Evaluation of possible connection between Situational Awareness and levels of Social Modes of Co-construction

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Abstract

Background Learning is a core part of how we grow as humans. Over the last few years it has been shown increasingly that learning in groups tends to be more effective than learning individually. This research aims to show a link between an individual's Situational awareness and the degree of collaboration.

Method An experiment was conducted where groups of participants navigated a maze. The maze was designed to require collaboration to reach the end. Data was gathered about both the situational awareness of the participants and their levels of Social Modes of Co-Construction.

Conclusion The current data suggests no strong correlation between Situational Awareness and Levels of Social Modes of Co-Construction. However, more data will need to be gathered to increase the reliability of this conclusion.

1 Introduction

Learning is a core part of how we grow as humans. Over the last few years it has been shown increasingly that learning in groups tends to be more effective than learning individually [3]. However, the factors that make this type of learning more or less efficient are largely unknown.

To shed light on these factors, this research aims to answer the question: Does an individual's situational awareness have an effect on their levels of Social Modes of Co-Construction when collaborating with others inside Virtual Reality?

Virtual Reality (VR) is a technology where a user is placed in a virtual environment through the use of a headset that has screens covering the field of view of the user [10]. For this research the complete virtual environment allows for the control of variables such as the surroundings of the participants and their access to certain tools that would not be possible in a non-virtual environment.

The tools given to the participants will be designed to affect their Situational Awareness (SA). SA describes to what degree a subject understands their current situation and how much control they feel they have over it. [2]

The levels of Social modes of Co-Construction (SMoCC) expresses how much participants refer to each other's contributions. This is a passable proxy to determine how well the group is collaborating, and thus how well they learn collaboratively. [9]

2 Method

2.1 Participants

Participants were collected from the social circles of the researchers. Several limitations on the eligibility of participants were enforced:

1. The participant should not be colourblind.
2. The participant needs to be able to communicate in English.
3. The participant should not be prone to motion sickness.
4. The participant should not be friends with any other participants in their group.

Ethical and Privacy Considerations

To ensure privacy, the participants were assigned an ID upon arrival at their first session. In all files they were only referred to with this ID. If the participants referred to each other by name during the experiment the name was replaced by their ID in the transcript.

One common issue with VR is motion sickness. Spending time in VR can make certain individuals very nauseous. To mitigate this, participants do not move continuously. Instead, the participants take distinct small steps in the direction they are looking when they press a button. While no structured study was found on its efficacy, this system was designed to allow for a large degree of freedom while minimising motion sickness [6]. As this still does not completely prevent motion sickness in all subjects, the participants were asked if they are prone to motion sickness. Participants prone to motion sickness were excluded. Participants were also informed at the start of the experiment that if they felt unwell during the experiment, they should inform the person conducting the experiment. The experiment would then be put on hold until the participant felt better.

One final danger with experimenting in VR, especially in groups, is that the participants are not be able to see their surroundings. So it is possible for them to run into walls or even each other. To mitigate this, there were always two people present during an experiment who kept an eye on the participants and moved them away from walls or each other when needed. To do this the experimenters needed to touch the participants on the shoulders and physically move them. Permission for this was obtained from all participants before the start of the experiment.

2.2 Materials

VR headsets

During the experiment the participants will be placed in a VR environment using first generation HTC Vive headsets and a single controller.

VR environment

In the experiment participants will have to navigate a maze that has been designed in such a way that cooperation is required to reach the goals [4]. This maze will come in two versions. One version gives the participants no extra tools for communication apart from their avatars and verbal communication. This version is referred to as the Control version. The other version, referred to as the experimental version, gives the participants access to both laser pointers and vision cones.

Vision cones are cones of color that will shade the area that a participant is looking in their color. This should allow the other participants to more easily understand what their teammate is looking at.

Laser pointers are visible lines that originate at the participants hand and should show what they are pointing at. Each participant can turn on the pointer originating in their hand by holding a button on their controller. Figure 1 shows both these tools.

Data collection methods

Two variables were tracked for this research. The first is Situational Awareness, which tracks aware a person is of their environment. Intuitively it follows that with additional tools for communication this will increase. In other words, it is hypothesized that during the experimental session the SA of the participants will be higher than during their control session. The second variable is the Levels of Social Modes of Co-Construction. It is expected that an increase in SA will cause an increase in Levels of Social Modes of Co-Construction.

To measure SA two measurement systems were used. The first is SART [1]. A questionnaire for this (Appendix A) was provided to the participants during a break in the experiment. The second is SALIANT [5]. SALIANT requires some calibration to the scenario in which it is used. This calibration was done by Nesse van der Meer. The final Rubric used can be found in Appendix B.

To measure the levels of Social modes of Co-Construction the SMoCC framework was used [9]. The final Rubric for this can be found in Appendix C.

2.3 Procedure

Two groups of three participants were gathered with the limitations discussed above. Both of these groups were scheduled for two sessions of the experiment. The sessions of a group were scheduled to be a little over a week apart. The first group navigated the control version of the maze in their first session and the experimental version in their second. The second group navigated the experimental version first and the control second. Each session consisted of 30 minutes of the participants solving the maze and a break about 10-20 minutes into the experiment. When the time window for a break was reached, the experimenters would interrupt the experiment at the next logical point. During the break the participants were asked to fill in the SART questionnaire. During the experiment OBS was used to record the screens and microphones of the participants [8].

After the experiment a video editing software was used to synchronise the audio and video of each session. The footage before the start and after the end of the experiment was also removed. Finally, the footage of the break was removed. This was then exported into 4 files: one video file per participant and an audio file with all microphone feeds combined and synchronised.

The audio file was then fed into an AI that produces transcripts [7]. The transcripts that came out of this were then checked by a researcher and any inaccuracies were fixed. This resulted in the final transcripts used for the data extraction.

For the SALIANT system the transcripts were divided into sections such that in each section the participants were discussing a different topic. Each section was then assigned one of five possible scenarios.

