The role of support during learning in space

Analysing the influence of support styles and discourse on performance, workload and emotion in a collaborative training task for astronauts

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Content

Glossary

CAI Cognitive Artificial Intelligence
COLT COLlaborative Trainer
CT Colored Trails
CTL Cognitive Task Load
ePartner electronic partner
e-Learning electronic learning
EP Essential pages
ES Emotional State
ESA European Space Agency
GEC Ground-based Experiment Complex
IBMP Institute of Biomedical Problems
ISS International Space Station
LIP Level of Information Processing
LL Lunar Lander
MECA Mission Execution Crew Assistant
SAM Self-Assessment-Manikin
SCOPE Supporting Crew OPErations
TOC Time OCcupied
TSS Task Set Switches

1 Introduction

For future manned long-duration missions to Mars and beyond new support methods for astronauts are required. Due to the distance between the astronauts and Earth there are fewer possibilities to get direct support from ground control on earth and therefore more autonomy is needed. The crew needs to be able to solve the problems by themselves without the help of ground control. Astronauts are in a dangerous and isolated environment for a long period. Therefore during long-duration missions there will be more and stronger stressors that can lead to personal problems and group problems during the mission (Kanas & Manzey, 2003). For these reasons improving the autonomy and resilience of astronauts in long-duration missions is an important research area.

A possible solution to improving the autonomy of astronauts is to equip astronauts with autonomous intelligent machines to support them during space missions (Flynn, 2005; Neerincx et al., 2008). Neerincx et al. (2008) suggest the Mission Execution Crew Assistant (MECA) to support the astronauts during future missions. MECA can be described as a network of intelligent systems that support astronauts during the mission. These intelligent systems are called electronic partners (ePartners). MECA supports collaboration between the ePartners and the future astronauts. MECA's goal is empowering the cognitive capabilities of astronauts by supporting automatic information sharing, facilitating communication between the different parties and improving the planning and execution of tasks.

MECA provides support for instant procedure training and refreshment training (i.e. training to keep the procedure knowledge of the astronauts on a high level during a long-duration mission) on board to improve the autonomy of astronauts. MECA uses the SCOPE (Bos, Breebaart, Neerincx & Wolff, 2004) learning environment to support astronauts with executing tasks. An extension of this program, called Collaborative Trainer (COLT), can be used for (supporting) learning new procedures and refreshment training. To improve the learning support (i.e. improve the performance of the astronauts on learning task) more knowledge about human learning and the factors influencing human performance in space is needed.

Several factors can be distinguished that influence learning and performance in general. The MECA support is focused on keeping these factors optimal for good performance. Furthermore the goal of the MECA support is to give the astronaut more insight in his performance and the factors influencing performance and to analyze and monitor the influence of these factors and performance.

One of the factors influencing performance is the workload of an astronaut. The workload is how occupied the astronaut is with his work and with how much intensity the astronaut is working on his task. These factors influence the performance of the execution of tasks and the learning of new tasks. Cognitive Task Load (Neerincx, 2003) (CTL) is a measure of the workload of a person. CTL uses three variables to capture the workload of a subject: the level of information processing during a task, the time-occupied with a task and the number of task-set-switches during the task. Kennedie (2009) showed that these values can be used to predict the performance of people on (learning) tasks.

A second factor influencing performance is the emotional state (ES) of an astronaut. A more positive mindset can help improve performance. For an astronaut, who is under stress and in a complex group dynamic during a space mission; it is crucial to stay in a positive mindset and not succumb to a psychological stressor (Kanas & Manzey, 2003). Trying to improve and predict the emotional state of an astronaut is therefore an important domain in human space research. Kennedie (2009) also showed that when ES and CTL variables are known an even better prediction of performance can be made than when using either the ES or CTL variables alone.

A third factor that can influence astronauts in space is the amount of communication and what kind of communication is used during space flights. The discourse of an astronaut can be a clear indication of his emotional state, but also of his performance (Kanas, Gushin & Yusupova, 2008). During a learning task the amount of communication can be an indication of the performance on the learning task. The number of communicative acts directly relates to performance. Thus the person who is communicating the most is expected to have the best performance (Levine, Resnick & Higgens, 1993).

In general during a learning task CTL, ES and performance can be influenced by the use of specific support from an instructor. A distinction can be made between a structured support style and a natural support style. The structured support style makes use of triggers for performing an action. A trigger defines when the instructor should perform an action. When a student performs an action, this triggers the instructor to perform a support action. The instructor follows structured rules to decide what kind of support he will give the student. Bowers, Jentsch, Salas and Braun (1998) show that assigning structured support rules to the instructor can improve the group performance on a learning task. The style in which no structured triggers are given to the instructor is the natural style. In the natural style the instructor himself decides when to tell a student something (Arnold, Clark, Collier & Leech, 2006).

Not only the assigned support style is influential (Bowers et al., 1998), students can request more information from an instructor or can act more sociable and therefore the amount of received sentences can differ within a support style. For this reason the amount of information communicated is also worth investigating. The information communicated can be found by discourse analysis. The discourse categories used and received by a student influences the amount of errors and emotional state of the student. When someone is frequently communicating this might indicate someone might need more information or support to perform his actions and this might be an indication of low performance (Bluemink, Hämäläinen, Manninen & Järvelä, 2009). Communicating is also another act the subject has to give his attention to; therefore the amount of communication might influence the workload of the subject. Communicating with other people can also influence the emotional state of the subject. People who act more sociable are likely to have a more positive emotional state than people who are less sociable (Kanas, Gushin &Yusupova, 2008).

This thesis focuses on the influence of the assigned support style and the influence of the actual support (i.e. the discourse categories used) on the performance and state of people. The assigned support style can be seen as the instructions given to the teacher (i.e. Feedforward, Feedback and Natural). The actual support will be investigated via discourse analysis. The influence on performance and the different personal factors influencing performance (i.e. CTL and ES) will be analyzed. New in this approach is the combination with these personal factors and the applicability of this approach in this environment.

1.1 Thesis Outline

This thesis is structured as follows. Chapter 2 describes the general background of the environment in which the learning environment should be used and which factors are relevant for this research. Chapter 3 describes the influence of and relation between CTL, ES and communication. Chapter 4 describes the experiment conducted in Soesterberg. Chapter 5 describes the results found in the experiment. The final chapter describes the conclusion, discussion and gives an indication for future research.

2 General Background

2.1 Long duration missions

Long-duration spaceflights occur in an extreme environment and have new challenges for humans traveling in space. The next logical step in human space exploration is beyond the International Space Station (ISS), perhaps even to Mars. These voyages require not only new technologies, but also research on humans in space. Long duration missions have different circumstances in which humans must perform, thereby creating new challenges for future astronauts. Manzey (2004) describes the relevant psychological features of orbital space missions (Table 2-1).

	Orbital ISS Missions	Mars Missions	Winter-Over in Antarctic Missions
Duration (in months)	4–6	36	10–14
Distance to Earth (in km)	300–400	60–400 million	
Transfer times to/from destination	1–2 days	200–300 days	2–3 days
Crew size	3–6	6	15–100
Degree of isolation and social monotony	Low to high	Extremely high	Medium to high
Crew autonomy	Low	Extremely high	High
Evacuation in case of emergency	Yes	No	No
Availability of mission support measures:			
Ground-based monitoring	Yes	Very restricted	Yes
2-way communication	Yes	Very restricted	Yes
E-mail up-/downlink	Yes	Yes	Yes
Internet access	Yes	No	Yes
Onboard entertainment	Yes	Yes	Yes
Re-supply Flights	Yes	No	No
Visual link to Earth	Yes	No	Yes

Table 2-1 Comparison of psychologically relevant features of orbital space missions, exploratory missions to Mars and winter-over in Antarctica; adopted from Manzey (2004)

As appears from Table 2-1 Mars-missions have such different properties that ordinary analogue environments (e.g. Antarctic missions) are not comparable to a Mars-mission. Due to the lack of communication and lack of monitoring, combined with the high degree of autonomy and a small crew size Mars missions will need more automatic support during the mission.

The most crucial factor in manned long-duration space missions is the human astronaut (Davis, Fogarty & Richard, 2008). The astronaut is responsible for the management of all the devices on board during a long duration mission. However, during regular missions most tasks are planned by ground control and an astronaut performs procedural steps one-by-one. Whether an astronaut can perform these task is influenced by different factors which are described in the following section.

2.1.1 The Human Factor

As mentioned in the previous section, astronauts traveling to Mars are in a completely new environment with new circumstances. First we will have a look at the different influences on human performance; Kanas and Manzey (2003) describe different influences on humans. These stressors (see Table 2-2) are caused by the environment the astronaut is in and will make it harder for astronauts to work. Furthermore they mention that these stressors probably have a stronger effect on humans over time, in which case a Mars mission will have to deal with these problems.

Physical	Habitability	Psychological	Interpersonal
Acceleration	Vibration	Isolation	Gender Issues
Microgravity	Ambient Noise	Confinement	Cultural effects
Ionizing radiation	Temperature	Danger	Personality Conflicts
Meteoroid Impacts	Lighting	Monotony	Crew size
Light/dark cycles	Air quality	Workload	Leadership issues

Table 2-2 Examples of stressors for humans in space missions. Taken from Kanas and Manzey (2003).

Physiological	Performance	Interpersonal	Psychiatric
Space sickness	Disorientation	Tension	Adjustment disorders
Vestibular Problems	Visual Illusions	Withdrawal/territorial behavior	Somatoform disorders
Sleep disturbances	Attention deficits	Lack of privacy	Depression
Bodily fluid shifts	Error proneness	Scapegoating	Suicidal thoughts
Bone loss and hypercalcemia	Psychomotor problems	Affect displacement	Asthenia

Table 2-3 Examples of stresses for humans in space missions. Taken from Kanas and Manzey (2003).

The stressors mentioned in Table 2-2 can lead to different personal problems for astronauts. Table 2-3 shows the problems (stresses) the stressors can lead to. These stresses for humans are the manifestation of the problems a human might have during space missions. One of the main aspects in aerospace research is to counter these stressors (Flynn, 2005; Kanas & Manzey, 2003; Kanas et al., 2006, 2007; Ilyin, Kholin, Gushin & Ivanovsky, 1992)

There are several methods to counter these stresses. For instance, physiological stresses are countered/controlled by physical exercises to keep the body in shape. This conclusion is based on studies on the ISS and in bed-rest studies, in which the lack of gravity is simulated by keeping the participants in bed for longer periods of time. Participants whom were given certain physical exercises lacked some of the stresses that other participants did feel (Greenleaf, Bulbulian, Bernauer, Haskell & Moore, 1989).

Research on people working in isolated, confined environments (e.g. Polar missions) showed that interpersonal and psychiatric issues do emerge due to the long times of isolation. However, Kanas et al. (2006) show that there were no significant changes in group dynamics and behavior in both the Mir and the ISS studies. They refer to the fact that in these missions the astronauts were well prepared for the psychological conflicts that might emerge during a space mission. Furthermore, these astronauts had continuous support of psychologists that provided them with counter measurements that helped them cope with boredom, stress and monotony of space missions (Kanas & Manzey, 2003).

The same support is not possible during long-duration missions due to the long delays in communication and the high level of autonomy (Ilyin et al., 1992). Therefore it is expected that these issues will arise in a mission to Mars.

Kanas and Manzey (2003) also describe the following factors that might have a stronger influence on group dynamics over time: crew heterogeneity and cultural differences. Different backgrounds, genders or motivations can also have stronger influence during prolonged isolation. Cultural difference in nationality, professionalism and organization style also can have a stronger influence during prolonged isolation.

For a successful Mars-mission a study on the effects of isolation, confinement and their countermeasures on performance in a human long-duration mission is needed. For this reason the Institute of Biomedical Problems (IBMP) in cooperation with the European Space Agency started the Mars-500[1] project in Moscow, which is a simulated mission to Mars.

