Do Individuals with Low Cognitive Control Benefit from Digitised Support?

An individual differences study on workload, situational awareness, performance and communication

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Abstract

Cognitive control serves goal directed behaviour and entails the ability to 1) inhibit dominant or prepotent responses, 2) switch between tasks and mindsets and 3) update working memory. Previous research on individual differences in cognitive control and task performance mainly focused on finding relations between these different components of cognitive control and rather abstract experimental tasks.

In contrast, in this thesis an applied method is adopted. To investigate the relation between individual differences in cognitive control and experienced workload, situational awareness (SA), performance and communication in an online coordination task, I joined the running "Commander Zone Management system" project of Thales Netherlands in cooperation with TNO. Sixteen participants performed a coordination task, in which they had to remotely coordinate and support three groups of gold prospectors. Participants performed the task twice: once supported by a paper map and once supported by a digitised support system providing up to date information about the current location of each group.

The results suggested that, first, people with low cognitive control benefit from a digitised support system regarding experienced workload. Second, people with high switching capacity communicate more (but shorter) when incidents occur in the paper map condition, leading to better performance. Third, there were indications that digitised support as well as a high inhibiting capacity are associated with a higher level of SA in general and especially with the level of SA concerning the projection of future actions of elements in the environment.

Due to some complications during the experiment some results remained unexplained or less interpretable. However, the results from this study clearly show the importance of including individual differences in cognitive control in future development of support systems and future studies on high workload situations.

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Last but not least, I would like to thank my parents and sisters for their unconditional support and faith and my boyfriend Victor for his understanding, loving and for any emotional support. Without them to turn to, I would not have succeeded.

Preface

In the course of obtaining my bachelor's and master's degree in *Cognitive Artificial Intelligence* (CAI) my natural interest converged to human performance, in particular human decision making. Possibly, this appears to be in conflict with my choice of education, but the opposite is the case.

Somewhere between my first year of the bachelor's program of CAI and today I read a column in a AI magazine[1] in which the author addressed a familiar uncomfortable situation in which a CAI student is asked what it is he or she is studying; saying *Cognitive Artificial Intelligence* has never been enough. As the column's author illustrated, at a family dinner (of your beloved) you are often sitting quietly in a corner, hoping that nobody will ask you about your education. Inevitably, someone will and you will have to try stutter your reddened head through an answer. The questioner's first response is usually either a rather tiresome joke like "Really, 'd you mind giving me some of that artificial intelligence?" or "So you are artificially intelligent?", or they think it sounds very interesting, but never really heard of it before. One way or another, it always results in the follow-up question: "So, then what... do you do?". The conclusion of this column: CAI students are faced with a problem of self-definition. There are students who, after some failures, settle with "Yeah, something with computers...". I usually adopted the other method, namely summing up the different disciplines of CAI (computer science, but also (!) logics, linguistics, psychology and a significant part of philosophy) followed by an awkward silence.

In fairness, I have to admit I still suffer from some kind of self-definition problem. However, in the course of the master programme three factors cleared the sky. First, as you had been told in the first week of CAI: it became clearer the further I got; pieces fell into place. Second, although my enthusiasm level for philosophy is relatively low, the material of the course Philosophy of AI: *Artificial Intelligence: A Philosophical Introduction* by Jack Copeland (Copeland, 1993), explains in clear language what it is we are doing in the field of artificial intelligence. Copeland addresses classical AI related issues regarding the differences between humans and computers and the extent to which we are interchangeable. I do not intend to step on thin ice and start the discussion on whether humans are machines or machines can be(come) 'one of us', but I do want to convey the importance of this book for my personal understanding of CAI. In addition, this book triggered (among other things) my interest for the differences between humans and machines and particularly my interest in getting the best of both entities by having them work together. Third, in my second year of the master programme I did a research internship at TNO and my graduation project was carried out at the D-CIS Lab / Thales Research & Technology. The internship as well as my thesis involved this cooperation between humans and machines and by now I am glad I can provide these two projects to illustrate the purpose of CAI, or at least what I believe is its purpose.