- Discussing markings on the floor.
- Deciding which way to go.
- Deciphering a passcode or at a gate.

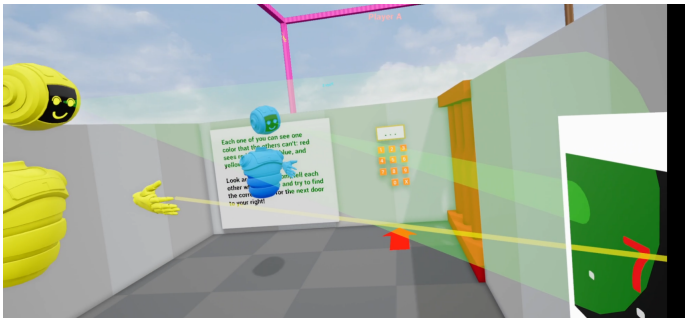

Figure 1: Reds vision on the others vision cones of blue and yellow. Yellow has turned on their laser pointer

- Lost or backtracking.
- Does not apply

All sections in the final scenario were disregarded as they contained discussions that had no bearing on the experiment. Next, each section in scenario 1 through 4 were graded according to the rubric in Appendix B. For each participant the achieved percentage of the total attainable points was then calculated.

For the SMoCC system each utterance of a participant was graded separately. The average score was then calculated over all utterances of that participant in that session. For this average 0 scores were disregarded as these utterances had no bearing on the experiment.

3 Results

3.1 SALIANT

ID	Control score	Experimental score
1	0.095	0.085
2	0.085	0.083
3	0.069	0.065
4	0.074	0.211
5	0.102	0.263
6	0.094	0.223

Table 1: SALIANT results

The scores for the SALIANT system can be found in table 1. These scores are obtained by calculating the average points per section, and then taking the average of those numbers. Participants 1, 2 and 3 were in the first group and participants 4, 5 and 6 in the second. One notable trend is that for group 1 the SALIANT scores experience a slight decrease from control to Experimental sessions. Group 2 however shows a large increase.

3.2 SART

The scores the participants got from the SART questionnaires can be found in table 2. The IDs refer to the same participants as with the SALIANT data. So participants 1, 2 and 3 were in the first group and 4, 5 and 6 in the second. Notable here is that for participants 1 and 2, the SART follows the trend of

ID	Control score	Experimental score
1	4	3
2	12	9
3	-14	4
4	5	-2
5	3	1
6	23	-5

Table 2: SART results

the SALIANT results. However, particpants 4 and 5 seem to directly contradict their SALIANT scores. The SART scores of participants 3 and 6 are extremely different from the others.

3.3 SMoCC

ID	Control score	Experimental score
1	2.35	2.29
2	2.33	2.47
3	2.17	2.16
4	2.15	2.52
5	2.50	2.79
6	2.38	2.68

Table 3: SMoCC results

Shown in table 3 are the average SMoCC scores for each participant and in table 4 are the standard deviations. Notable here is first that no consistent trend can be identified for group 1. One member increases from control to experimental, another decreases and the last one stays approximately the same. However group 2 has a clear trend. The SMoCC of group 2 increases from their control to their experimental session.

4 Discussion

Several ways can be imagined to increase the reliability of this experiment for future research. The primary way is to increase to amount of data. Until that is done it is difficult to say whether or not the results are significant or coincidental. Secondary to that is the issue of inter-rater reliability. Very few steps were taken in this research to ensure uniform coding of data between coders. This could account for the great difference between most SALIANT results and the SALIANT results from the experimental session of group 2. Thirdly, the data would probably be more reliable if each group only traversed the maze once. While some details were different between sessions, the general layout and core mechanics remained the same.

ID	Control SD	Experimental SD
1	1.01	0.95
2	0.91	0.91
3	0.99	0.92
4	1.24	1.02
5	1.24	0.92
6	1.25	0.94

Table 4: Standard deviations SMoCC

Another point in which the reliability can be improved is the SALIANT rubric. During the coding of the data it was found that scenarios one and two have a large amount of overlap in this use case. Many situations would not happen in a scenario 2 section because the information had already been discussed in a preceding scenario 1 section. This has likely led to an artificial lowering of scores.

5 Conclusion

Due to the extremely limited sample size very few true conclusions can be drawn from the available data. Some interesting deviations from what was expected can still be identified. For example, the SART results are, with one exception, lower during the experimental session. In the SALIANT data we also see that group 1 had a slightly lower scores during the experimental session, while group 2 had significantly higher scores during their experimental session compared to their controlled session.

One possible cause for this high variability in the data is that group 2 did their experimental session before their control session, while group 1 did their control session first. This could mean that group 2 used the visualisation tools extensively during their first session, which left them feeling unable to communicate effectively when those tools were not available during their second session. In contrast, group 1 learned to communicate effectively without the tools available during the experimental session. So when they received these tools in their second session, they had limited additional benefit from them. A different explanation is that the tools given worked too well, in that communication that happened verbally during the control session was done using the laser pointers in the experimental session. The lack of measurement of non-verbal communication would cause both the SALIANT and the SMoCC data to not represent all relevant communication.

As for the primary research question: “Does an individual’s situational awareness have an effect on their level of social modes of co-construction when collaborating with others inside Virtual Reality?”. The data to answer this is contradictory. While the SALIANT results for group 2 do seem to connect to an increase in SMoCC, the SART results for the same group contradict this. Group 1 seems to show no correlation for either SA metric. So if a correlation exists, it is a fairly weak correlation.

Future work should focus primarily on executing this experiment with a significantly larger sample. Another piece that should be examined is the SALIANT rubric. If a way can be found to combine scenarios one and two, that would likely lead to more accurate data.

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Appendices

A SART survey

Virtual Reality Experiment

Participant ID: ☐ **Session number:** ☐

Please answer each of the below questions on a scale of 1 to 7 where **1 = LOW** and **7 = HIGH**.