2.1.2 MARS-500

Mars-500 is a test ground for the measures helping crews stay autonomous for the voyage to Mars. The experiment will be conducted in the Ground-based Experiment Complex (GEC) of SCC RF-IBMP RAS. The compound consists of 5 modules, one of the modules is meant for the imitation of a “Martian Surface”, the remaining modules simulate the spaceship traveling to Mars. A crew of six will be locked in the modules and will stay

[1] www.idmp.ru/M500 and www.esa.int/esaMI/Mars500/

there for 520 days. The crew will stay in conditions of artificial atmospheric environment (i.e. normal gravity) at normal barometrical pressure. The main differences with this simulation compared to other simulations (e.g. Antartica, ISS, Deepsea Simulations) is the combination of long term autonomy of the crew, lack of communication with earth and prolonged isolation. Since these are specific requirements for a Mars voyage, this experiment is one of the best ways to test the psychological effects of a voyage to Mars.

This experiment has already gone through two phases: a 15 and a 105-days trial experiment in which logistical and technical issues of the compound were identified and fixed. In the third phase a 520 days experiment is conducted. In the 520 days experiment all problems encountered will have to be solved by the astronauts themselves. The 520 days consists of a 250 days trip to Mars, in which Earth will appear out of view. Followed by a 30 days period on Mars, in which three members of the crew are simulating a landing on Mars and are performing different tests. This is followed by a 240 days return trip to Earth. Most facets of a real Mars mission are simulated, for example ground control-crew communication delays will be simulated and the participants will have high autonomy on board.

The 520 days experiment has started the third of June 2010 when 6 crew members (3 Russian, 2 European and 1 Chinese) were locked in the GEC. With this experiment valuable data on psychology and physiology will be obtained. During this experiment new technologies and support functions are tested; the astronauts will also perform biweekly experiments of the MECA consortium.

2.2 The MECA-project

The research in the MECA-project is done by a consortium funded by the European Space Agency (ESA). The partners in this consortium are TNO Human Factors, and Science and Technology from the Netherlands, Ok-Systems from Spain, and EADS-Astrium from Germany. They are trying to create a prototype of an artificial support system during long-duration space missions. The objective of the MECA-project is "to empower the cognitive capacities of human-machine teams during planetary exploration missions in order to cope autonomously with unexpected, complex and potentially hazardous situations" (Neerincx, 2006).

This support system, MECA, will be a distributed system of intelligent systems (ePartners). These ePartners will help the crew to assess situations, determine a suitable course of action to solve problems and will safeguard the astronauts from failure (Neerincx et al., 2008). Table 2-4 shows the processes in which MECA should fulfil a support function. These processes and functional requirements are based on a work domain and support analysis and an expert review.

Process	**MECA function**
Information Gathering	detect needs for operations and training
Goal Setting	select and prioritize goals for operations and training
Plan Generation or Selection	generate plans, or select pre-generated plans and procedures, for operations and training
Plan Evaluation	evaluate operational and training plans
Prepare for Execution	prepare the resources for executing operational and training plans.
Execution	execute operational and training plans
Processing Evaluation of Results	evaluate execution results for operational and/or training purposes

Table 2-4 Outline of functional requirements. Adopted from Neerincx et al. (2008)

MECA supports human performance by helping during execution and countering the degradation of the performance by training. MECA will try to signal when stressors influence the performance of astronauts. The MECA-project is researching measures that can be used to determine the personal state of an astronaut. Furthermore they are investigating the relation between the personal state, time effects and human performance. The MECA-project is also researching appropriate ways to give astronauts feedback on these factors and the influence of these factors.

In Mars-500 MECA will give the astronauts feedback on their personal state (CTL and ES, see section 3.2 and 3.3) and performance. These factors are recorded during gaming sessions and after each game feedback will be given about their state and performance. The MECA experiments in Mars-500 are performed in two groups of three astronauts, which each will have their own gaming session. They will perform a session every two weeks. During the sessions they usually perform three different games. These games are Lunar Lander, Colored Trails and Collaborative Trainer (see the next sections). To get different information on the state of the astronauts, during these game sessions the faces of the astronauts are recorded and will be analyzed using Noldus' FaceReader[2]. Improving the feedback to the astronauts and the recording and analyzing of the astronaut's state during these tasks is one of the major research areas in this project.

2.2.1 Lunar Lander

Lunar Lander is a single player arcade game; the objective of the game is to land the Lunar Lander on landing spots as many times as possible without crashing. The Mars-500 crew plays a Java version of the game (see Figure 2-1). The goal of this task is entertainment (Rauterberg, Neerincx, Tuyls & Loon, 2008; Kennedie, 2009).

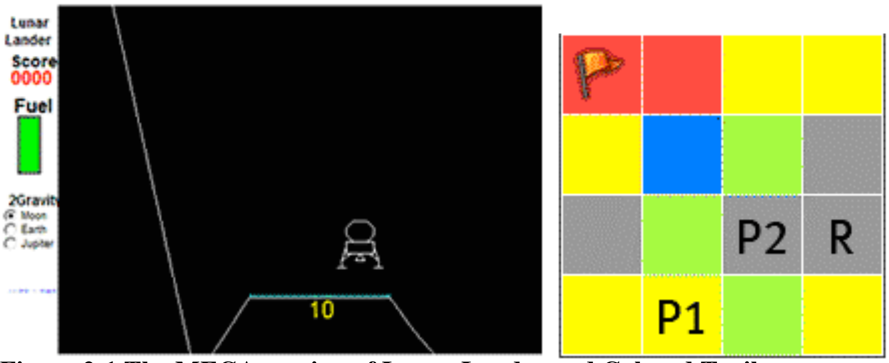

Figure 2-1 The MECA version of Lunar Lander and Colored Trails.

2.2.2 Colored Trails

The game Colored Trails is designed to investigate group behavior and collaboration (Liviatan, Trope & Liberman, 2008). Colored Trails is a three-player negotiation game, which is played on a board of 4 by 4 squares. Each player possesses a piece located on the board and a set of colored chips. The colored chips can be used to move the player's piece to an adjacent square of the same color. The general goal of the game is to move as close as possible to the goal location (i.e. the flag in Figure 2-1).

Colored Trails has three roles Proposer 1 (P1), Proposer 2 (P2) and Responder (R). Each proposer can propose a chip exchange to the responder. The responder can accept one, or no proposal. All players are aware of the board state. The proposers only have information about their own chip set and the one of the responder, while the responder can see all chip sets.

During a single game the proposers can only make one proposal and the responder can only accept one or reject both proposals. Once the responder has reacted to the proposals, the chips are exchanged according to the chosen proposal or if the responder rejected both proposals no chips are exchanged. Then, the best possible sequence of moves is computed and each player receives a personal score.

2.2.3 Collaborative Trainer

Collaborative Trainer (COLT) is a three person tasks in which an instructor helps two students learn and execute different procedures. COLT combines game-based learning and collaborative learning techniques (see sections 2.3.1 and 2.3.2).

The instructor tries to support the students during learning by making sure they learn the correct things and learn all the objectives. Furthermore the instructor tests the students by giving a quiz and different assignments during learning.

[2] www.Noldus.com/FaceReader

The students use the learning environment SCOPE (Bos et al., 2004; Bos et al., 2006), which is an astronaut procedure support tool. They use the learning environment to learn the procedures they should perform and why they should perform the different procedures.

This setup has been used in the previous Mars-500 experiment and has been used in different experiments concerning performance prediction. In total 35 new COLT exercises were created for Mars-500.

2.3 Learning in Space

Current training for space mission takes about three times more than the actual mission. Hughes (2004) indicates the need for new training methods, especially for long-duration mission. Long-duration missions require a whole new set of skills from the astronauts (e.g. psychological skills, interpersonal skills and procedural skills). Furthermore the different stages of spaceflight require different engineering and flight skills. To learn these skills the astronauts will have to learn to perform many highly procedural tasks. Training for a mission to the ISS takes many times more than the length of the mission. The complete training and learning of the skills needed for a long-duration mission would take even longer than the training for an ISS mission. For this reason Hughes (2004) mentions the need for on-board training and simulations.

Konoske and Ellis (1986) define procedural tasks as an ordered sequence of steps or operations performed on a single object or in a specific situation. They involve few decisions, are generally performed the same way every time. Most tasks performed by astronauts are procedural tasks. They show that learning the procedures is relatively easy, the remembrance of these acquired skills, retention, however proves to be more difficult. Van den Bosch (1999) argues for several ways to improve skill retention even after long periods of no practice. By giving the student a more thorough understanding of the system and task the retention of learned skills should improve significantly, however how a more thorough understanding should be achieved van den Bosch does not specify.

In the following section two different learning methods are described: Collaborative Training and game based learning. Both these methods are behind the Collaborative Trainer of the MECA M520 experiment and can be seen as implementations of so called electronic learning (e-Learning). e-Learning makes knowledge and information available to students without time restrictions or geographic restrictions. In the aerospace domain these are favorable circumstances, since astronauts do need immediate access to information even if they are far away from Earth. Since direct communication is not available game-based learning and collaborative learning are still valid options.

2.3.1 Game-based Learning

In Game-based learning users can perform different scenarios in a simulated environment (Pivic, Dziabenka & Schinnerl, 2004). Users are directly confronted with the consequences of their actions and are able to perform several trials. Furthermore it is possible to support the user by informing them about correct decisions and directly showing them different outcomes to stimulate the learning effect. Game-based learning gives the student, via the interaction it provides, deeper understanding of the matter. This makes it especially useful for learning structured procedural tasks, such as the task astronauts have to perform. Since the consequences can be directly seen by the students the results over time improve.

It is also shown that support by an emotional agent in a game-based learning environment can improve the performance of students. The emotional agent tried to get each participant in an optimal learning state (Chaffar, 2004). The use of this emotional agent significantly improved performance.

2.3.2 Collaborative Training

Collaborative training methods entail that two or more persons together solve a problem. This collaborative learning improves performance compared to solving the problem alone. This can be explained in two different ways:

- The students can subdivide the problem and each try to solve part of the problem (Aronson et al., 1978). This improves performance and social contacts between group members.
- The competition between the students improves performance and social contact between group members (Johnson & Johnson, 1989).

Since there are indications that interpersonal issues will arise in long-duration missions it is important to keep the group in positive contact with each other (Kanas & Manzey, 2003). It is shown that group dynamics and individual performance and attitude can be improved by using collaborative training methods (Aronson, Blaney, Stephen, Sikes, & Snapp, 1978; Johnson, Johnson & Smith, 1991a, 1991b; Johnson & Johnson, 1989 and Cavalier, Klein & Cavalier, 1995). Ishizaki, Fukuoka, Ishizaki, Tanaka. & Ishitobi (2004) also indicate this in a bed rest study. They show that participant who played a collaborative game had an improved mental state and were in more positive contact with each other during other activities.

Curtis and Lawson (2001) show that online cooperation can have the same effects on group behavior and individual performance as personal cooperation as long as the interaction stays effective. This means a chat-room or discussion board can have the same effect as personal interaction and there is no specific need for face-to-face communication within collaborative learning tasks. Three key types of learning interactions are distinguished as important by Moore (1993): interaction with the teacher, interaction with the peers and interaction with the information. Curtis and Lawson (2001) show that effective collaborative learning can be done in an electronic learning environment (e.g. Blackboard) and Moore's three interactions can be used in this environment. These factors show the importance of communication in a collaborative learning task.

Bluemink et al. (2009) combine a game-based environment with Collaborative training/learning. The participants to this study performed a collaboration task within a virtual environment. The participants played a multiplayer adventure game in this virtual environment. They tried to finish the adventure together. It was found that the amount of communication and what sort of communication was used was an indication of the performance of each group. Furthermore Bluemink et al. indicate that playing such a game can be used to promote team cohesion and development.

3 Experimental Background

This chapter explains the different factors researched in this thesis. The Collaborative Trainer and what it entails is explained, furthermore the measures ES, CTL and communication are explained. These factors are considered important for learning and execution of tasks. Since in normal environments these are less critical for the group process and mission success, especially astronauts have to make sure these factors stay stable and positive (Kanas & Manzey, 2003).

In this thesis the role of communication is investigated, thus what kind of influence does different communication styles and acts have on the performance in a COLT-task. Performance in the COLT-task has been previously researched. The workload and emotional state that have been found during this task influence the performance on the task (Kennedie, 2009; Neerincx, et al., 2009). Communication between the student and instructor might also influence the performance, workload and emotional state during COLT. Therefore we are researching the influence of communication between the instructor and students on the performance, workload and emotional state in a learning task. These are important factors during long-duration missions and should be monitored/controlled during tasks. One of tasks astronauts perform is the COLT-task.