Of course the relevance of a research project for any scientific field cannot be conveyed or explained, when the scientific field does not know how to define itself. Forgive my personal existential history on this matter, but it does serve a purpose, namely the purpose of this thesis. This thesis serves the field of CAI in two ways.

[1] I do not recall the magazine (possibly *De Connectie*) nor the author and was unable to find it.

First, it provides insights about the human nature and second, these insights form a stepping stone towards developing intelligent (decision support) systems enhancing human computer interaction. The more is known about our own nature, the more we know about how we can be supported best. This thesis is only a beginning of the trajectory of enhancing human machine cooperation. The aim of this thesis is to provide insights about individual differences and thereby to contribute to the (future) development of adaptive intelligent machines that account for these differences and can respond to that by providing personal support.

– Enjoy the read.

Contents

1 Introduction

Decision support systems are flourishing. Think of car navigation systems, which have become seemingly indispensable or the autopilot in the cockpit of an aircraft, making human pilots almost redundant. These decision support systems are supposed to make life easier. But what happens though, when the road is blocked due to construction (without the system knowing) or the autopilot fails? These are the situations that require human interpretation, flexibility or possibly some human emotions. Some tasks are much better performed by humans than by machines and if we want machines to support us properly it should be clear what it is we are good at (and what it is machines are good at) and to what extent we want machines to take over.

Ideally, automated support systems should complement human performance (as opposed to replacing it). However, for some people or in some situations there is more to complement than for others. Some people might benefit more from a certain level of automation than others do. If this is the case, the automated support system should be designed properly. That is, a higher level of automation should alleviate the operator's workload without excluding the operator. The operator has to be part of the operational loop and has to be included in the machine's automated actions to guarantee intervention when problems occur and some human interpretation/flexibility when the *"computer says no"*[2]. For instance, when the car navigation systems fails, the driver should at least know its whereabouts and when the system tells you the road in front of you does not exist the driver should conclude that it does (and possibly adjust its goals). These issues become particularly important when the supposed support systems are intended to support individuals when time is critical and the decisions that have to be made can have serious consequences.

The aim of this thesis is to investigate individual differences with regard to the extent that automated support is beneficial for performance. This will be investigated in a high workload situation requiring problem solving, multitasking, novel situations and adequate and appropriate actions in limited time. This situation is assumed to require cognitive control, which can be described as the set of abilities that serve goal directed behaviour (especially in non-routine situations). Therefore, the main goal of this thesis is to investigate whether individual differences in cognitive control are related to the level of automated support (no automation or partial automation) that is beneficial for performance. That is, the main research question will be whether individuals with low cognitive control benefit (more) from automated support than people with high cognitive control and this will be investigated with respect to experienced workload, situational awareness (SA), task performance and communication in a high workload situation.

To investigate the individual differences in cognitive control in relation to automated support, I joined the running research project of Thales Netherlands in cooperation with TNO[3], called Commander Zone Management system (henceforth "CZ-man"). The complete method and results of the CZ-man project can be found in the project report (Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011).

[2] From the television sketch show *Little Britain.* A bank employee, Carol, refuses to help customers, because the "computer says no"

[3] "Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek" is a Dutch organisation for applied scientific research

This thesis is structured as follows: *section 2* provides an introduction to cognitive control and elaborates further on cognitive control in relation to experienced workload, SA, performance and communication. *Section 3* describes the conducted experiment followed by the results (*section 4*). Finally, the results will be discussed in *section 5* followed by a general discussion and conclusion (*section 6*).

2 Cognitive Control

Daily life asks for the constant processing of incoming information and for adequately acting on it. For instance, approaching and detecting a red traffic light should result in stopping your car. Having the choice between a healthy salad or French fries for lunch should ideally result in choosing the salad. Having a flat bike tire, when you are already late for an exam requires change of (transportation) plans. How adequate these actions are, cannot just be ascribed to motivation or willingness. Individual differences exist as to how well we are able to guide our behaviour towards a specific goal based on the available information.