1. How changeable is the situation? Is the situation highly unstable and likely to change suddenly (high), or is it very stable and straightforward (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

2. How complicated is the situation? Is it complex with many interrelated components (high) or is it simple and straightforward (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

3. How many variables are changing in the situation? Are there large numbers of factors varying (high) or are there very few variables changing (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

4. How aroused are you in the situation? Are you alert and ready for activity (high) or do you have a low degree of alertness (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

5. How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (high) or focused on only one (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

6. How much is your attention divided in this situation? Are you concentrating on many aspects of the situation (high) or focused on only one (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

7. How much mental capacity do you have to spare in the situation? Do you have sufficient to attend to many variables (high) or nothing to spare at all (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

8. How much information have you gained about the situation? Have you received and understood a great deal of knowledge (high) or very little (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

9. How good is the information you have gained about the situation? Is the knowledge communicated very useful (high) or is it insufficient (low)?

   O 1 O 2 O 3 O 4 O 5 O 6 O 7

10. How familiar are you with the situation? Do you have a great deal of relevant experience (high) or is it a new situation (low)?

    O 1 O 2 O 3 O 4 O 5 O 6 O 7

B SALIANT rubric

		Scenario #01	Scenario #02	Scenario #03	Scenario #04
		Markings (**symbols/text**) on floor (guide participants)	**Deciding** which **path** to take when faced with multiple	**Deciphering** / **discussing** the **passcode** for / at **gates**	**Participant** / **group** is **lost** (and **backtracking**)
		Explanation of scenario: The participants are looking at and discussing the symbols on the floor used to guide them to the exit	*Explanation of scenario:* The participants face several directions and need to decide which one(s) to take	*Explanation of scenario:* The participants need to decipher a passcode together which they then have to use to unlock a gate	*Explanation of scenario:* The participants have vocalized that they are unsure of their location and/or the location of components
1: Demonstrated Awareness of Surrounding Environment					
1.1: Monitored environment for changes, trends, abnormal conditions	Acceptable responses	Participant (correctly) highlights that markings are used in a different way compared to previously Participant identifies trends with markings correctly	Participant looks for clues (markings), mentions those should normally help find the right path Participant bases directions of paths on other elements (e.g., markings, themselves, landmarks)	Participant recognizes that the passcodes in each section of the maze differ slightly in how they look Participant understands that each gate requires three numbers as passcode to be opened	Participant attempts to get their bearings by looking for recognizable elements in environment Participant tries to get their bearings based on elements (e.g., markings, themselves, landmarks)
Explanation of category: Participant identifies a change, trait or point of interest regarding the environment that he/she deems abnormal or worth discussing	Incorrect responses	Participant ignores that markings (without changing their meaning) are used differently Participant does not identify trends associated with markings	Participant completely ignores markings when selecting a path and does not look for clues Participant does not address surroundings when choosing the path	Participant does not recognize or acknowledge slight changes between passcodes in mazes Participant treats every passcode and decipher-process as the same despite differences	When final segmentation of dialogue is decided, the segmented transcript is scanned for instances of the four scenarios; every instance of each of these scenarios is counted (ex.: "Scenario #1 occurs 15 times, Scenario #2 occurs 12 times...). Participant makes no attempt to recognize elements that could help reestablish their location Participant randomly chooses paths in hopes of reestablishing their location
1.2: Demonstrated awareness of where he / she was	Acceptable responses	Participant uses markings correctly to get his/her bearings Participant uses markings correctly to find next destination	Participant bases choice of path (which direction) on his/her surroundings Participant knows which way to go based on having read the markings around the paths	Participant identifies that the passcode found is required for a gate located somewhere else Participant recognizes that the locked gate signifies a new section of the maze (i.e., progress)	Participant re-establishes their location during/after being lost Participant recognizes a previous location they visited while backtracking
Explanation of category: Participant shows awareness of his/her location in relation to something else (e.g., a prior position, other participants, the overall maze)	Incorrect responses	Participant incorrectly uses markings to orientate Participant simply never uses markings to orientate current location / surroundings	Participant expresses not knowing which direction the paths go towards Participant goes back the way they came when choosing one of several paths	Participant states they do not know where to find the gate and/or the passcode Participant does not understand significance of the gate in relation to the rest of the maze	Participant continues to be lost for several minutes Participant loses sight of group members while attempting to backtrack / find their bearings
2: Recognized Problems					
2.1: Reported problems	Acceptable responses	Participant identifies that markings are not clear to him/her (and require all to share what they see) Participant lets group member know he/she incorrectly interpreted markings	Participant acknowledges that they cannot immediately determine which path to choose Participant addresses that randomly selecting a path will not help them progress	Participant acknowledges that he/she alone cannot decipher the passcode (only toaether) Participant reports that the passcode is incorrect at the gate or he/she does not remember it correctly	Participant acknowledges that he/she is lost or does not know if they have been at that position Participant lets other group members know that he/she has lost them or is lost him/herself
Explanation of category: Participant communicates an element that obstructs completion of the task at hand (i.e., an issue preventing them from progressing)	Incorrect responses	Participant does not report to other group members when having difficulties with markings Participant does not inform other group members when they are mistaking markings' meanings	Participant does not realize there are several paths to take Participant does not communicate with other members when deciding which route to take	Participant does not communicate, tries to decipher passcode alone Participant types in passcode at gate without communicating with members	Participant does not acknowledge the fact that he/she does not know where they are Participant loses other group members but does not communicate this
2.2: Located potential sources of problem	Acceptable responses	Participant addresses that group members are not communicating what markings they see Participant addresses that every member needs to tell what markings they see in order to succeed	Participant recognizes that not following the markings will result in taking incorrect paths Participants recognize that splitting up can exacerbate the situation	Participant identifies that they have not yet found the passcode needed to open the locked gate Participant acknowledges that passcodes will not be deciphered alone as it requires communication	Participant addresses that not paying intention to markings' suggestions got them lost Participant provides specific reason for getting lost (can be several things)
Explanation of category: Participant identifies the origin of the problem, i.e., what is causing the issue at hand	Incorrect responses	Participant does not suggest teamwork when trying to decipher markings, is passive in behavior Participant is source of problem, i.e., does not communicate at all what markings he/she sees	Participant does not address potential pitfalls when talking about choosing a path Participant does not seem to see any potential problems and does not discuss them	Participant ignores the need for a passcode / deciphering it and tries to guess the code instead Participant tries to decipher passcode alone without help / feedback of other members	Participant keeps attempting the same strategy while backtracking / trying to find their bearings Participant ignores pleas from other members attempting to change tactics while backtracking