3.1 Collaborative Trainer

The objective of COLT is to learn new procedures or make sure students are able to perform certain procedures. An instructor is assigned to students to help them learn new procedures.

COLT is a combination of a remote-desktop viewer for the instructor and the SCOPE (Bos et al., 2004; Bos et al., 2006) learning environment for the students. The instructor is only able to communicate to the students via chat. In the latest version the chat client is integrated within the MECA software (Figure 3-1), which allowed for easy synchronization of the actual steps in COLT and the chat communication between the instructor and students.

Performance on the COLT-task has been previously researched. The workload and emotional state that have been found during this task can predict performance on the task using a Bayesian network (Kennedie, 2009; Neerincx et al., 2009). Three performance groups were created: high, medium and low performance. The Bayesian network created predicted 67% correct when using the CTL and ES variables.

Communication between the student and instructor might also influence the performance, workload and emotional state during COLT. Therefore we are researching the influence of communication between the instructor and students to find more information about the performance on a learning task. Furthermore we are looking for the best way to give support during this task. Thus what should the instructor say and at what points should the instructor say something. Structuring this support can influence the performance, workload and emotion of the students performing the task.

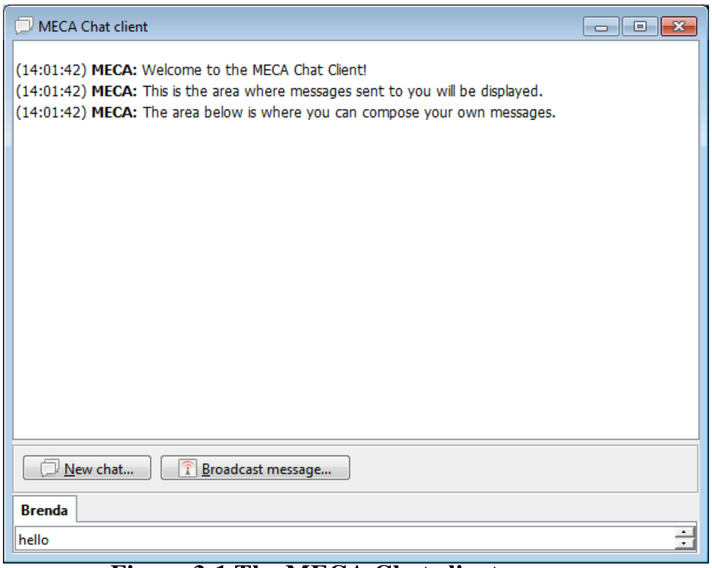

Figure 3-1 The MECA Chat client.

The students can learn about the procedures from the Cardiopres, this is called a payload. A payload consists of procedures and documentation. The procedures (e.g. Figure 3-2) showed how to use a certain application or tool (the payload). The background documentation became available when the student pressed the green link in the procedure steps (see Figure 3-2). The documentation provided background information on why you should perform certain procedures and for more difficult procedures it also provided a more detailed explanation. Furthermore the payload holds a virtual simulation of the tool (e.g. the Cardiopres) the students are learning about. The simulation is a game-based learning element in which the students could perform the learned procedures.

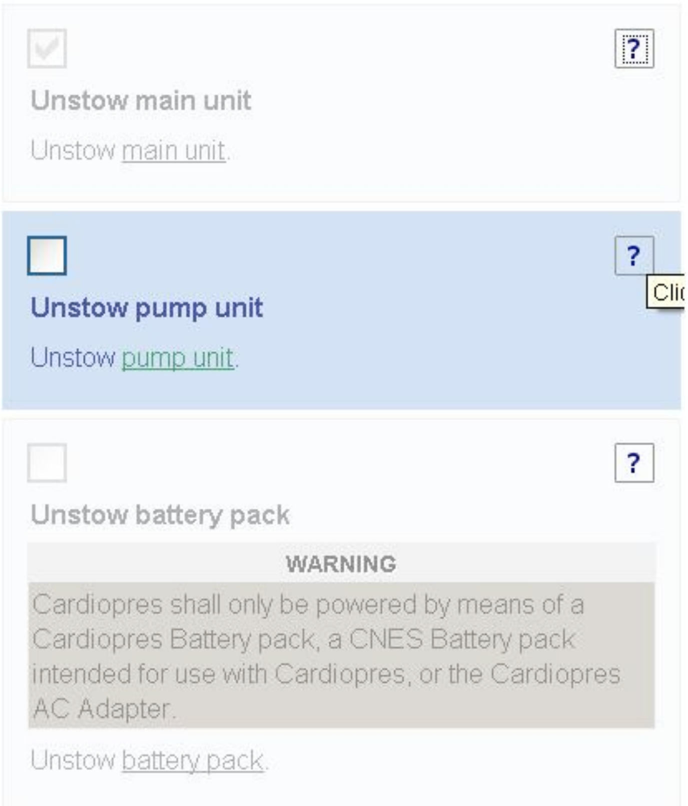

Figure 3-2 The procedure steps in the COLT learning environment.

3.1.1 *Cardiopres*

Cardiopres is a medical device astronauts use to check blood pressure, heart rate and respiration. This payload describes how to perform the actions with the Cardiopres to get an adequate reading. The simulated Cardiopres allowed the user to fill in data about a hypothetical subject and perform small measurements on the hypothetical subject. Figure 3-3 shows the Cardiopres payload and learning environment.

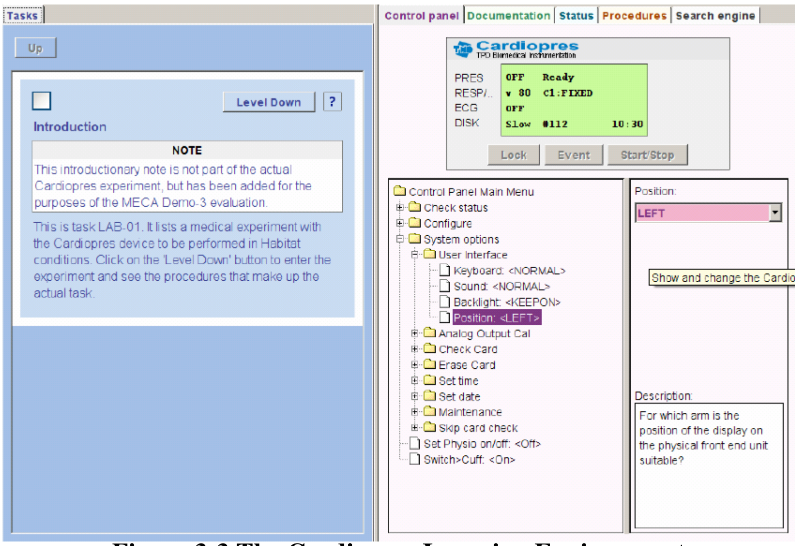

Figure 3-3 The Cardiopres Learning Environment

3.2 Cognitive Task Load

The cognitive task load (CTL) theory (Kennedy, 2009; Neerincx, 2003; Neerincx, Veltman, Grootjen & Veenendaal, 2003; Neerincx, Grootjen, & Veltman, 2004) is a measure of workload. CTL distinguishes three dimensions that have significant influence on task performance:

- *Time Occupied (TOC):* This is the percentage of time a human operator uses for a certain task. TOC is high when the operator has to work with maximum cognitive processing speed to search and compare known visual symbols or patterns, to perform simple (decision-making) tasks, and to manipulate and deal with numbers in a fast and accurate way.
- *Level of Information Processing (LIP):* This dimension is low when information is processed automatically. This results into actions that are hardly cognitively demanding. This is also called the skill-based level. LIP is medium for routine procedures, such as applying simple if-else- then rules (rule-based level). These actions involve rather efficient information processing. At the knowledge-based level, LIP is high. This occurs for problem solving and action planning in relatively new situations and involves a heavy load on the limited capacity of working memory. LIP is adopted from Rasmussen (1986).
- *Task-Set Switches (TSS):* Complex tasks situations consist of different tasks, with different goals. They rely on different sources of human knowledge and capacities, and may refer to different objects in the environment. This third load dimension addresses the demands of attention shifts or divergences in which different sources of human task knowledge have to be activated.

These values can be self assessed by a person via questionnaires (e.g. answering questions such as: “How much time were you occupied with your task?”) or exercises can be created that have different values for the variables itself (e.g. a boring task, many switches required during task) (Kennedie, 2009; Neerincx et al., 2009).

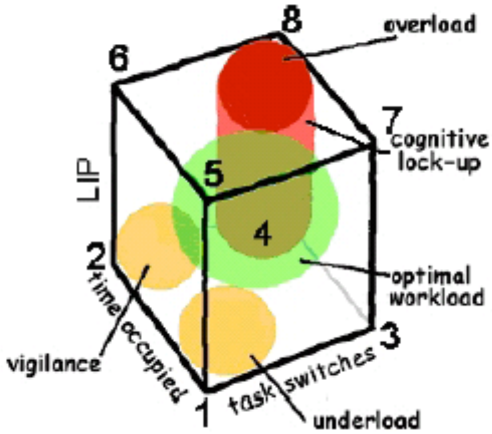

Figure 3-4 The dimensions of CTL and the expected workload. Adopted from Grootjen, Bierman, Neerincx (2006).

Figure 3-4 shows the dimensions of CTL. The green area describes the workload of a person that leads to the optimal performance; when the TOC, LIP and TSS are average. When all dimensions are high (the red area in Figure 3-4) an overload will occur, the person will not be able to perform his task because the task is too demanding. The person will experience an underload when all the dimensions are low. When experiencing an underload, more mistakes are made due to the monotony of the task.

While overload problems can occur any time, underload problems will only occur after a longer work period (Neerincx, 2003). Performing a certain task for a longer period of time will increase the changes of performance errors during a task (see Table 3-1 for more details)

	Task Performance Period		
	Short	Medium	Long
TOC: low LIP: low TSS: low	No Problem	Underload	
TOC: high LIP: low TSS: high	No problem		Vigilance
TOC: high LIP: all TSS: high	Cognitive lock-up		
TOC: high LIP: high TSS: high	Overload		

Table 3-1 The effects of the task period and the different area's of CTL. Adopted from Neerincx (2003).

CTL has been previously used in the field of naval operators (Grootjen, Neerincx & Weerd, 2006) and been used to predict performance of naval operators, a multi-player First-Person-Shooter and the MECA COLT-Task. (Neerincx, Kennedie, Grootjen, Grootjen, 2009; Kennedie, 2009) In these experiments the CTL dimensions were combined with the ES of a person to predict performance.

3.3 Emotional State

The relationship between the ES and the performance on a task has been researched often. In sports for example, it is shown that a positive emotional state of an athlete improves the performance of teams and individuals. Furthermore in the correct emotional state there is a lack of error and a lack of injury during performance (e.g. Devonport, Lane & Hanin, 2005;

Hanin, 2003; Jones, Mace & Williams, 2000). Astronauts also appear to have similar relations between emotional state and performance. However, astronauts on long-duration missions have more outside influences on their emotional state and are therefore more vulnerable to changes in mood (see Section 2.1.1).

To improve the emotional state during learning Chaffar (2004) combines an intelligent tutoring system with an emotion inducer to get better performance from the students. This program tried to get each student in the correct mindset, before and during the learning. The use of this program resulted in a significant improvement of the learning. It has to be noted that for different types of persons different types of emotions were needed.