The set of abilities required to effort-fully guide behaviour toward a goal, especially in non-routine situations, is referred to as *cognitive control* or *executive functioning* (Banich, 2009). Norman and Shallice (1986) outlined five of these non-routine situations in which automatic behaviour does not suffice and conscious control is required to adequately carry out tasks. These situations include (1) situations that involve planning or decision making, (2) error correction or trouble-shooting, (3) situations where responses are ill-learned or contain novel sequences of actions, (4) situations judged to be dangerous or technically difficult or (5) situations that require the overcoming of a strong habitual response or resisting temptation. To deal with these kind of situations attentional control is required for which Norman and Shallice introduced the Supervisory Attentional System (SAS). The SAS modulates performance by conscious, attentional control, by (de)activating appropriate behaviour schemas in accordance with the current goals. The SAS is often compared to the central executive of Baddeley's multicomponent model of working memory (Baddeley, 1986). This multicomponent model consists of, besides the central executive, two "slave" components: a component for auditory input (the phonological loop) and for visual and spatial input (the visuospatial sketchpad). The role of the central executive in this model is to control the information flow in the two slave systems and has, just like the SAS, attentional control on behaviour.

The controlling character that is ascribed to the central executive in Baddeley's model of working memory and the SAS in Norman and Shallice's theory can be compared to cognitive control. However, these earlier theories assumed that the control mechanism was a unitary mechanism, while recent theories shifted to a model with distinct components. That is, recently more and more has become clear regarding the unity or rather the diversity of cognitive control. Three main components of cognitive control have been identified, namely *switching* between tasks or mental sets, *inhibition* of prepotent or automatic responses, and *updating* and monitoring working memory, henceforth "*switching*", "*inhibition*" and "*updating*", respectively. These three components have been found to be clearly distinguishable, yet not independent of each other (e.g., Miyake et al., 2000; Del Missier, Mäntylä & Bruine de Bruin, 2010; Smith & Jonides, 1999).

Previous research mainly focused on distinguishing these three components and finding relations between these components and rather abstract experimental tasks. For instance, low cognitive control has been related to making fewer utilitarian judgements (Greene, Morelli, Lowenberg, Nystrom & Cohen, 2008), a greater endorsement of risky activities and an over-emphasis of the benefits associated with risky activities (Magar, Phillips & Hosie, 2008). Low cognitive control has also been related to impulsiveness (Whitney et al., 2003), which in turn has been related to high working memory load as well, that is, high working memory load contributed to a "myopic" decision making style, characterised by choices being guided by immediate outcomes rather than overall past experiences (Dretsch & Tipples, 2008). Moreover, previous research using the Adult Decision-Making Competence tasks (A-DMC, Bruine de Bruin, Parker & Fischhoff, 2007) found that high cognitive control is related to better decision making competence. High cognitive control has been related to applying decision rules adequately (inhibition and updating), being more resistant to framing (inhibition and updating) and being more consistent in risk perception (switching) (Del Missier, Mäntylä & Bruine de Bruin, 2011).

These studies involved rather abstract experimental tasks, for instance, the A-DMC included tasks in which the participant had to indicate "*the probability that you will have a cavity filled during the next 5 years*" (risk perception) or had to select one player from a list of several DVD players based on the different features and personal preferences (applying decision rules). The relations found by these studies are promising and do serve as an incentive for follow-up research, however the more experimental the set-up, the less the results might be translated to real-life situations, let alone to high workload, non-routine situations. Thus, although the controlled experimental studies are useful in determining the theoretical underpinnings of cognitive control, little is known about the influence of individual differences in cognitive control in the applied field.