2.3: Demonstrated knowledge of problem consequences	Acceptable responses	Participant shows understanding that they will get lost if they do not communicate the markings Participant shows understanding that ignoring the markings' instructions will get them lost	Participant addresses the risk of getting lost if they do not think before they choose a path Participants recognize the risk of splitting up when facing several paths	Participant recognizes that unless the passcodes are used correctly, progression will not be possible Participant recognizes that the group is not communicating sufficiently when deciphering	Participant recognizes that continuously getting lost and backtracking will prevent progress Participant stresses the need to get their bearings when lost in order to progress and succeed
Explanation of category: Participant shows awareness of short-term and long-term consequences of problem (i.e., what will happen if the problem is not solved)	Incorrect responses	Participant ignores the markings while attempting to find the correct way through the maze Participant does not show understanding of significance of markings for progression	Participant shows no awareness or understanding of the importance of choosing the right path Participant ignores the markings that are there to signify which path should be chosen	Participant expresses that the passcodes can wait until later (thus misunderstanding the need for them) Participant does not show understanding of the link between the passcodes and the locked gates	Participant does not consider being lost an issue and does not try to solve it Participant vocalizes not being worried about being lost and acts as though it is not a problem
2.4: Resolved discrepancies	Acceptable responses	Participant recognizes inconsistencies in what one group member and another see in the markings Participant asks other member what they see on a marking as they know they need more information	Participant resolves dispute between two other group members in regards to which path to take Participant informs other member they are wrong about which path they want to go	Participant corrects group member when that member incorrectly assumed something Participant corrects him/herself in relation to deciphering / typing in the passcode	Participant addresses the cause of getting lost and suggests how to solve it (i.e., find the correct way) Participant recognizes where they went wrong while backtracking, readjusting their next steps
Explanation of category: Participant resolves inconsistencies/disparities between two (or more) elements he/she encountered	Incorrect responses	Participant does not recognize inconsistencies between their and the others' markings Participant does not solve discrepancies between their markings and those of other members	Participant does not resolve a dispute but instead goes his/her separate ways Participant does not discuss choice of path and the group follows whoever picks a path first	Participant does not correct group members when they incorrectly assume something Participant does not show willingness to correct any miscommunications regarding the passcodes	Participant does not actively attempt to find back the correct way / get their bearings Participant does not recognize the cause of getting lost and continue to be lost
2.5: Noted deviations	Acceptable responses	Participant notices the differences in markings in between mazes (e.g., symbols and text) Participant addresses markings are used differently the further they progress in the maze	Participant acknowledges that they are changing tactics in regards to choosing which path to take Participant addresses when a member begins to use a different tactic when choosing paths	Participant comments on group member deviating from normal method to unlock the gate Participant comments on deciphering process of passcodes being different to previous ones	Participant suggests/addresses that they are trying a different tactic to find their bearings Participant recognizes that a member is attempting to find their bearings via a different tactic
Explanation of category: Participant acknowledges a deviation has taken place in regards to a norm (i.e., the default instructions, a member's suggestion, etc.)	Incorrect responses	Participant does not seem to notice differences in changes between mazes Participant does not address differences in markings between mazes	Participant does not acknowledge whenever he/she changes tactics in choosing the path Participant does not address when a member changes tactics in choosing the path	Participant does not comment when members deviate from prior/normal method of deciphering Participant does not recognize or acknowledge slight changes between passcodes in mazes	Participant does not attempt different tactics when trying to find their bearings Participant does not comment on member attempting a new tactic to find their bearings
3: Anticipated a Need for Action					
3.1: Recognized a need for action	Acceptable responses	Participant recognizes that other members need to communicate what markings they see Participant recognizes that markings need to be used in order to find the correct path	Participant addresses that a decision needs to be made in regards to choosing a path Participant addresses that choosing a path requires a tactic (such as reading the markings)	Participant recognizes the deciphering process is stuck and different tactics need to be used Participant recognizes that they did not get the proper passcode and thus need to readjust	Participant recognizes that they are lost and need to find their bearings Participant addresses that current tactic does not work while attempting to find bearings
Explanation of category: Participant states that something (i.e., an action) needs to happen	Incorrect responses	Participant does not address the need to communicate in order to understand the markings Participant's behavior towards the markings does not include other members	Participant does not recognize that a correct path must be chosen Participant does not take action and instead lets other group members decide on the right path	Participant never acknowledges that deciphering process is not progressing or remains mute Participant does not recognize their passcode is incorrect and attempts to brute-force the gate	Participant does not acknowledge that he/she is lost Participant does not call for a different tactic when trying to find their bearings
3.2: Anticipated consequences of actions and decisions	Acceptable responses	Participant anticipates a certain direction is the right way because of what the markings say Participant describes what different directions will bring based on the markings	Participant vocalizes what they expect they will find when taking a certain path Participant addresses what they think will happen if they follow suggestions found in markings	Participant finds gate before finding passcode, states that they need to look for the latter first Participant finds passcode, states that they will need to decipher it to unlock the gate later	Participant predicts what comes up around the corner while backtracking Participant anticipates what will happen if they do not find their bearings
Explanation of category: Participant vocalizes expectations of things to come as concequences of actions/decisions taken at that moment	Incorrect responses	Participant incorrectly assumes that something is up ahead because of the markings Participant does not try to anticipate what is up ahead based on the markings	Participant does not discuss what they think one or more paths will bring Participant does not appear to anticipate based on the markings they decipher	Participant attempts to unlock gate despite not having found passcode yet Participant does not mention needing the passcode later to unlock the gate	Participant does not vocalize expectations of what to find during backtracking Participant does not vocalize anticipation in terms of consequences related to finding their bearings
3.3: Informed others of actions taken	Acceptable responses	Participant informs other members that he/she is pointing out a marking they are describing Participant informs other members he/she is following the markings' suggestions	Participant states that they are taking one of several paths Participant announces he/she will look further on ahead to see what is there	Participant tells others that he/she is typing in the passcode at the gate Participant communicates he/she has found the passcode / gate	Participant announces he/she recognizes elements and takes the lead in finding their bearings Participant informs others he/she is going in a certain direction to find their bearings
Explanation of category: Participant communicates that he/she has performed a certain action	Incorrect responses	Participant does not inform other members that he/she is decipherina markinas Participant does not inform other members that he/she is taking action based on the markings	Participant does not let other members know he/she is takina a different path Participant does not let other members know he/she is separating from the group	Participant attempts to unlock gate without communicatina this action Participant does not inform others that he/she has found the passcode before attempting to decipher	Participant does not inform group members when trvina to find their bearinas Participant does not announce that he/she takes a different path from the group while backtracking
3.4: Monitored actions	Acceptable	Participant guides group members in describing what they see in the markings	Participant follows logic of other group member when deciding path to take and provides feedback	Participant monitors group member typing in passcode, provides (positive/negative) feedback	Participant checks where his/her other group members are while backtracking