3.3.1 Measuring the Emotional State

There are different methods to measure the emotional state of a subject. Kanas, Gushin and Yusupova (2008) use a long questionnaire called Profile of Mood State (POMS) which the astronauts have to fill in. The POMS-questionnaire takes a long time to fill in and it is not directly clear to the participant what his state is. A quicker and more easily used method in which a person quickly fills in his current ES is the Self-Assessment-Manikin (SAM) of Bradley and Lang (1994). This manikin consists of three variables: valence, arousal and dominance. Valence can be considered the amount of happiness the subject feels; arousal how excited the subject feels and dominance how much in control the subject feels. The participants has to chose a picture which resembles his emotion at that time (see Figure 3-5)

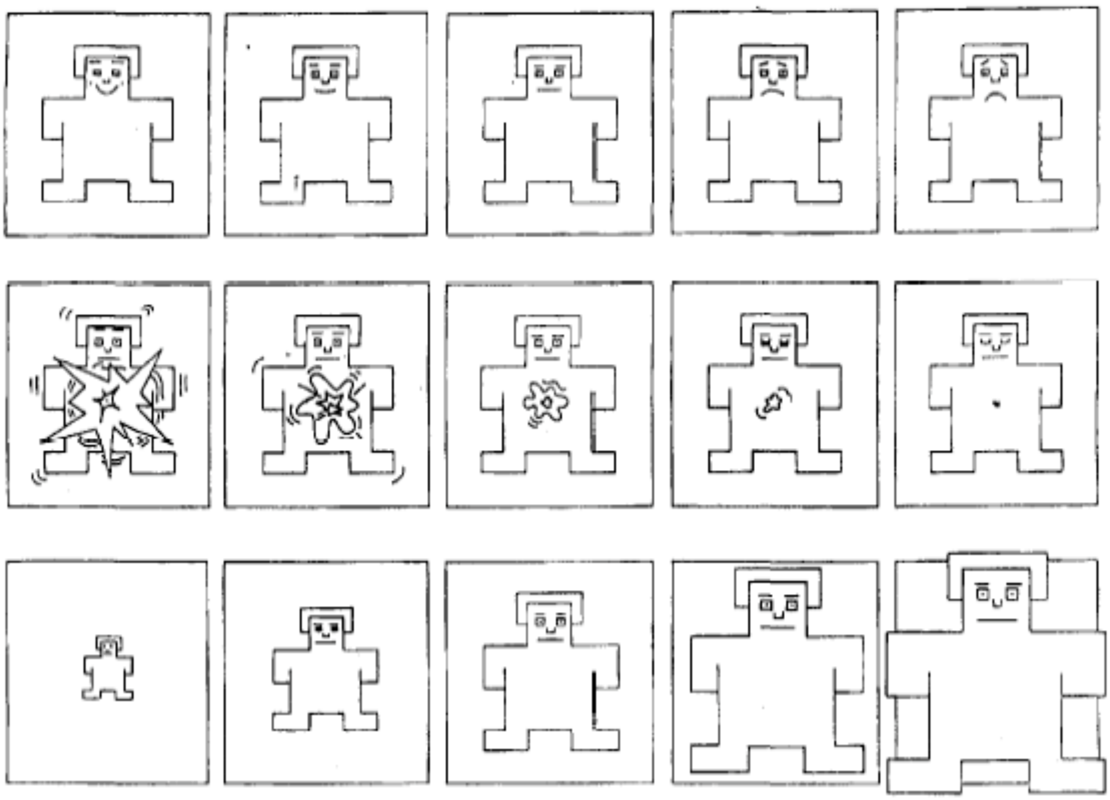

Figure 3-5 The SAM questionnaire as used by Bradley and Lang (1994)

As mentioned in section 3.2 CTL and ES relate, for specific load conditions specific emotional reactions are expected. For example, when the task-load increases, the arousal value is expected to increase as well (i.e. the subject will increase his effort to maintain the task performance). This is visualized in Figure 3-6.

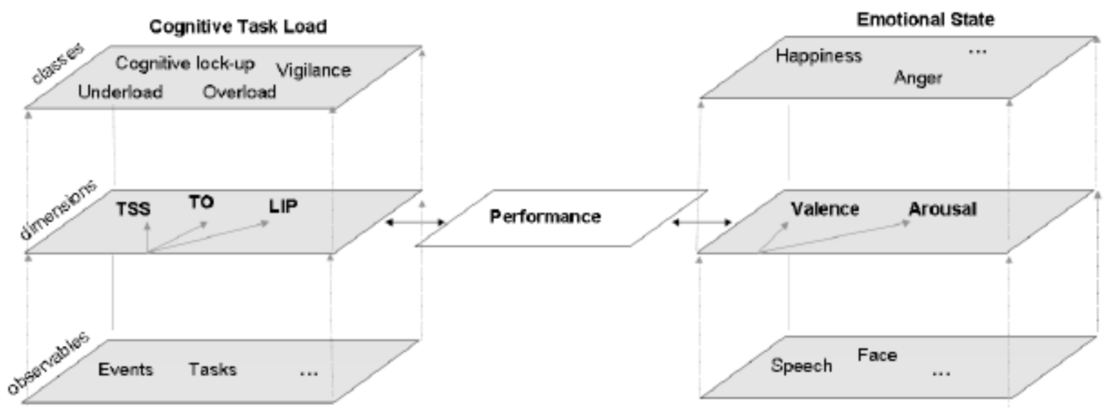

Figure 3-6 Cognitive Task Load and Emotional State relate (Neerincx, 2003).

3.4 Communication

In this thesis we are interested in the role of communication within the COLT-task. Astronauts need a stable ES, workload (CTL) and good performance (Kanas & Manzey, 2003). Therefore in this thesis the influence of support style of the instructor and the discourse categories used in the COLT-task on these factors is investigated. Furthermore the discourse analysis can be used as indication for weak performance or changes in ES and CTL within the COLT-task.

The general influence of communication is extensive. Three participants in the communication can be distinguished when analyzing the communication of astronauts during space missions: the crewmembers, ground control and relatives on earth. Kanas, Gushin and Yusupova (2008) show a correlation between the sentences used during crew – ground control communication and the mood of an astronaut. They distinguished three main communication categories (i.e. Discourse Categories): informative, regulatory and emotional statements. These categories were subdivided in more specific discourse categories (e.g. for emotional statements: Emotional Consents, Emotional Discords and Jokes) and then correlated to the mood of the astronaut. The astronaut's mood and changes in mood were measured via a questionnaire which the astronauts filled in on a weekly basis. The authors show that there is a relation between the emotional state of an astronaut and their communication with ground control.

During long-term isolation the communication patterns follow the same pattern as the emotional effects on astronauts. During the first period of isolation lots of communication takes place. Despite the fact that space crews rely heavily on ground support and the lack of communication might decrease mission success, in the second period (during the halfway point to the end of the mission) less communication between crew and ground-control took place (Gushin, 2003; Morukov, Gushin, Vinokhodova & Shved, 2009; Kanas et al., 2006). This is probably because less support was needed during the second period. The astronauts had acquired a steady workflow and knew how they had to perform the actions and therefore did not need the support. In the third period there are new procedures and new actions to be performed by the astronauts and therefore they needed more support.

3.4.1 Support style

From Table 2-1 it is clear that the communication from ground control to the crew is restricted during Mars missions. Therefore further research is needed on what kind of support is required during what kind of task.

In different studies concerning team work and communication it is shown that not only the amount of communication and what exactly is said is important for mission success, but especially the sequence and timing of the support actions is important (Bowers et al., 1998; Vortac, Edwards & Manning, 1994). There is a distinction between structured and non-structured/natural support. The structured support can be subdivided in 2 categories:

feedforward and feedback (Nakatsu, 2004; Dhaliwal & Benbasat, 1996; Beun, Baker & Reiner, 1995). Non-structured support is support which is not predefined and can take any form.

In the structured support styles there are three important properties that define the support style: Temporal order, Cue and Case Specificity. The temporal order defines the point at which the support is given. The cue defines what kind of advise the instructor should give to the student. When the student has performed an action in the feedback group the advice would be about the action just performed and how to correct mistakes made (i.e. advice based on the outcome of the student's actions). In the feedforward group the instructor will give advice prior to the action and the advice will consist of what to do next.

The case specificity is how specific the support of the instructor is. In general the feedback support gives very specific support (e.g. specific on what went wrong) and feedforward support is more general. The feedforward instructor is giving more general pointers on what the student should do next. Table 3-2 shows the basic properties of the different support styles as described in the different articles.

	Feedforward	**Feedback**	**Natural**
Temporal order	Prior task	Post task	No predefined order
Cue	Input cues	Output cues	No predefined cue
Case Specificity	Generic	Specific	No predefined specificity

Table 3-2 Basic properties of the different styles of supportive communication.

Some different aspects need to be taken into consideration while using such support strategies. Horii, Jin and Levitt (2005), for example, show that performance deteriorates by changes in leadership style during the performance of tasks. When the manager, or instructor, changes the leadership style this leads to confusion and loss of performance during tasks caused by the expectancy of the users. This is especially the case in cross-cultural teams in which different management style have more influence.

Arnold et al. (2006) show that feedback and feedforward strategies are used differently between experts and novices. In their experiment on support styles 40 participants per group used a learning environment and performed several tasks. It was found that novice users prefer more feedforward support due to their lack of knowledge. Experts however prefer more feedback support to overcome problems during their task performance. Gonzalez (2004) tested different support functions within a dynamic decision making task. Such a task is characterized by the need to make multiple and interdependent decisions in an environment that changes and interacts with the decisions the user makes. It is shown that within such a task feedforward strategies in the form of an experienced individual can help improve performance (Sengupta & Abdel-Hamid, 1993). Furthermore it is shown that more frequent and specific feedback improves performance. This kind of feedback is best given by an expert user.

In this thesis the role of the support style is analyzed. The distinction between 3 support styles is made: Feedforward, Feedback and Natural. The influence of these three styles on the workload, emotional state and performance is analyzed.

3.4.2 Discourse Analysis

All communication patterns in previous mentioned research have been categorized by discourse analysis. Discourse analysis entails giving each sentence used a specific category which describes the sentence. Table 3-3 shows the commonly used discourse analysis categories.

Category	**Example**
Social Statement	"Hey! How are you?"

Content Statement	"I am now learning the Unstow Component-procedure"
Responds	"You should be in the Water Tank-payload."
Acknowledgement	"Ok"
Question	"Am I following the correct Procedure?"

Table 3-3 Commonly used discourse analysis categories. Based on Bluemink et al. (2004).

Different research on the discourse categories and performance has been conducted. For individual success during learning it is shown that students that respond more in an electronic chat discussion generally perform better on quizzes (Wang, Newlin & Tucker, 2003). Students that perform better also make use of different discourse categories. This is also indicated by Bluemink et al. (2004); they analyzed the discourse during a multiplayer collaboration game. They, however, found that the group that performed best used the least discourse. Although it should be noted that performance was measured in time and the best group had the fastest time and therefore also the least time to communicate. Furthermore they found that informative statements (e.g. Content Statements) were needed and most used during the collaboration games. This confirms the findings of Levine, Resnick & Higgins (1993) that content statements are crucial in collaboration.

Bowers et al. (1998) found that the use of content statements and acknowledgments significantly improves the performance of teams of airplane pilots. The pilots that performed better communicated more observations and made more leadership statements. They also found that not only what was said, but also in which sequence the actions were performed.

The discourse analysis in the previously described research is all done by hand and is done afterwards. A different possibility for categorizing the communication is to let a computer automatically categorize the used statements. Martin and Foltz (2004) used a Latent Semantic Algorithm to assign tags to different communication acts. This algorithm got comparable results on the annotations as human annotators. When they used their results on the prediction of performance of airplane pilots they found similar results as Bower et al. (1998); the use of acknowledgements and informative statements significantly improved performance of the teams. In this thesis the usage of discourse analysis within the COLT-task is analyzed. The question is whether the usage of certain discourse categories leads to changes in workload, emotional state or performance?

3.5 Combining the factors

In this research we are analyzing two factors in a Collaborative Training task: the support style and the discourse. A collaborative task is executed with one instructor and two students. The instructor has an assigned support style (Feedback, Feedforward or Natural) and will support the students during the task.

The support style is expected to influence the performance, cognitive task load and emotional state of students. The feedforward style is expected to have a positive influence on performance and should make the task easier for the astronauts thus having a lower cognitive task load (Sengupta & Abdel-Hamid, 1993). In the Natural support style it is expected that more social statements are sent and thereby improve the emotional state of the student.

Furthermore the communication between participants is analyzed via discourse analysis. These discourse categories might be used to monitor astronauts during their mission. It is expected that the number of sentences used of a specific category can influence the other factors (i.e. cognitive task load, emotional state and performance). This can be used to find changes in performance, workload and emotional state. The usage of content statements and questions can be an indication of performance (Bowers et al., 1998). Furthermore the number of social statements can be an indication of the emotional state (Kanas, Gushin & Yusupova, 2008). The number of questions can also be an indication of a high cognitive task load, because the student probably has difficulty with the task. In the following experiment all these factors are addressed.