In real-life (in routine or non-routine situations) individuals are, more and more, supported by automated systems, of which the sole purpose is to make life easier. Research on how to optimize these systems has mainly focused on the relation between automation and workload (e.g., Young & Stanton, 2007; Thomas, 2011; Parasuraman & Riley, 1997), automation and situational awareness (SA, for an overview see Endsley, 1996) or automation and both workload and SA (e.g., Kaber & Endsley, 2004). Less can be found on studies investigating the role of cognitive control. However, considering previous research, it might be fruitful to include individual differences in cognitive control in the design process of (semi) automated support systems, especially when focusing on those who might benefit from it the most: people with low cognitive control.

Del Missier et al. (2011) summarise three main conclusions that can be drawn from research to date on decision making and cognitive control, namely that:

> “First, EF [(executive functioning)] and working memory processes appear to be more relevant to decision making tasks that require more extensive processing of decision options, their consequences, or other information. (...) [s]econd, decision-making tasks require less executive control when they can be completed using cognitively less demanding strategies, for example when responses are driven by clear "perceptual" patterns or environmental cues (...) [and t]hird, performance on some decision-making tasks may rely more on emotion-related regulation processes.” (p. 2)

Especially the conclusion regarding perceptual patterns and environmental cues (the second conclusion) is of interest when investigating the advantages of digitised support in relation to cognitive control. Difficult tasks require less of the so-called controlled system when responses are driven by perceptual information. For instance, the height of a tower consisting of separate blocks can be better estimated when the blocks are placed on top of each other as opposed to when they are placed next to each other in a square (Kahneman, 2003, see Figure 2.1). Kahneman (2003) argues that this example (among others) serves to establish the dimension of accessibility, that is, the ease or effort with which particular mental contents come to mind.

Two kinds of processes to enable accessibility of mental contents can be distinguished. On the one hand there are processes of the *perceptive* and *intuitive system* which are rapid, automatic, associative and effortless. On the other hand there are processes of the *controlled system*, which are serial, slow, rule-based and effortful. This distinction (also known as dual-processing theories) between different systems and processes is closely related to cognitive control. Where cognitive control "belongs" to the controlled system and automatic behaviour either to the perceptive or to intuitive system. The difference between the perceptive and the intuitive system is that the perceptive system is bound by current stimulation (percepts) and this "restriction" does not apply to the intuitive system. However, in order to invoke the intuitive system, the task has to be intuitive, for instance, learned associations like driving the same route from work to home.

In non-routine situations containing novel sequences of actions, involving planning, trouble-shooting and so on, tasks might not be that intuitive. A digitised support system could provide visual feedback and thereby invoke the perceptive system. As a result less will depend on the controlled system or put differently less cognitive control is required to perform difficult tasks. The supposed gain thus comes from the perceptive system.

The visual feedback, or perceptual cues, have to be relevant though for the current task. For example, consider the example in Figure 2.1 again illustrating the accessibility of specific mental contents. The question "What is the height of the blocks in Figure 2.1.A ?" is easier to answer than "What is the height of the blocks in Figure 2.1.B once you place them on top of each other?". To calculate the height of 2.1.A you will only have to mentally compare the tower with an appropriate scale. To calculate the height of 2.1.B you will first have to mentally place all blocks on top of each other, keep that image in mind, and then compare the resulting tower with an appropriate scale, which will depend more on cognitively controlled processes.

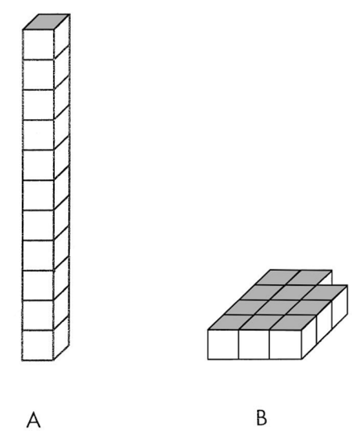


Figure 2.1: **Accessibility example** (from Kahneman, 2003)

Thus, less cognitive control is required when relevant perceptual cues are present. Therefore it is expected that people with low cognitive control will benefit the most from digitised support, because the digitised support system contains more perceptual cues. Individuals with high cognitive control though, can do without the cues and therefore the benefit of the digitised support system is expected to be less strong or absent.