Step 1:	Coders individually provide segmentation of the transcripts; dialogue is segmented on what the coders deem separate topics of dialogue, i.e. the dialogue is segmented whenever a new topic is focused on in the dialogue.
Step 2:	Once segmented and after inter-rater reliability is calculated, the coders discuss the individual segmentation and attempt to find a "common ground", i.e. create a final segmentation of the transcript based on agreements.
Step 3:	When final segmentation of dialogue is decided, the segmented transcript is scanned for instances of the four scenarios; every instance of each of these scenarios is counted (ex.: "Scenario #1 occurs 15 times, Scenario #2 occurs 12 times...).
Step 4:	For each instance of one of these scenarios, each participant is graded individually using the scheme; per category, each participant either scores a 0 (if only incorrect responses) or a 1 (if one or more acceptable responses).
Step 5:	Each participant's final score (after grading is finished) is divided by the total number of instances of the four scenarios. This produces a final Situational Awareness score for each of the individual participants.
Step 6:	The score of all three participants is then summed up and divided by three; the resulting number is the Team Situational Awareness of the group.

General description:

The Situational Awareness Linked Instances Adapted to Novel Tasks (SALIANT) was developed to measure team SA. The SALIANT methodology requires five phases:

(1) identify team SA behaviors
(2) develop scenarios
(3) define acceptable responses
(4) write a script
(5) create a structured form with columns for scenarios and responses

Strengths and limitations:

SALIANT has been validated using twenty undergraduate students in a four-hour tabletop helicopter simulation. Inter- rater reliability was r = +0.94. There were significant correlations between SALIENT score and communication frequency (r = +0.74), between SALIENT score and performance (r = +0.63). There were no significant correlations between SALIANT score and the teams' shared mental model (r = –0.04). Additional validation data are available in Muniz et al. (1998a) and Bowers et al. (1998). In a large experiment (80 men and 180 women), Fink and Major (2000) compared SART and SALIENT related to a helicopter flight simulation game (Werewolf v Comanche). The authors reported that SALIENT had the better measurement characteristics but SART enabled them to assess the interaction between the game and the operator. Kardos (2003) applied the SALIANT methodology to develop a checklist of behavioral SA indicators during development of Tactics, Techniques, and Procedures (TTPs) for the Australian Defence Science and Technology Organisation (DSTO). She described the difficulty in observing some of the behaviors identified such as "monitor others." She recommended excluding some of the behaviors due to lack of applicability, constancy, and not being observed.

Data requirements:

Although the generic behaviors in Table 3.1 can be used, scenarios, responses, scripts, and report forms must be developed for each team task.

Thresholds:

Not stated.