4 Method

4.1 Subjects

The participants were students or graduated students with good knowledge of the English language. Twenty two males and nine women with the average age of 22.6 years and a standard deviation of 2.5 years took part in the experiment. The experiment took place from the 26th of April to 12th of May 2010 at TNO Defense, Security and Safety, Soesterberg.

4.2 Apparatus

Each student had a Dell Pentium 4 computer with 2,80 GHz and 1,00 GB of RAM. The computers ran Microsoft Windows XP Professional Version 2002 with Service Pack 3 installed. The students had one iiyan 17" inch flat screen with a resolution of 1280 by 1024 pixels. The computer for the teacher and the computer in the control room had identical computers only with two iiyan 17" inch flat screens connected to it. The computers were connected via LAN.

Since the participants were not allowed to talk to each other screens were placed between the participants workplaces. A conference call to the teacher was made using Skype to make sure the participants were not talking to each other.

BonjourSDK was installed on all computers as prerequisite for the MECA Software; it was used as a network tool. UltraVNC[3] 1.0.8.2 was installed for remote desktop viewing. The teacher had Cool Timer[4] installed, which was used as a timer for the teacher. The MECA-t2-mars520-1.0.0b1 version of the MECA software was used for groups two to twelve. The MECA-t2-mars520-1.0.0a7 was used for the pilot and the first group.

4.3 Experiment design

The performance of students in COLT Learning Environment was recorded during this experiment. The experiment featured a between subject design and tested the communication style. The communication style was the only categorical independent variable and consisted of three levels. The different communication styles were Feedback, Feedforward and a Natural style in which no deliberate instruction was given. The differences between the styles are described in the previous section. The communication styles are tested in the Cardiopres payload of the COLT learning environment. There are twelve groups of three (two students and one teacher). For each group there were two students who performed the tasks.

4.4 Structure of the session

Each group performed a 3 hour session in which a total of 9 tasks are performed. The schedule of each session is provided below.

	Activity	**Time (in minutes)**
General Introduction	Start Questionnaire	10
	Introduction	20
	Practice COLT Task	10
	Questions	5
COLT Tasks	COLT Task 1	13
	COLT Task 2	13
	COLT Task 3	13
	COLT Task 4	13
	Break	15
	COLT Task 5	13
	COLT Task 6	13

[3] http//www.ultravnc.com
[4] http://www.harmonyhollow.net/cool_timer.shtml

	COLT Task 7	13
	Final Quiz	10
Debriefing	Debriefing	10
	Total Time	171 (2h 51min)

Table 4-1 Session schedule.

4.4.1 General introduction

During the general introduction the participant filled in the introduction questionnaire with demographic questions and questions related to working in a computer-based learning environment.

After this the general goal and how to use the learning environment was explained. Furthermore the instructor received instructions in private how to perform his support-task: at what times the instructor should perform a support act and what kind of support act (for more details see Appendix B). Furthermore a more detailed description of the tasks was given to the instructor. After this a practice COLT task was performed after which all participants could ask questions. Furthermore it was checked whether the instructor understood the instructions.

4.4.2 Structure of the COLT-tasks

The students were supposed to learn some part of the Cardiopres procedures. Sometimes they also had to execute some of the procedures on the virtual Cardiopres in the Learning Environment. Every COLT-task has three phases, the startup phase, the learning phase and the quiz phase. The phases are described now.

4.4.2.1 Startup phase

The students and teacher read the assignment in the User Manual. The students read their objectives for the task. The teacher read what actions the students are supposed to perform in the learning environment. The students started COLT by clicking the appropriate link in the timeline. The task is started and the participants are asked to fill in their current emotional state (arousal, valence and dominance) on a SAM-scale (Bradley & Lang, 1994), see Figure 4-2. After this a performance screen is shown in which the participants can see their own performance and state on the previous tasks. The instructor started the remote desktop viewer and the timer. After this the instructor communicated to the students that they had to start learning.

4.4.2.2 Learning phase

In the learning phase the learning environment SCOPE would become available for the students. The students had to learn according to the Student's Assignment in the Manual. The teacher guided the students through the learning environment and tried to make sure the students learned the correct things and followed the correct path. The teacher had to use the provided communication style as his guideline.

During the learning phase several questionnaires appeared for the students. After 1 and 3 minutes an emotional state and a cognitive task load questionnaire appears (Figure 4-2). After 8 minutes the timer made a sound and the teacher would indicate that the learning phase was over and the students closed the learning environment and filled in two more questionnaires, the cognitive task load questionnaire (Figure 4-2) and the game specific questionnaire (Figure 4-1) in which they grade the teacher and their own performance. After this the quiz phase is initiated.

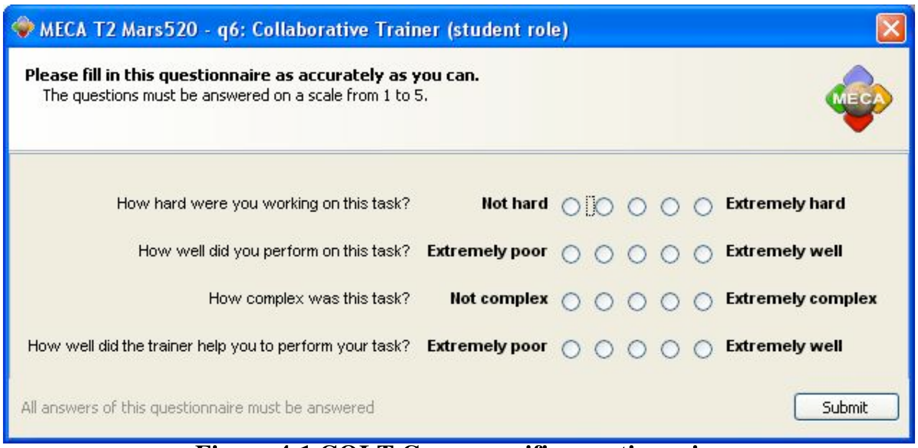

Figure 4-1 COLT Game specific questionnaire

4.4.2.3 Quiz Phase

During the quiz phase the students had to answer the questions from the teacher via chat. The teacher started asking the questions provided in the manual using the chat. When the students had answered the questions the teacher gave feedback on the correct answers. After this the next task was started.

4.4.3 Debriefing

The debriefing is used to evaluate the session and to explore any problems during the execution of the tasks. Furthermore, during the debriefing the students discussed the teacher's performance based on the communication. The teacher was asked about his performance during the session.

4.5 Measures

4.5.1 Communication

The chat was logged in combination with the procedure steps every student takes. The chat communication was manually processed and divided in several categories. When a message could be categorized in multiple categories, the context of the sentence was used to assign a discourse category. The different discourse categories are described in Table 4-2.

Category	**Example**
Social Statement (SS)	"Hey! How are you?"
Content Statement (CS)	"I am now learning the Unstow Component-procedure"
Technical Issue (TI)	"My chat is not working?"
Responds (R)	"You should be in the Water Tank-payload."
Acknowledgement (A)	"Ok"
Feedforward (FF)	"You should now open the Unstow Components"
Feedback (FB)	"You are in the wrong procedure, you should open the "Unstow Components" procedure."
Learning Related Question (LR)	"Am I in the correct Procedure?"
Quiz Question (QQ)	"What is the main unit?"
Quiz Answer (QA)	"A"

Table 4-2 Discourse analysis categories (and their abbreviations) and Examples used in the experiment. Combination of Wang et al. (2001) and Bluemink et al. (2004), added with necessary COLT procedure categories.

4.5.2 Cognitive Task Load

CTL was measured via the CTL-questionnaire that appeared multiple times during each session (i.e. at the start, after three minutes and at the end of the session). The students were asked to judge their experienced Level of Information Processing (LIP), Time Occupied (TOC) and Task Set Switches (TSS). The different variables were explained during the introduction. The difference in these scores (between pre and post) indicates a change (negative or positive) in CTL due to the task. The absolute difference indicates whether the CTL variables are changing.

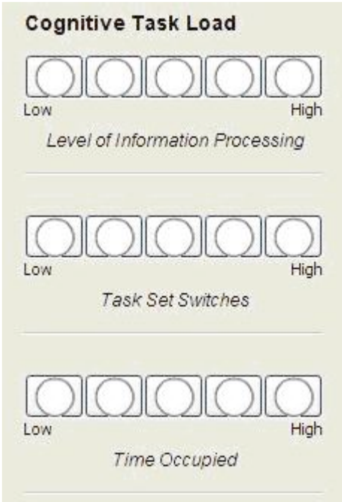

Figure 4-2 The Cognitive Task Load questionnaire used during the MECA experiment.

4.5.3 Emotional State

The ES of the students was measured using the Self-Assessment-Manikin (Bradley & Lang, 1994). The students had to fill in their Arousal, Valence and Dominance values at the start of the session, after three minutes and at the end of the session. Each variable receives a score (1-5). The difference in these scores (between pre and post) indicates a change (negative or positive) in emotion due to the task. The absolute difference only indicates whether the emotions are changing.

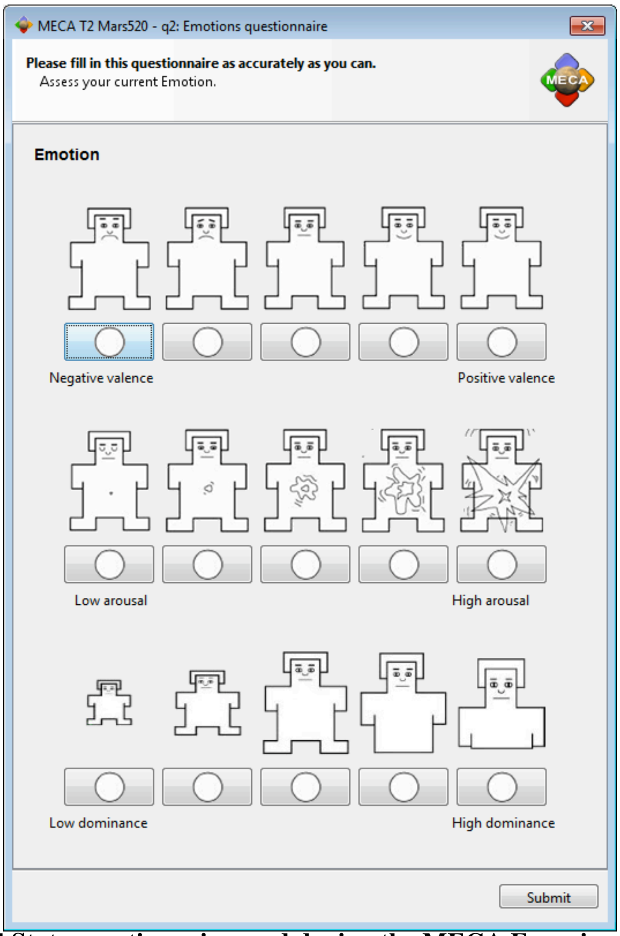

Figure 4-3 The Emotional State questionnaire used during the MECA Experiment. Based on Bradley and Lang (1994)

4.5.4 *Performance*

The performance score is either per task or over the complete session.

4.5.4.1 *Performance per task*

The performance was based on task quizzes and the efficiency of learning. The number of questions answered correctly in the task quiz was the task quiz score.

The efficiency of the student per task is based on the navigation in the COLT learning environment. Three variables were distinguished per task: the number of essential pages navigated to (EPN), the number of missed essential pages (EPM) and the number of non-essential pages navigated to (ExP). The number of missed essential pages and the number of essential pages complement each other.

$$\text{Efficiency per task} = \frac{(\#EPN - \#ExP)}{(\#EPN + \#EPM)}$$

Two programs were created to test whether a student had navigated to the essential pages for that task. These programs compared the navigation of the student during the task to a reference file. The first program created new files for each user and task, containing the useful information, the second file compared the created file to the reference file. The reference file contained all actions to be made by the student during a task. These programs are described in Appendix A.