The main goal of the present research is to investigate whether people with low cognitive control benefit (more) from digitised support than people with high cognitive control. To that end it will be investigated how two kinds of support systems, radio communication together with either a traditional paper map or a digitised version of this map providing more up to date information, influence experienced workload, situational awareness (SA), performance and communication. This will be investigated with respect to individual differences in cognitive control in a complex online group coordination task in which the participant will have to remotely coordinate three distributed groups of gold prospectors.

2.1 Cognitive Control and Experienced Workload

Automated systems have found their way into our cars (navigation systems), into the cockpit (the autopilot) and, for instance, into the classroom (calculators). Whether or not automation always improves human performance is questionable (i.e., because of a possible 'out-of-the-loop effect', see section 2.2). However, it does reduce (experienced) workload. This was shown by, for example, a recent study on the effects of increased automation (and feedback of the system's automated actions by means of voice messages) in the cockpit on the pilot's abilities to solve a non-normal event. They found that workload was decreased when a pilot was supported by automated systems and in addition, that there was a preference for partial automation as opposed to full or no automation (Thomas, 2011). Hence, regarding experienced workload some automation is desired, but does this apply to all people and to the same extent?

To the best of my knowledge, less is known about how individual differences in cognitive control are related to experienced workload (in relation to automated systems). Previous research did show that other individual differences play a role. For instance, age was found to influence subjective workload (Bunce & Sisa, 2002). The same result was found regarding personality, for example, neuroticism has been related to frustration (one of the six sub scales of the NASA-Task Load Index of workload) (Rose, Murphy, Byard & Nikzad, 2002). Although these studies do not necessarily relate to individual differences in cognitive control, they do show that experimentally induced workload is experienced differently across different people.

Thus, it can be assumed that the experience of workload is inherent to an individual and therefore that there exist individual differences as to how the induced workload is experienced. It is hypothesised that the level of cognitive control is one of these individual differences. It is hypothesised that people with low cognitive control in general (participants who score low on all three components) will experience more workload than those who have high cognitive control. In a complex task as will be used in this research it is expected that a high switching, updating and inhibiting capacity will result in less experienced workload. It will naturally take people with a high switching capacity less effort to deal with switching between the different kinds of tasks (e.g., communicating with three separate groups, updating the map and keep track of changes in the resources of the groups). It will naturally take people with a high updating capacity less effort to keep an updated image of the current situation (e.g., update information based on the communication). Lastly, it will naturally take people with a high inhibiting capacity less effort to inhibit habitual or automatic responding. Because it will take people with high cognitive control (a high score on all three components) naturally less effort to perform the tasks, it can be expected that they will experience less workload than people with low cognitive control.

In addition, because the presence of (relevant) perceptual cues reduces the level of cognitive control required to perform a task, it can be expected that the support method will affect experienced workload as well. That is, it is expected that mainly people with low cognitive control will benefit from the digitised support, due to the presence of updated perceptual cues, which will result in less dependence on cognitive controlled processes. People with high cognitive control *can* do without these cues and therefore the benefit is expected to be less strong.

2.2 Cognitive Control and Situational Awareness

Situational awareness (SA) has three levels: the first level concerns the perception of elements in the current situation (*perception level*), the second level concerns comprehension of the current situation (*comprehension level*) and the third level concerns projection of future actions of the elements in the environment (*projection level*) (Endsley, 1995).