3.4: Monitored actions	Acceptable responses	Participant asks group members to indicate the position of the markings they see	Participant comments on group member taking a specific path	Participant follows group member deciphering passcode, provides comments on member's logic	Participant provides feedback on other group member's logic when backtracking
Explanation of category: Participant monitors the action(s) of group members (and provides support, i.e., not just silently watching the group member)	Incorrect responses	Participant does not provide support when other members face difficulty deciphering markings Participant does not seem to monitor when other members are deciphering their markings	Participant does not take into account what other group members think is the correct path Participant ignores group members splitting up	Participant does not provide feedback to actions of group members during typing in the passcode Participant does not provide feedback to actions of group members during deciphering	Participant does not communicate with group members about their locations Participant does not respond to or comment on members' suggestions for finding their bearings
4: Demonstrated Knowledge of Tasks					
4.1: Demonstrated knowledge of tasks	Acceptable responses	Participant correctly identifies that a marking is meant to show a correct path Participant uses a marking's meaning correctly to progress (i.e. select the right path)	Participant recognizes that markings provide information related to which path is correct Participant recognizes that communication is key when identifying where to go	Participant correctly types in the passcode at the gate / shows other members how to do so Participant stresses the importance of the deciphering for progression	Participant attempts to use markings to find their bearings again Participant finds a gate and uses that gate as a point of recognition to find bearings
Explanation of category: Participant displays understanding of the objective(s), i.e. vocalizes what the task(s) involve and which components it contains	Incorrect responses	Participant misinterprets a marking's meaning / purpose (i.e., interprets the incorrect meaning) Participant ignores the marking (and its meaning) before taking actions (i.e., symbol is disregarded)	Participant does not show understanding of relation between the markings and which path to take Participant does not show understanding that communication is required to progress	Participant randomly tries codes or does not know how to enter a code to unlock the gate Participant does not understand what to do with the passcode or ignores it when found	Participant does not use markings to re-establish where they are in the maze Participant does not use other recognizable components of the maze to find their bearings
4.2: Exhibit skill time sharing attention among tasks	Acceptable responses	Participant is able to ask questions to other members while trying to decipher markings Participant is able to answer questions by other members while trying to decipher markings	Participant is able to share the discussion on which path to take while inspecting the surroundings While discussing which path to take, participant recaps what everyone saw/sees in the markings	Participant is able to type in the code at the gate while discussing the passcode with other members Participant is able to decipher his/her part of the passcode while also discussing what the others see	Participant is able to discuss how to find their bearings with other members while backtracking Participant can identify recognizable elements while listening to other members' feedback
Explanation of category: In case of multiple tasks, the participant shows the ability to multitask, i.e., efficiently switches attention between these tasks	Incorrect responses	Participant seems inable to ask questions to other members when trying to decipher markings Participant seems inable to answer questions from other members when trying to decipher markings	Participant appears unable to simultaneously discuss and determine which path to take Participant does not recap or summarize what the group sees in the markings	Participant is not able to simultaneously discuss the passcode and discuss it with other members Participant is not able to decipher their part of the code while simultaneously talking with the others	Participant does not communicate with group while trying to find their bearings Participant does not simultaneously backtrack and discuss tactics with group members
4.3: Monitored workload	Acceptable responses	Participant recognizes the need to communicate and does so when finding new markings Participant states he/she will have to tell the others what they see when encountering markings	Participant realizes he/she is constantly taking lead in choosing where to go, addresses this Participant makes sure every member describes what they see before choosing a path	Participant states what he/she is focusing on during deciphering / unlocking a gate Participant vocalizes what he/she needs to do to help decipher the passcode	Participant checks what he/she is supposed to do while backtracking Participant shows awareness of what he/she and their team needs to do to find their bearings
Explanation of category: Participant communicates and/or vocalizes the tasks he/she is currently set to do, showing awareness of their workload	Incorrect responses	Participant does not recognize the need to discuss markings and does not do so when finding them Participant only discusses markings when prompted by group members, does not initiate themselves	Participant does not seem aware of his/her workload (i.e. misses out on some of their tasks) Participant does not take into consideration what other members say / feel about the paths	Despite having a designated role during the decoding process, participant does not keep to it Participant does not seem to know or understand what role to take during the decoding process	Participant does not seem to have a tactic or method for backtracking / finding their bearings Participant does not appear to be aware of what is required to orientate his/her surroundings
4.4: Shared workload within station	Acceptable responses	Participant lets group members help to communicate what they see in the markings Participant lets others help when he/she is unable to proceed (e.g., cannot figure out the markings)	Participant lets other members decide which path they will choose Participant lets other members help him/her trying to identify which direction to go to	Participant lets group member help him/her when they do not understand how to unlock the gate Participant lets rest of group help when deciphering the passcode	Participant discusses taking on different roles while trying to find their bearings Participant agrees with taking on different roles when group members suggest this
Explanation of category: Participant shows ability to share workload with group members, letting members help them in their individual tasks / objectives	Incorrect responses	Participant does not let other members help with deciphering the markings Participant does not ask for help when having trouble with deciphering markings	Participant only chooses the path him/herself, does not give the chance to members Participant never provides a decision regarding which path to take, does not show decisiveness	Participant does not accept help from other members when stuck Participant does not ask or allow for other members to help in their deciphering of the passcode	Participant attempts to find their bearings on their own without collaboration Participant does not or barely communicate with group members while trying to find bearings
4.5: Answered questions promptly	Acceptable responses	Participant responds within 5 seconds when asked by member what they see in the markings Participant responds within 5 seconds when member verifies what they see in the markings	Participant responds within 5 seconds when asked which way they think they should go Participant responds within 5 seconds when asked which way they think the markings suggest to go	Participant responds within 5 seconds when asked by member what they see in the passcode Participant responds within 5 seconds when asked what the code was/is during unlocking of the gate	Participant responds within 5 seconds when asked by member where they are Participant responds within 5 seconds when asked if they recognize something / have been there
Explanation of category: When asked by fellow group members, the participant promptly answers (i.e., without first stating something else and doing so after)	Incorrect responses	Participant does not respond when asked by member what they see in the markings Participant does not respond directly when member tries to verify information regarding markings	Participant does not respond when asked for their opinion on the path they should take Participant does not respond when asked what path they think is the right one based on the markings	Participant does not share with the other members what their part of the passcode is (what they see) When prompted, participant does not share what the passcode of the gate is (when at the gate)	Participant does not actively respond when other members ask where he/she is in the maze Participant does not actively respond when asked to identify elements while backtracking
5: Demonstrated Awareness of Information					
5.1: Communicated important information	Acceptable responses	Participant communicates what he/she sees in the markings that the others do not Participant communicates when he/she finds new markings while exploring the maze	Participant communicates markings related to which path to choose that only he/she sees Participant states he/she sees relevant elements down one of the paths in the distance	Participant communicates what only they see when trying to decipher the passcode Participant communicates when other member misunderstands mechanics of the passcode/gate	Participant lets other members know he/she recognizes elements while backtracking Participant lets other members know he/she has found their bearings and they can continue
Explanation of category: Participant vocalizes information related to/required for completion of task(s) to group members	Incorrect responses	Participant does not communicate (all) information regarding what only they see in the markings Participant does not let others know he/she found markings	Participant does not communicate what markings he/she sees related to which path to choose Participant appears to know vital information regarding the path, but does not share it	Participant does not sufficiently share their vision of the code (for the others to decipher) Participant does not help other members when they struggle deciphering the code	Participant does not communicate information that could help while backtracking Participant does not inform other members when he/she has individually found their bearings
5.2: Confirmed information when possible	Acceptable responses	Participant confirms when asked by other group member if they see a specific marking Participant confirms when a group member summarizes what all the markings together mean	Participant confirms what their markings said about one/several paths when asked about it Participant confirms a certain path will be taken when asked for verification by other members	When asked by other members, participant confirms what he/she sees in passcode Participant recaps at end of deciphering to confirm the correct passcode	Participant responds when asked if he/she has seen markings on floor while backtracking Participant responds when asked by other member if he/she recognizes their location
Explanation of category: Participant confirms specific information when vocalized by group members or when discovering the information himself/herself	Incorrect responses	Participant does not respond when other member asks him/her to confirm information Participant does not vocalize agreement when other member summarizes what the markings mean	Participant does not confirm when asked by other members what their markings indicate Participant does not confirm choices made with the others when selecting a path	Participant does not respond when asked about what he/she sees in the passcode Participant does not recap or confirm the group's final decision on what the passcode says	Participant does not respond when asked by members about markings while backtracking Participant does not respond when asked by members about recognizable locations
5.3: Challenged information when doubtful	Acceptable responses	Participant steps in when he/she thinks a group member incorrectly assumes meaning of markings Participant argues a group member's interpretation of what the markings suggest they do	Participant disagrees with logic of group member when deciding which path to take Participant does not immediately trust markings that show the path, questions their interpretation	Participant questions what elements he/she sees of the passcode when deciphering it Participant questions contributions of group member (regardless of whether it is true or not)	Participant doubts member that claims they found their bearings, questions their logic Participant expresses doubt about recognizing / identifying surroundings while backtracking
Explanation of category: Participant does not immediately believe all information encountered, but questions it when he/she considers it doubtful	Incorrect responses	Participant does not question other members' input regarding markings' meanings Participant does not discuss other members' interpretations of the markings	Participant does not argue or debat with group when deciphering which path to take Participant does not reconsider meanings of markings, accepts initial interpretation	Participant does not second guess or doubt member's contributions, blindly believes them Participant does not second guess or doubt passcode-related information, blindly believes it	Participant does not doubt or question other members' claims regarding location Participant does not question whether or not a member recognizes certain locations
5.4: Re-checked old information	Acceptable responses	Participant verifies what the other group members claim they see in the markings Participant checks with other members if he/she remembers the markings' meanings correctly	Participant re-checks what other members know about which path to choose Participant checks which symbols mean what in regards to the paths	Participant checks more than once with group members what the passcode was / is Participant recaps once more what passcode is after having deciphered with group members	Participant re-checks if everyone in the group is still together while backtracking Participant continuously checks if other members recognize an area while backtracking
Explanation of category: Participant verifies information related to task either by asking other group members or even the experiment researchers	Incorrect responses	Participant does not inquire about what other members see or saw in the markings Participant does not verify information given by members	Participant does not verify prior information regarding the paths with other members Participant does not verify the meanings of markings with other members of the group	Participant never asks other members to recall the passcode Participant does not inform other members what the passcode was later on when it is needed	Participant does not check if group is together Participant does not continuously ask other members if they recognize areas
5.5: Provided information in advance	Acceptable responses	Participant communicates that he/she sees markings on the floor in the distance Participant lets other members know he/she found new markings, tells them what he/she sees	Participant announces he/she will separate from the group by taking one of several paths Participant lets other members know which path shows markings before hearing what they see	Participant tells group members what the correct passcode is when they (first) encounter a gate Participant informs other members when he/she has found the passcode location	Participant announces he/she sees something they recognize in the distance while backtracking Participant describes sections to help members to recognize previously visited locations
Explanation of category: Participant provides information before that information becomes relevant (e.g., before the information is required for the task(s))	Incorrect responses	Participant does not let others know he/she found markings Participant does not communicate that he/she sees markings somewhere in the maze	Participant separates from group unannounced Participant shares what their markings say about the paths without being asked by others	Participant does not swiftly provide information regarding passcode when the gate is found Participant does not inform others immediately when he/she finds the location of passcode	Participant does not announce when he/she recognizes elements Participant does not describe or identify elements of the area to help with backtracking
5.6: Obtained information of what is happening	Acceptable responses	Participant asks what group members see when encountering new markings Participant asks members if they see anything out of the ordinary / different than before	Participant verifies that a path is chosen Participant asks other members what their markings say about the paths	Participant asks group members how things are going on their end while deciphering Participant asks group members if any of them have found the passcodes and/or the gates	Participant asks other members if they are still together / still see each other while backtracking Participant actively asks other members if they recognize anything while backtracking
Explanation of category: Participant queries about ongoing events and/or succesfully acquires information to provide an update about current situation	Incorrect responses	Participant does not ask other members about what they see in the markings Participant does not ask others about points of interest or irregularities when discussing markings	Participant does not verify information regarding the paths with other members Participant does not ask other members what their markings say about the paths available	Participant does not ask members to brief their status Participant does not inform about whether other members have found the gate / passcodes	Participant does not inform about location or status of other members while backtracking Participant does not ask others whether or not they recognize anything while backtracking
5.7: Demonstrated understanding of complex relationship	Acceptable responses	Participant shows understanding of need to combine several markings to understand meaning Participant recognizes that all members need to provide input to fully understand markings	Participant recognizes that to select the correct path, every member must share what they see Participant connects the meaning of several markings to determine which path is the right one	Participant shows understanding of the sequence of the passcodes that have 1st 2nd 3rd under them Participant explains the logic behind the passcodes necessary to decipher it	Participant uses the 4 corners of the maze (high pillars) to find their bearings Participant uses markings to find their bearings while backtracking through the maze