4.5.4.2 Performance per session

At the end of a session the overall effectiveness of the learning was measured by a final quiz. The session performance can be subdivided in three variables: the overall results of the task quizzes, the overall Efficiency of the tasks and the results on the Final Quiz.

4.6 Analysis

4.6.1 Support style

One-way between groups analyses of variance (ANOVAs) were conducted to explore the impact of style (Natural: n=7; Feedback: n=8; Feedforward: n=8) on several outcome measures. These outcome measures (Performance, Communication, ES and CTL) were compared across the three groups based on style. Post-hoc t- tests were performed to determine whether the Feedback group, the Feedforward group and the Natural group differed from each other.

The compared measures in the performance category were:

- Final Quiz results
- Sum of all Task Quizzes
- Navigation Performance

The compared measures in communication category were:

- Total number of sentences sent by the student
- Total number of sentences sent by the student to the teacher
- Total number of sentences sent by the student to the student
- Total number of sentences received by the student
- Total number of sentences received by the student from the teacher

For the following outcome measures the average difference between start and final CTL and ES state questionnaires per subject during a task were compared across groups. The start was considered the baseline and the final questionnaire was the end result of task. Any changes between the values of both questionnaires are caused by performing the task. The difference and absolute difference between the values was computed. The absolute difference indicates changing emotions or workload (no difference between positive or negative) during the task. The difference indicates what the change is during the task.

The compared measures in the workload category were:

- Difference in the sum of CTL variables.
  - The sum of the post task TSS, LIP and TOC values minus the sum of the pre task TSS, LIP and TOC values.
- Absolute difference in the sum of CTL variables.
  - The absolute value of [the sum of the post task TSS, LIP and TOC values minus the sum of the pre task TSS, LIP and TOC values].
- Difference in Task Set Switches
  - The post task TSS value minus the pre task TSS value.
- Absolute difference in Task Set Switches
  - The absolute value of [the post task TSS value minus the pre task TSS value].
- Difference in Level of Information Processing
  - The post task LIP value minus the pre task LIP value.
- Absolute difference in Level of Information Processing
  - The absolute value of [the post task LIP value minus the pre task LIP value].
- Difference in Time Occupied
  - The post task TOC value minus the pre task TOC value.
- Absolute difference in Time Occupied

  - The absolute value of [the post task TOC value minus the pre task TOC value].

The compared measures in the emotional state category were:

- Difference in the sum of ES variables (pre/post)
  - The sum of the post task Arousal, Valence and Dominance values minus the sum of the pre task Arousal, Valence and Dominance values.
- Absolute difference in the sum of ES variables (pre/post)
  - The absolute value of [the sum of the post task Arousal, Valence and Dominance values minus the sum of the pre task Arousal, Valence and Dominance values].
- Difference in Arousal
  - The post task Arousal value minus the pre task Arousal value.
- Absolute difference in Arousal
  - The absolute value of [the post task Arousal value minus the pre task Arousal value].
- Difference in Valence
  - The post task Valence value minus the pre task Valence value.
- Absolute difference in Valence
  - The absolute value of [the post task Valence value minus the pre task Valence value].
- Difference in Dominance
  - The post task Dominance value minus the pre task Dominance value.
- Absolute difference in Dominance
  - The absolute value of [the post task Dominance value minus the pre task Dominance value].

4.6.2 Discourse Categories

Linear regression analysis was conducted to explore the impact of the discourse categories (e.g. number of Social Statements) received and sent during a task (n=184) on several outcome measures.

The outcome measures were:

- Navigation performance
- Changes in the sum of the ES variables during the task
  - The sum of the post task Arousal, Valence and Dominance values minus the sum of the pre task Arousal, Valence and Dominance values.
- Changes in the sum of the CTL variables during the task
  - The sum of the post task TSS, LIP and TOC values minus the sum of the pre task TSS, LIP and TOC values.

5 Results

First the results per support style are described; the second part describes the individual task results.

5.1 Results per support style

5.1.1 Communication

Table 5-1 shows the results of the analysis of communication between support styles.

Variable	Natural		Feedback		Feedforward		ANOVA	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	F(2,20)	p-value
Total Messages Sent	73.7	50.9	42.1	10.8	68.8	41.0	1.586	0.230
Total Messages Received	128.4	78.1	99.6	26.9	147.7	17.7	2.105	0.148
Student to Student	29.7	33.8	0.13	0.4	12.1	16.2	3.627	0.045*
Teacher to Student	184.9	102.3	141.5	35.1	191.9	36.4	1.456	0.257
Student to Teacher	65.0	41.5	42.0	10.7	56.6	28.7	1.218	0.317

Table 5-1 Mean and Standard deviation of the communication acts per support style and the ANOVA results. * indicates significance at the p<0.05 level.

The difference in the total number of messages sent by the students to the other for the three groups based on style was significant [F (2,20)=3.627, p=0.045]. Post-hoc tests showed that the Feedback group significantly differed from the Natural group (p=0.014). The Feedback group did not significantly differ from the Feedforward group (p=0.112) and the Feedback and Natural group did not significantly differ from each other (p=0.832). This indicates that in the Feedback group the students communicated less to the each other than in the Natural group.

5.1.2 Performance

Table 5-2 shows the results of the analysis of performance between support styles.

Variable	Natural		Feedback		Feedforward		ANOVA	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	F(2,20)	p-value
Final Quiz	22.3	4.4	24.4	3.2	23.9	3.4	0.647	0.534
Total Task Quiz	21.3	5.0	18.7	3.9	19.8	2.9	0.858	0.439
Navigation Performance Score	0.45	0.15	0.48	0.07	0.44	0.14	0.180	0.836
Missed Essential Pages	128.8	25.4	139.3	33.3	135.8	36.2	0.199	0.821
Extra Pages	53.3	38.0	33.9	20.0	49.2	30.9	0.89	0.426
Positives	199.9	26.9	190.7	33.3	194.3	36..2	0.147	0.864

Table 5-2 Performance and ANOVA results per support style.

No significant changes were found between the different assigned support styles and the performance measures.

5.1.3 Emotional State

Variable	Natural		Feedback		Feedforward		ANOVA	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	F(2,20)	p-value
Combined ES								
Difference	-3.29	3.15	-0.5	138	-0.5	3.50	2.257	0.131
Absolute Difference	8.4	3.6	4.8	1.7	6.8	3.9	2.488	0.108
Valence								
Sum Dif	-1.6	2.1	-0.38	2.00	-0.13	1.96	1.061	0.365
Sum Abs. Dif	4.42	3.36	2.63	2.77	3.88	2.70	0.755	0.483
Arousal								
Sum Dif	-0.14	1.35	0.38	2.13	-0.88	1.88	0.933	0.410
Sum Abs. Dif	2.71	1.60	2.13	2.30	3.63	2.97	0.799	0.464
Dominance								
Sum Dif.	-0.86	0.90	-0.50	1.93	0.5	1.07	1.950	0.168
Sum Abs. Dif	4.86	1.68	2.75	2.12	2.50	1.51	3.809	0.040*

Table 5-3 Emotional State results per Support Style. The * indicates p <0.05.

The absolute difference in dominance for the three groups based on style was significant [F(2,20)=3.809, p<0.05]. Post-hoc tests showed that the Feedback and the Feedforward group significantly differed from the Natural group (p=0.024 and p=0.020, respectively), no significant difference was found between the Feedback and Feedforward group (p=0.783). This indicates that the perceived dominance of the students in the Natural group changed more during their tasks than in the Feedback and Feedforward group. Thus, in the natural style during a task they sometimes felt dominated and sometimes felt more in control. While in the structured styles (i.e. Feedback and Feedforward) the dominance variable changed less.

5.1.4 Cognitive Task Load

Table 5-4 shows the results of the analysis of Cognitive Task Load between support styles.

Variable	Natural		Feedback		Feedforward		ANOVA	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	F(2,20)	p-value
Combined CTL								
Difference	14.0	13.7	7.9	11.5	8.1	14.0	0.513	0.606
Absolute Difference	21.6	10.7	18.9	6.7	18.7	12.8	0.182	0.835
Level of Information processing								
Sum Dif.	7.3	5.6	5.51	6.1	3.3	4.3	1.056	0.366
Sum Abs. Dif.	3.4	6.5	1.1	8.3	1.9	5.6	1.045	0.370
Task Set Switches								
Sum Dif.	2.1	2.8	0.6	6.6	0.7	4.2	0.218	0.806
Sum Abs. Dif.	10.1	3.6	8.1	5.0	6.8	4.8	1.922	0.172
Time Occupied								
Sum Dif.	3.4	6.5	1.1	8.3	1.9	5.6	0.214	0.809

Sum Abs. Dif.	8.0	5.1	10.1	3.0	6.9	5.1	1.071	0.361

Table 5-4 Cognitive task load results per Support Style

No significant changes were found between the different assigned support styles and the Cognitive Task Load variables.

5.2 Results per task and Discourse Analysis

The following results are based on the analysis of the discourse analysis and other outcome measures per task. The categories Quiz Question (QQ) and Quiz Answers (QA) are not shown since these categories were obligated during the tasks. Furthermore no acknowledgements (A) were sent between the students, thus these are also not shown in the results.

5.2.1 Navigation Performance

Messages	B	P	R2	Messages	B	p	R2
Sent to Instructor				*Received from Instructor*			
Total	-0.008	0.011*	0.035	Total	-0.007	0.001*	0.059
SS	0.001	0.923	0.000	SS	0.010	0.132	0.012
TI	-0.063	0.013*	0.034	TI	0.006	0.733	0.001
R	-0.024	0.109	0.014	R	-0.034	0.000*	0.066
A	-0.029	0.035*	0.024	A	-0.056	0.081	0.017
FF	-0.045	0.517	0.002	FF	-0.011	0.023*	0.028
FB	-0.028	0.730	0.001	FB	0.002	0.798	0.000
LR	-0.037	0.000*	0.068	LR	-0.045	0.067	0.018
Sent to Student				*Received from Student*			
Total	-0.008	0.049*	0.021	Total	-0.008	0.097	0.015
SS	-0.037	0.024*	0.028	SS	-0.007	0.646	0.001
TI	-0.266	0.079	0.017	TI	-0.363	0.009*	0.193
R	-0.063	0.173	0.010	R	-0.174	0.418	0.004
FF	-0.310	0.148	0.011	FF	0.252	0.240	0.008
FB	-0.335	0.027*	0.027	FB	-0.252	0.239	0.008
LR	-0.051	0.181	0.010	LR	-0.041	0.318	0.005

Table 5-5 Navigation performance and discourse categories. The * indicates p <0.05.

The number of sent messages to the teacher showed a negative relation to navigation performance (B=-0.008, p=0.011, R2=0.035). So when a student sent more messages his performance became lower. The number of sent messages to the teacher in the category “Technical Issue” (TI) and “Learning Related Questions” (LR) also showed a negative relation with navigation performance (respectively, B=-0.063, p=0.013, R2=0.034 and B=-0.037, p<0.001, R2=0.068). Thus, when a student sent more messages of either category it is a sign of lower performance.

When receiving messages from the teacher the total amount of received messages showed a negative relation with navigation performance (B=-0.007, p<0.001, R2=0.059). This indicates that when a student receives more messages from the teacher the performance is lower. Furthermore, the received sentences in the “Feedforward” category also showed a negative relation with performance (B=-0.007, p<0.025, R2=0.028).

When looking at the communication between the students and performance, there is a significant negative relation between the receiving of “Technical Issues” (TI) and performance (B=-0.363, p<0.009, R2=0.193). Thus, when a student receives more “Technical Issue” statements the performance was lower.

A significant relation was found between sending messages and navigation performance (B=-0.008, p=0.049, R2=0.021). Furthermore there is a negative relation between sending messages from the categories “Social Statements” (SS) and “Feedback”(FB) to the other student and performance (respectively, B=-0.037, p=0.024, R2=0.028 and B=-0.335, p=0.027, R2=0.027). This indicates that when sending more messages (of certain categories) to the other student performance is lower.

