding	Interaction: B	
523	B	Light input	temp: "30 degrees"; light: "quite dark"; growth: 3mm	01.08.51	responding	Action	Insignificant: 523, 526
524	**A**	**Type message**	**Show the temps**	01.08.55	initiating	Responsibility: A	Significant: 524-530
525	B	Light input	temp: "30 degrees"; light: "very dark"; growth: 1mm	01.08.55	initiating	Perseverance	Insignificant: 525
526	B	Light input	temp: "30 degrees"; light: "quite dark"; growth: 3mm	01.08.57			
527	B	Light input	temp: "30 degrees"; light: "quite bright"; growth: 4mm	01.08.58		Action	
528	B	Light input	temp: "30 degrees"; light: "very bright"; growth: 6mm	01.08.59		Action	
529	**B**	**Type message**	**30: 1,3,4,6**	01.09.07	initiating	Collecting info: B	

Cued Retrospective Reporting (CRR) Interviews:

Student A:

'Well but then we started to study what we can see there**. I noticed that there are two such slide controls** there and here I might just read those also the instruction quickly and about observing what's the daily growth here and I tried to get it adjusted [pause] the **lower slide control even several times I tried, it didn't work**. I wondered that if there is now some fault here. Well, **[the partner] then commented there that you apparently put it to 30 Celsius there and I replied that yes that's right**. [pause] And soon we did find out that – we have this kind of situation that **we can adjust them contrastedly, or we can't adjust both at the same time**.'

Student B:

'And started to investigate and there then, the partner already adjusted those temperatures onwards. And I asked that you apparently like changed them. And then **we noticed really quickly that like [pause] he has the other control and I have the other control what the partner then hadn't then**. But like the same screenview **– there in the upper section of the page anyway**. And then **I asked the partner to keep it stable**, to set it back to 30 there, so that **we reach a certain systematic approach there.** And then well we increased them one by one. This amount of light, or I increased then and well, listed them then – **we noted there on chat that it's better to leave a kind of clear memory trace to which we can return when needed** and what was like working well so we wrote there that.'

Discussion and conclusions

The aim of this explorative study was, via two contrasting cases, to acquire a preliminary understanding of how commitments and successful CPS processes come together during remote interactions in dyads. The results revealed how commitments were strongly interrelated with efficient coordination of interactions during CPS processes. In example, the coordinated, well-communicated problem solving trails of Dyad 2 resulted in positive outcomes regarding the problem solutions, whereas for Dyad 1, lacking systematically coordinated joint actions and explicit verbal agreements, the solution path was less successful. Accordingly, when performing joint actions

together, which not only involves short-term temporal and precise action coordination (e.g., playing a piano duet together), but requires more long-term thinking and communication about the joint activity, the role of language, intentionality, and commitment become crucial (e.g., Vesper et al., 2010). These aspects are especially critical when the participants are not aware of the details of the other participants' actions or they are separated in time or space from their partners (Vesper et al., 2010), as was the situation in this study.

Moreover, processes related to successful CPS, such as a continuous and conjoined effort towards elaborating a "joint problem space" (Baker, 2015) and expressions of shared intensions (Michael & Pacherie, 2015), can be vulnerable and uncertain, as also recognised here. However, at large, commitments— if credible— are seen to reduce the uncertainties often related to the fulfilment of joint goals and facilitating the planning and coordination of joint actions (Michael & Pacherie, 2015; Siposova et al., 2018). Uncertainties can be in various forms, including motivational (e.g., how convergent the partners' intentions are with their own), instrumental (e.g., how the roles should be divided among partners to reach the shared goal), or common ground uncertainties (e.g., whether the motivations and plans to reach the shared goal are aligned with the partners) (Michael & Pacherie, 2015). As uncertainties can endanger mutual predictability and thereby efficient coordination of joint actions (Michael & Pacherie, 2015) required in successful CPS, it is crucial to better recognise the various forms of uncertainties related to remote CPS and how to support participants in overcoming them. For example, encouraging participants to make commitments explicit can increase the possibility of reducing uncertainties regarding common ground, which, in turn, concerns the very basis of successful collaboration and CPS (e.g., Baker, 2015). Taken together, as collaboration is not a state but a dynamic process, there is a quest for deeper understanding of under what conditions participants agree to collaborate and what socio-cognitive exchanges regarding CPS are more supportive and enable participants to perform actions together (see Perret-Clermont, 2015).

Finally, the current study provides a starting point to deeper understanding of the "anatomy" of commitments (Michael & Pacherie, 2015) and what function they perform in successful remote CPS in dyads. The apparent complexity of the concept and the initial discoveries point to the need for considering study designs and methodological choices that can capture longer stretches of time with a broader population of participants. While the automatically generated log files incorporate multiple pieces of information from joint processes (Graesser et al., 2018) with the CRR interviews, the subjective reports as free-form personal accounts, delayed in time, were not fully applicable and sensitive enough to reach when implicit commitments were at place. Next, the aim is, along with the objective measures of CPS interaction (e.g., as log files or video recordings), to capture more detailed, session-specific subjective measures from the individual participants (i.e., intra-individual measures; Tetzlaff et al., 2021, e.g., in forms of diaries) to acquire a deeper understanding of what, for example, motivates participants to appreciate commitments or whether they contribute because they are only expected to do so, and thereby to fulfil the social function of commitments (e.g., Gilbert, 2009; Michael & Pacherie, 2015; Michael et al., 2016b).

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