Explanation of category: Participant shows awareness of a correct connection between one component and the other	**Incorrect responses**	Participant shows no understanding of need to talk with others to understand the markings Participant shows no understanding of the markings only making sense when all of them are combined	Participant does not seem to understand that communication is key in choosing the correct path Participant does not connect meanings of markings in order to find the correct path forward	Participant does not seem to understand what sequence to take when deciphering the passcode Participant does not show understanding of the logic behind the passcodes	Participant does not use elements of the maze (e.g. the corners) to find their bearings Participant does not use markings found to find their bearings
5.8: Briefed status frequently	**Acceptable responses**	Participant on several occasions describes markings that they see without being asked to Participant points out when they are and are not looking for markings on the floor	Participant frequently states when they are taking a specific path forward Participant lets other members know he/she is taking a specific path separately from the group	Participant actively communicates what he/she sees when deciphering passcode Participant lets other members know when he/she is typing in a passcode to unlock the gate	Participant frequently checks if the group is together while backtracking Participant frequently asks the other members if they can still see him/her while backtracking
Explanation of category: Participant frequently communicates status in relation to task (i.e., what is worked on, what is finished, their destination etc.)	**Incorrect responses**	Participant does not describe markings that they see to other group members Participant does not vocalize when he/she is looking for markings	Participant does not specify when he/she is taking a specific path Participant does not let other members know he/she is separating from the group / taking a different path	Participant does not brief others on what he/she sees while deciphering (unless prompted) Participant does not inform others that he/she is typing in the passcode and/or deciphering it	Participant does not (frequently) check if group members are all together while backtracking Participant does not frequently ask others if they can see him/her while backtracking