5.2.2 *Emotional State*

Messages	B	P	R2	Messages	B	p	R2
Sent to Instructor				*Received from Instructor*			
Total	0.052	0.080	0.129	Total	0.080	0.000*	0.081
SS	0.127	0.228	0.008	SS	0.163	0.012*	0.034
TI	-0.311	0.200	0.009	TI	-0.293	0.124	0.013
R	0.234	0.120	0.013	R	0.123	0.205	0.009
A	0.124	0.380	0.004	A	0.485	0.138	0.012
FF	0.806	0.246	0.007	FF	0.051	0.276	0.007
FB	-0.121	0.884	0.000	FB	0.284	0.000*	0.080
LR	0.143	0.176	0.010	LR	0.398	0.116	0.014
Sent to Student				*Received from Student*			
Total	-0.009	0.819	0.000	Total	-0.025	0.594	0.002
SS	0.231	0.161	0.011	SS	0.205	0.200	0.009
TI	0.604	0.640	0.001	TI	0.601	0.782	0.000
R	0.385	0.411	0.004	R	0.496	0.271	0.007
FF	-0.103	0.908	0.000	FF	1.607	0.458	0.003
FB	2.612	0.227	0.008	FB	0.601	0.782	0.000
LR	1.615	0.293	0.006	LR	0.284	0.497	0.003

Table 5-6 Relation between discourse categories and changes in ES. The * indicates p <0.05.

Sending messages to the instructor did not show a significant relation with changes in ES (p>0.05).

The total number of messages received from the instructor however did show a significant relation (B=0.080, p<0.001, R2=0.081). Thus, when a student received more messages from the instructor the ES of the student became higher. Furthermore messages from the instructor in the “Social Statements” (SS) and “Feedback” (FB) categories showed a significant relation with changes in ES (respectively, B=0.163, p<0.012, R2=0.034 and B=0.284, p<0.001, R=0.080). Thus, when receiving more messages in the “Social Statements” or “Feedback” category during a task the ES value became higher.

The messages sent or received between the student did not show any significant relation with ES (p>0.05).

5.2.3 *Cognitive Task Load*

Messages	B	P	R2	Messages	B	p	R2
Sent to Instructor				*Received from Instructor*			
Total	0.089	0.076	0.017	Total	0.155	0.000*	0.108
SS	0.162	0.363	0.005	SS	0.200	0.067	0.018
TI	0.368	0.398	0.004	TI	0.334	0.298	0.006
R	0.112	0.660	0.001	R	0.289	0.083	0.016
A	0.709	0.030	0.049	A	1.098	0.045*	0.022

FF	0.878	0.453	0.003	FF	0.387	0.000*	0.130
FB	2.123	0.129	0.013	FB	-0.179	0.154	0.011
LR	0.182	0.306	0.006	LR	0.398	0.116	0.014
Sent to Student				*Received from Student*			
Total	-0.017	0.806	0.000	Total	-0.077	0.330	0.005
SS	0.395	0.155	0.011	SS	-0.082	0.761	0.001
TI	-0.824	0.750	0.001	TI	0.632	0.734	0.000
R	-0.980	0.214	0.008	R	-0.977	0.197	0.009
FF	5.213	0.152	0.011	FF	-0.820	0.822	0.000
FB	3.220	0.212	0.009	FB	0.601	0.782	0.000
LR	-0.070	0.914	0.000	LR	0.284	0.497	0.000

Table 5-7 Relation between changes in CTL and discourse categories. The * indicates $p < 0.05$.

The total number of messages sent to the instructor showed no significant relation with changes in CTL. The number of received “Acknowledgements” (A) did show a positive relation with CTL (B=0.709, p=0.030, R2=0.049). This indicates that when sending acknowledgements to the instructor the CTL became higher.

The number of received messages from the instructor also shows a significant relation with changes in CTL (B=0.155, p<0.001, R2=0.108).There was a significant relation ship between messages received from the instructor in the categories “Acknowledgements” (A) and “FeedForward” (FF) and changes in CTL (respectively, B=1.098, p=0.045, R2=0.022 and B= 0.387, p<0.001, R2=0.130). Thus, when receiving more messages from the instructor in either category the Cognitive Task Load became higher.

5.3 Debriefing Results

Almost all the participants felt like they were able to perform the tasks assigned to them (e.g. instructor/student role). Furthermore they felt able to fill in all the required questionnaires and had no problems with understanding English exercises.

The working of the chat was the main annoyance during this experiment. Although a completely new chat was created for this experiment, since the previous chat was not working properly, the new chat still had some problems of not showing when a new message was received and not automatically scrolling down. Due to this problem some of the participants missed out or found out later that there was important information in the chat window. It must be pointed out that the problems of the chat were explained during the introduction, but still many participants found it very disturbing.

6 Conclusion & Discussion

This chapter describes the conclusion and discussion of this experiment. The results regarding the different support styles and discourse analysis are discussed. Furthermore the limitations of the research method and indications for future research are mentioned.

6.1 Support Styles

One of the objectives of this experiment was to determine the optimal support style (Feedback, Feedforward and Natural) for an instructor in a collaborative training task during a long duration mission. Three factors were taken into consideration: performance, workload and emotional state, as they appear to be important factors during long duration missions. The support style that had the best results for these three factors was considered as the optimal support style.

Persons in the Natural group showed more changes in emotion during the task than persons in the structured styles. Both structured support (Feedback and Feedforward) styles were similar in CLT, ES and performance. However, the amount of communication between students was different between the structured styles. Persons in the Feedforward group showed more communication with their instructor than persons in the Feedback group. Therefore it can be concluded that the Feedforward style is the best style for an instructor during a collaborative training task since extensive communication in collaborative learning usually is better for performance. This conclusion is discussed in more detail in the following sections.

6.1.1 Performance, emotion and workload

The only significant difference between the support styles were the changes in emotional state (especially the dominance factor). Compared to the structured support groups, persons in the Natural group showed more changes in dominance during the task. This indicates that persons in the Natural group felt in control at the start but not at the end of the task, or vice versa. Thus, the experience of control changed more in the Natural group than in both structured groups. Since Kanas and Manzey (2003) indicated that changes in mood (i.e. emotion) can lead to lower performance during a mission, we can conclude that an instructor during a collaborative training task can best use a structured support style (e.g. Feedback or Feedforward).

An unexpected finding was that the performance and workload of the students did not differ between the support styles. This is in contrast with findings of Sengupta and Abdel-Hamid (1993) and Arnold et al. (2006) as they found that Feedforward and Feedback were associated with favourable outcomes regarding workload/performance. This discrepancy in research findings may be the result of a low number of participants in the present study as we could only include 7 or 8 persons per group. Arnold et al. (2004) evaluated the support styles with approximately 40 students per style.

Furthermore, the task itself might have been too uncomplicated (i.e. too little choices for the user). Persons had only a few real choices (i.e. which procedure steps to follow) during the learning and execution of the task and most of the tasks could be performed without the support from the instructor. In the Cardiopres learning environment every procedure step was a follow up to the previous step. However, it has to be noted that even in the Cardiopres learning environment the students made a lot of mistakes.

A different payload with more simulations and procedures might be better suited to train real procedures. The students would be really learning the procedures and performing the procedures they had learned directly in the environment. This was not the case with Cardiopres payloads, only some parts of the procedure were applicable in the simulated Cardiopres. A better virtual simulation will improve the complete understanding of the Cardiopres. Furthermore a different payload can have more specifically defined choices in the scenario.

6.1.2 Communication

An unexpected finding was that the students in the feedback style communicated less to each other than students in the other support styles. This might be due to the fact that the instructor in the experiment had a more reactive role and therefore communicated less than in the other groups. More communication might be preferred between the students since this may improve performance (Aronson et al., 1979). The influence of communication will be discussed in the following section.

6.2 Discourse Analysis

Several indications of changes in performance, emotional state and cognitive task load were found in relation to the use of certain discourse categories. This confirms the fact that discourse analysis can be used to predict performance in a collaborative training task. Furthermore, discourse analysis can be used to monitor or at least gain insights in the state of astronauts and can be used as an observation method by the MECA ePartner. The following sections discuss which discourse categories lead to different performance, workload or emotional state values.

6.2.1 Performance

The number of sentences received and sent to the instructor showed a negative relation with performance. Thus, receiving or sending of messages was associated with a lower performance. This is in contrast with the assumption that the use of statements would improve information sharing and, thereby, performance (Wang, Newlin & Tucker, 2003; Bowers et al., 1998). It is, however, in line with the assumption of Bluemink et al. (2004) and Morukov et al. (2009); when someone is able to perform a task, less support is needed which may be reflected by less communication between student and instructor. This is likely to be the case because the learning environment was easy to use by the students and most communication acts were made when a student made a mistake and needed help from the instructor.

The fact that communication acts of the student were mostly made when the student needed help becomes more evident when looking at the discourse categories used. It is especially the communication with the instructor and with the usage of discourse categories such as “Learning Related Questions” and “Technical Issues” when the performance was lower. Thus, any information sharing between instructor and student was only needed to correct mistakes made by the students. For this reason it is clear that communication between student and instructor indicates problems with the task.

From the assigned instructions to the instructor it also follows that communicating is a sign of lower performance. The instructor, especially in the Feedback group, only communicated when a student made a mistake. When a student made no mistakes during the task, the instructor did not say anything. Although some positive feedback (i.e. communicating that someone has performed the task well) was given during the task as well, this was given less than negative feedback.

The amount of “Social Statements” sent to the other student also showed a negative relation with performance. This may be explained by the fact that such statements do not have a direct link with information sharing and therefore will not positively influence performance, but will only be a distraction from the learning task.

Finally, it is important to note that in more difficult tasks, in which more sharing of information is needed, different relations might be found. In such a case the need for information sharing with the other participants might be more important than the actual need of support from an instructor.

6.2.2 Emotional State

The number of messages received from the instructor influenced the ES in a positive way (i.e. higher arousal, valence or dominance). Thus, when receiving more messages the ES of the participants became more positive. Especially when receiving more “Social Statements” the ES became higher. This is in line with the findings of Kanas, Gushin and Yusupova (2008); the amount of social statements is positively related to the emotional state of an astronaut.

6.2.3 *Cognitive Task Load*

The receiving of messages showed a positive relation with CTL. Thus, when more messages were received, the workload became higher. This may be explained by the fact that when someone is receiving more messages they usually make more mistakes. Hereby the student creates more work that has to be done in the same time, thus increasing the workload.

The connection between number of sentences received and CTL can also be explained by the problems with the chat. Since most students found the usability of the chat low, the higher CTL can be caused by having to work with the chat and therefore has less to say about the performance on the learning task.

6.3 Generalizability

The results from this thesis are applicable to any collaborative training task with a similar structure. However, the structure of each task may influence the importance of different discourse categories. Therefore, the setup of the task should be evaluated as well, when comparing the results with other experiments. For example when information sharing is necessary for task completion, more communication between the instructor and the student will probably improve performance. Furthermore, some of the measures (i.e. ES and CTL) are less important in a general environment than in an aerospace context. The results on performance however are also applicable and useful in other environments.

The role of long-term isolation is not the objective of this thesis. It is expected that isolation plays a crucial role within groups (Kanas & Manzey, 2003). Changes in discourse might also be caused by the long-term isolation and not by the mood or workload of an astronaut. The specific influence of prolonged isolation on the discourse between subjects is still unknown. These effects can be analyzed during the MECA Mars-500 experiment.

6.4 Measurements

Several issues regarding the measurements used are discussed in this part. The method of manually processing the chat logs is very time consuming and mistakes can be made during manually processing. Automatic processing of these files will give more reliable and faster results, although a large dataset will be needed to perform automatic processing.

The personal data found during this experiment was based on the subjective feelings of the participants. Participants judge their own ES and CTL; this cannot always be trusted and might influence the results. Different methods of gathering the state of a subject need to be investigated. Especially less intrusive methods are useful since these are less subjective and can be used more frequent (e.g. recording facial expressions during the MECA Mars-500 experiment). Discourse analysis can be a new way to find out about the ES/CTL of participants, although more specific research is needed.

Furthermore, recording and evaluating all communication between astronauts, even if it is only during scheduled tasks, might not be appreciated by the astronauts. Recording all the communication between the astronauts might not be considered ethical and an invasion of privacy. Since this is an extreme environment and most communications are already logged, this also might not be an issue.