Gaining information requires perception and attention, conscious or unconscious (think of subliminal perception). As mentioned earlier, perception does not depend, or less, on executive control (Kahneman, 2003). On the contrary, the comprehension and especially the projection level of SA are expected to require cognitive processing. The comprehension and projection level of SA concern reasoning about all available (perceptual) information and how future outcomes can be predicted and anticipated on, based on what is known now. That is, the second and third level are levels of awareness that are not visible, but have to be derived from what *can* be seen. That this derivation requires more cognitive controlled processing was shown by a study on driver's distraction. Performing a secondary task, that loaded working memory, while driving a car had detrimental effects on predicting future traffic situations (the projection level of SA) (Baumann, Petzoldt, Groenewoud, Hogema & Krems, 2008). Baumann et al. (2008) argued that updating working memory content, removing irrelevant information and retrieving information from long term memory is crucial for maintaining an updated situation model. Interference of this updating process (by a secondary memory task, specifically tapping the executive function of updating working memory) would disturb comprehending the situation (comprehension level of SA) and predicting future development of the traffic (projection level of SA).

In the present study the participant is required to coordinate three groups of gold prospectors. The participant has to maintain a complete image of the situation, that is, where the groups are, if they are close enough to each other in case they need each other's help, whether any of the groups encounters problems and so on. At the perception level of SA no real differences are expected with regard to cognitive control, as perception is rather undemanding of cognitive capacity. However, it is hypothesised that participants with high cognitive control, especially high updating capacity, will have higher SA than those who have not. This effect is expected to mainly become visible at the comprehension and projection level of SA. Comprehending a situation and projecting future outcomes of the elements in the environment requires deriving information that cannot just be perceived. This would be in accordance with the earlier findings by Baumann et al. (2008).

The relation between SA and automated support is an important branch of research in these times of innovation and automation taking over many tasks in everyday life, but even more in critical situations. It has regularly been suggested that SA decreases when the operator of a system is supported by (too much) automation. The operator would be taken "out-of-the-loop": when an operator only acts as monitor of an automated system, "[p]eople are frequently slow in detecting that a problem has occurred necessitating their intervention. Once detected, additional time is also needed to determine the state of the system and sufficiently understand what is happening in order to be able to act in an appropriate manner." (p. 163, Endsley, 1996; also for numerous examples and research references). For instance, a passive role instead of an active role in controlling the system and (lack of) feedback of the system are both important contributors to this out-of-the-loop performance problem (Endsley, 1996). In order to avoid this problem it is important to find the right mixture of automation and human involvement.

The digitised support system that will be used in the present research could be seen as partial automated support. Almost all tasks will require the involvement of the operator and therefore an out-of-the-loop effect is not expected, while a general improvement in SA ís expected. Improvement is expected as the basic building block for higher level SA (comprehension and projection level), plain pieces of information (perception level), is constantly updated in the digitised version of the map. That is, the digitised version of the map automatically updates the current location of each group in de field. In contrast, when supported by a traditional paper map these locations have to be requested through communication or inferred and manually updated on the map. People with high cognitive control, a high updating as well as a high switching capacity, will have fewer difficulties with the manual updating and the required higher communication rate when supported by a paper map (see section 2.4). Therefore it is expected that their SA level (all levels) will not significantly improve with the digitised support system, because they *can* do without the perceptual cues. However, people with low cognitive control will benefit from these perceptual cues since the cues result in less dependence on cognitive capacity. Hence, with digitised support there will be less need for communication in order to acquire situational awareness (i.e., communication about the group's current location becomes rather unnecessary). Consequently, there is more time left for other tasks and there is less need for multitasking and individuals with low switching capacity will have clear benefit of the digitised support system.

To summarise, it is expected that participants with low updating capacity will have lower SA in general. Regarding the support method, it is likely that participants with low updating as well as low switching capacity will benefit from the digitised support system. Individuals with low updating capacity will benefit because of the higher number of perceptual cues. Individuals with low switching capacity will benefit because there will be less need to communicate about locations (i.e., less need to switch between different tasks).

2.3 Cognitive Control and Performance

Previous research has shown some promising relations between decision making competence (concerning applying decision rules, framing and risk) and cognitive control. In the present research, task performance will concern problem solving, which requires decision-making. Problem solving involves judging a situation, considering possible outcomes and consequences of a proposed solution to a problem, overseeing possibilities as well as possible dangers and so on.