C SMoCC rubric

1: Externalization
Learners externalize what they know (to explain their perspective) New contributions to discourse without any explicit or implicit references to previous contributions (e.g. a first message on a discussion board) or contributions that do not comment on any other message are considered externalization. They make contributions to discourse without reference to other contributions, restructuring their knowledge into a lineair form. Discussions usually start with externalization, which is mainly motivated by social situations.
2: Elicitation
Using learning partners as a resource by asking questions, receiving information from them in the process Segments through which learners actively request information from learning partners are considered elicitation. These include not just the asking of comprehension questions, but also requesting for feedback and requesting specific actions from learning partners (e.g. "you need to change this part here!"). Elicitation appears to only facilitate knowledge acquisition if learners receive help and apply this help in the situation themselves
3: Quick consensus building
Learners accepting the contributions of their learning partners, not because they are convinced, but in order to be able to continue discourse When learners accept peer contribution without modification or indication that the peer perspective has been taken over by the learner, this behavior is considered quick consensus building. This acceptance can be explicitly signaled (e.g "That's right!") or in the form of learners rephrasing the original statement unmodified (i.e. the original reasoning remains the same despite rephrasing).
4: Integration-orented consensus building
When (individual) learners operate on the basis of the reasoning of their learning partners, i.e. showing a willingness to revise or change their own views in response to their partner's (persuasive) arguments When learners take over the perspectives of their learning partners, it is considered integration-oriented consensus building. Not only does a learner accept a peer's contribution, but the learner then uses that contribution to continue the reasoning. Note that the integrative move significantly differs from a juxtaposition of perspectives, but rather indicates a further development of the analysis from a learning partner.
5: Conflict-oriented consensus building
By facing critique, learners may be pushed to test multiple perspectives or to find more and better arguments for their positions When learners do not accept the contributions of their learning partners as they are, this is considered conflict-oriented consensus building. Possible indicators are rejection, exclusion or negative evaluation of peer contributions, as well as replacing, modifying or supplementing them (so not just explicit and absolute rejections, but also slight repairs of peer contributions). When building consensus in such a scenario, learners need to pinpoint specific aspects of their peers' contributions and modify these or present alternatives (thus having to more closely pay attention to their peers' reasoning).

Social Modes of Co-Construction (SMoCC)	
Step 1:	Each individual line / utterance by each individual participant is treated as a micro-level segment since the experiment's tasks, which are surface-level, do not fit macro-level segmentation). each participant has a total number of lines / utterances.
Step 2:	Coders determine the level of transactivity for each of these utterances. If none of the levels apply, the utterance is given a 0; otherwise, the appropriate level (1 to 5) is given to the utterance.
Step 3:	Once coding is completed and every utterance for each participant is graded, each individual participant receives a final score by dividing the participant's final score by the total number of utterances.
Step 4:	The overall transactivity score for each group for one session can be calculated by adding up the final individual score of all three participants and dividing it by three.

- **Segmentation of discourse**: the text that collaborative learners produce is divided into units of analysis or segments.
  - → To properly divide this text into segments:
    1. Various raters need to **segment the whole sample** based on a **set of rules**, thereby **producing comparable segments** that capture learning activities.
    2. Independent from segmentation, all segments should be **categorized** so the **frequency of specific discourse activities** related to knowledge acquisition can be analyzed.
       - → These segments can vary in size, between individual signs and complete essays.
    3. The **granularity** ("scale or level of detail in a set of data") **of segmentation** needs to be **adjusted** at multiple levels; these levels should represent different levels of knowledge in the discourse: **macro** and **micro**.
  - → **Micro-level** segments represent the **correct reproduction of single concepts**.
    - What epistemic steps are taken to solve the problem?
    - What relations do learners construct between conceptual and problem space?
    - Are these relations adequate?
    - These segments consist of **relations between theoretical concepts** and/or **case information**. For example: *"Michael's father was telling a story about his (Michael's) problems in mathematics"* is a micro-level segment that connects two pieces of case information (*[Michael's father]* and *[telling a story (about Michael)]*) with the construction of a problem space (*[Michael's problems in mathematics]*).
  - → **Macro-level** segments represent **how learners connect principles and concepts**.
    - On this level, the relationship between micro-levels are analyzed.
    - In the following sentence, a number of micro-segments can be detected:
      "The teacher simply cannot understand what's going on with Michael and she somehow doesn't care. You should send her to re-attribution training as well"
      1. The one speaking is arguing that the teacher needs re-attribution training;
      2. This is because (according to the speaker) the teacher does not take the problematic behavior of the student into consideration;
      3. Michael is showing problematic behavior;
    - One macro-level segment must consist of **at least two micro-level segments**.
    - Different process dimensions of argumentative knowledge construction require different grain sizes of macro-level segments.
  - → Note that the main goal of connecting micro-segments with macro-segments is to acquire an understanding of how learners construct sequences of argumentation and refer to contributions of their learning partners.