6.5 Future Research

This section describes interesting findings that may be studied further. The first effect that might be analyzed further is the finding that during the feedback style, the students did not communicate to each other. When in an environment where more information and information sharing is needed, this may be more important. It might be interesting to study whether the feedback support style will still have the same effect on between students communication in such an environment.

6.5.1 *Personal Effects*

For further improvement of support and monitoring of astronauts personal effects should also be taken into consideration. Each person might be different in his needs for support. These personal factors have not been analyzed during this experiment. Some people might react different on certain support styles or discourse categories. This can be investigated in the Mars-500 experiment in which people are performing the COLT-sessions over a longer period of time. This experiment will gather more data about the performance and emotions of the astronauts.

Furthermore, it may be interesting to examine whether the student's expectancies of support style influence the behavior (Horii, Jin & Levitt, 2005). Therefore, the structured support styles might be of better use. Although knowing when the teacher will do something might make the students rely more on the teacher and therefore forget to learn the procedures.

As already mentioned, personal preferences play a role, but also the background of the user is of importance. If a user is more experienced, he needs different support during each task than not experienced users. Therefore experienced users may prefer different support styles. Furthermore, a more experienced teacher can give better explanations during each task. For this reason it might be useful to have longer sessions with the participants and see whether this influences the behavior. Different combinations of support and participants are worth researching.

6.5.2 High performance

Performance is crucial in the space domain. Astronauts' tasks are very strict since even a small error can have enormous consequences. Although this was not integrated in this approach, a next experiment might address this factor more. Furthermore, the focus must be on making sure the students are performing as good as possible and seeing what kind of methods can be used to ensure error free performance. This can also be done in combination with the expert/experienced users and the novice/less experienced users.

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Appendix A. Java Programs

Compare.java

```java
import java.io.BufferedReader;
import java.io.FileReader;
import java.io.IOException;
import java.util.*;
/**
 * Compares the processed logfile to the reference logfile.
 * @author Jimmy Boschloo
 *
 */


public class Compare {
	int Positives,Extra,Missed,chatsentences=0;
	int Statement,
ES_Val,ES_Ar,ES_Dom,CTL_tss,CTL_lip,CTL_toc,CTL_Tot,ES_Tot=0;
	ArrayList<Integer> EmotionalStateArray = new ArrayList<Integer>();
	ArrayList<Integer> CTLArray = new ArrayList<Integer>();
	ArrayList<Integer> Q4Array = new ArrayList<Integer>();
	ArrayList<String> ReferenceArray;


	public static void main(String[] args) {

			Compare Test;
			Test = new Compare();
			String Testfile = "";
			String ReferenceFile="";
			Test.ReadLogFiles(ReferenceFile);
			Test.CompareLogFiles(Testfile);
	}

		/**
		 * Creates a new Compare datastructure.
		 */

		public Compare(){
				Statement = ES_Val
=ES_Ar=ES_Dom=CTL_tss=CTL_lip=CTL_toc=CTL_Tot=ES_Tot=0;
				EmotionalStateArray = new ArrayList<Integer>();


			}

	/**
	 * Reads the important lines of the reference log and stores them in
ReferenceArray[]
	 *
	 *
	 */
	void ReadLogFiles(String Referencefile){
		BufferedReader in;
		String line;
		try{
			in = new BufferedReader(new FileReader(Referencefile));
			ReferenceArray = new ArrayList<String>();
			while((line = in.readLine()) != null) {
				ReferenceArray.add(line);
			}
		}
		catch (IOException e) {
			System.out.println(e);
		}
```

```
	}
	/**
	 * Reads in the logfile and compares it with the lines in
ReferenceArray
	 * @param testPath
	 */
	void CompareLogFiles(String testFile){
		BufferedReader in;
		String line;
		int temp;
		try{

			in = new BufferedReader(new FileReader(testFile));

			/**The lines from the logfiles are checked. ES/CTL/CHAT
lines are processed by their Method,
			 * the lines containing procedure steps are compared to
the referenceArray
			 * They are considered a Positive or an Extra.
			 * When all the lines of the logfiles have been checked
the remaining lines in
			 * the reference array are the Missed lines.
			 */
			while((line = in.readLine()) != null) {

				temp= ReferenceArray.indexOf(line);
				if(ChatLine(line)){
				chatsentences++;
				}else{
					if(ESCTLVar(line)){
					}else{
						if(Questionnaire4(line)){
							}else{
							if( temp>-1){

	ReferenceArray.remove(temp);
								Positives++;

							}else{
								Extra++;

//System.out.println("Extra" +line);
							}
						}
					}
				}
			}
				Missed = ReferenceArray.size();
			}

		catch (IOException e) {
			System.out.println(e);
		}
	}


	/**
	 * The following get-methods are used to request the variable.
	 */

	void getES(){

	System.out.print(EmotionalStateArray.get(0)+","+EmotionalStateArray.g
et(EmotionalStateArray.size()-1)+",");

	}
	void getCTL(){
		if(CTLArray.size()>0){
```

```
	System.out.print(CTLArray.get(0)+","+CTLArray.get(CTLArray.size()-
1));
	}
	}

	int getSentences(){
		return chatsentences;
	}
	int getPositives(){
		return Positives;
	}
	int getExtra(){
		return Extra;
	}
	int getMissed(){
		return Missed;
	}




	boolean ChatLine(String line){
		return line.indexOf("INFO: Adding message '") > 1;
	}
	boolean Questionnaire4(String line){
			if(line.indexOf("q6_ 1 = ")>-1){

	System.out.print(Character.digit(line.charAt(line.length()-
1),10)+",");
					return true;
					}
			return false;
			}



	/**
	 * ESCTLVar method adds the ES/CTL lines to their respective
variable.
	 *
	 *
	 */

	boolean ESCTLVar(String line){


		if(line.indexOf("Emotion_Valence =") > -1){
			ES_Val =
Character.digit((line.charAt(line.indexOf("Emotion_Valence =") + 18)),10);
			ES_Tot=ES_Tot+ES_Val;

			//System.out.println(ES_Val);

			return true;
		}
		if(line.indexOf("Emotion_Arousal =") > -1){
			ES_Ar =
Character.digit(line.charAt(line.indexOf("Emotion_Arousal =") + 18),10);
			ES_Tot=ES_Tot+ES_Ar;

			//System.out.println(ES_Ar);
			return true;
		}
		if(line.indexOf("Emotion_Dominance = ") > -1){
			ES_Dom
=Character.digit(line.charAt(line.indexOf("Emotion_Dominance = ") +
```

```
20),10);
                        ES_Tot=ES_Tot+ES_Dom;
                        EmotionalStateArray.add(ES_Tot);
                        //EmotionalStateArray.add(ES_Tot);
                        ES_Tot=0;
                        return true;
                }
                if(line.indexOf("CTL_lip = ") > -1){
                        CTL_lip =(Character.digit(line.charAt(10),10));
                        CTL_Tot = CTL_Tot + CTL_lip;
                        return true;
                }
                if(line.indexOf("CTL_tss = ") > -1){
                        CTL_tss =(Character.digit(line.charAt(10),10));
                        CTL_Tot = CTL_Tot + CTL_tss;

                        return true;
                }
                if(line.indexOf("CTL_toc = ") > -1){
                        CTL_toc =(Character.digit(line.charAt(10),10));
                        CTL_Tot = CTL_Tot + CTL_toc;
                        CTLArray.add(CTL_Tot);
                        CTL_Tot = 0;
                        return true;
                }else
                        return false;


        }


}
```

ReadLogFile.java

```
import java.io.*;
import java.util.*;


public class ReadLogFile {
        /**
         * ReadLogFile was used to get the important lines out of the
logfiles and creates
         * new logfiles for each task.
         *
         */
        //String openfile = "StudentAlpha";
        File file;
        BufferedReader in;
        ArrayList<String> Bestand;
        public static void main(String[] args)
        {
                String StartPath ="";
                String openfile ="";
                int Group =0;

                ReadLogFile Test = new ReadLogFile();
                Test.readTags(StartPath, Group, openfile);

        }

        public ReadLogFile(){

        }

/**
 *
 * readTags is the actual method that creates new logfiles that can be
compared.
 *
```

```
 *   */
      public void readTags(String StartPath, int Group, String openfile){

            String line="";
            PrintWriter output = null;

            try {
                  in = new BufferedReader(new FileReader(StartPath+"Group
1/StudentOne "+openfile+".log"));
                  file = new File(outPutMap(StartPath,Group) + openfile+
"test.log");
                  output = new PrintWriter(new FileWriter(file));
                  int begin = 0;
                  while((line = in.readLine()) != null) {
                        begin=begin+1;
                        {if(line.indexOf("URL Click: Task Panel >") > -1){

                              output.println(line.substring(line.length()-
45, line.length()-1));


                        }
                        if(line.indexOf("[QuestionnairePanel.saveToKb] - ")
> 1) {
                              output.println(line.substring(61,
line.length()));
                        }

                        int tempChat = line.indexOf("INFO: Adding message
'");
                        if( tempChat> 1) {
                              output.println(line);
                        }
                        //Creating a new file, since a new cardiopres has
been opened.
                        if(line.indexOf("INFO: Executing scheduled task
action: 'COLT (Student mode) - Cardiopres'") > 1) {
                              System.out.println((outPutMap(StartPath,
Group) +openfile+line.substring(105, line.length() - 20)+".log"));
                              output.close();
                              file = new File(outPutMap(StartPath, Group)
+openfile+line.substring(105, line.length() - 20)+".log");
                              output = new PrintWriter(new
FileWriter(file));

                        }
                        if(line.indexOf("[LogManager.log] Button: Task Tab
> Level Down") > 1) {

                              output.println("Level Down");
                        }
                        if(line.indexOf("[LogManager.log] Checkbox: Task
Tab > true") > 1) {

                              output.println("Checked Procedure");}
                        }
                        int temp = line.indexOf("Display option: Control
Panel Tab >");

                        if( temp > 1) {
                              output.println(line.substring(temp+36,
line.length()));
                        }
                  }
                  in.close();
                  output.close();

            }catch (IOException e) {
                        System.out.println(e);
```

```
                }



        }
        /**
         * The methods were used for finding the correct output and input map
         *
         */
        public static String outPutMap(String StartPath, int Group){
                return StartPath + "Script 1/Group " + Group +"/";
        }
        public static String StartPathRead(String StartPath, String openfile,
int Group){
                return StartPath+"Group "+ Group+ "/" + openfile+"Chat.log";
        }

}
```

Appendix B. Instruction documents

B.1. Feedback

As a teacher your role is to guide the Students through the learning environment. You should do this using the Roadmap provided in the Colt Assignments- document.

You should only communicate to a student in the following cases:

- On **start up** of the Learning Environment (Starting from the timetable)
- **Answer** a question form the students
- The student **deviates** from the roadmap
- The student **forgets** to press a green link in the documentation
- The student has performed the correct actions mentioned in the Roadmap
- When **stated** in the roadmap (in the case of an event)
- To **ask** the quiz questions to the students.
- On **quiz completion** send the correct answers to the students.

B.2. Feedforward

As a teacher your role is to guide the Students through the learning environment. You should do this using the Roadmap provided in the Colt Assignments- document.

You should only communicate to a student in the following cases:

- On **start up** of the Learning Environment (Starting from the timetable)
- **Answer** a question from the students
- Before each step in the Roadmap remind the students to do this step. (e.g. Learn the Unstow Main Unit component – procedure, also tell them to press the green links in the procedures)
- When **stated** in the roadmap (in the case of an event)
- To **ask** the quiz questions to the students.
- On **quiz completion** send the correct answers to the students.

B.3. Natural

As a teacher your role is to guide the Students through the learning environment. You should do this using the Roadmap provided in the Colt Assignments- document.

- Always **make sure** the student has opened the correct Procedure, Cardiopres.
- Always **make sure** the students press the green links in the COLT procedures and the different green links in the COLT documentation.
- Always **make sure** the students follow the right order of learning (follow the roadmap).
- **Initiate** the events mentioned in the roadmap
- Always **make sure** the students try to solve the events initiated by you.
- Try to answer the students' questions as best as you can.
- When the timer is finished, ask the questions to the students as given in the Questions part of the session.
- On **quiz completion** send the correct answers to the students.