The three components of cognitive control have all been related to some aspects of decision making (Del Missier, Mäntylä & Bruine de Bruin, 2011). The complex task in the current research does not concern one decision making aspect in particular, but rather a broad range of abilities to solve the different occurring problems. That is, it is expected that in order to solve occurring problems, the ability to oversee the possibilities and consequences is crucial. In addition, the groups of gold prospectors will often find themselves in urgent situations that require immediate response. In order to solve problems, the participant thus will have to act both adequate and fast. For this, the ability to switch between different ongoing tasks, the ability to inhibit automatic responses or irrelevant information as well as the ability to update working memory with the most recent available information will be necessary. Therefore it is not hypothesised that specific components of cognitive control affect task performance (problem solving), but rather a general level of cognitive control, that is, that people with high cognitive control will generally perform better.

The digitised support system will include more up to date information, that is, there will be more perceptual cues, which will result in less dependence on cognitive capacity (i.e., tasks will require less cognitive control). It is expected that participants with low cognitive control will benefit from a digitised system, because of these perceptual cues. Remotely coordinating three groups and solving their problems is expected to be easier when the current location of these groups is constantly updated and available. Hence, it will be easier to judge the situation and to oversee the possibilities. The same advantage will be less strong for participants with high cognitive control, since they will experience fewer difficulties with acquiring a full overview of the situation (and all means necessary to achieve that), when supported by a paper map. For that reason, it is hypothesised that their performance will remain more or less stable across conditions.

2.4 Cognitive Control and Communication

From previous research it became apparent that much can be learned from communication analysis. For instance, analysing cockpit communication revealed relations between a high word count and better task performance, between a high word count and error decrease and between a high word count and increased workload (Sexton & Helmreich, 1999). This same result followed from another cockpit communication study regarding the number of communications. Foushee and Manos (1981) flew a simulated scenario with several complete crews and analysed all communications between the crew members and correlated them with performance measures concerning for instance, decision making and operational errors. The results indicated that the total number of communications was related to better performance. Nonetheless, Foushee and Manos emphasise that although significant relations were found between communication frequency and performance, "[t]he type and quality of communications are the important factors - not the absolute frequency" (p. 70), hence, no blind conclusions should be drawn from quantity alone.

From these previous studies it appears that communication in general and its content give a good indication about the team performance. Although these studies concerned cockpit communication, similar results are expected in the current study, that is, a high communication rate is expected to be related to better performance. Furthermore it is expected that, to be effective and perform well, a high communication rate will be correlated with a smaller mean duration of a single communication, which followed from a study on Air Traffic Control communication events (Manning, Mills, Fox, Pfleiderer & Mogilka, 2001).

To the best of my knowledge, little is known about cognitive control with respect to communication style and task performance. Nevertheless, it is hypothesised that participants with low cognitive control, especially with regard to the switching component, will have trouble communicating with the different groups in the field while performing other tasks. It is hypothesised that they will communicate less for controlling purposes, but more and especially longer to solve problems. In contrast, participants with high switching capacity will communicate more (though short) to remain updated on the current situation, especially when problems occur and no digitised support is available. Finally, it is expected that participants with high cognitive control will solve occurring problems faster as opposed to participants with low cognitive control, which will follow from the communication analysis.

In general, an advantage for the digitised support system is expected regarding the communication rate, since communicating about current locations becomes rather unnecessary, which saves the participant time and effort. However, this advantage will mostly become visible for participants with low switching capacity, since they - as opposed to people with high switching capacity - will be less able to cope with the different tasks that have to be performed concurrently, when supported by a paper map, especially in critical situations (e.g., communicate about current locations, interact with the map and keep track of any changes in the resources of the groups). Hence, the advantage of the automated system taking over tasks, will be larger for people with low cognitive control compared to people with high cognitive control.

Overview Prior Expectations Table 1 provides an overview of the prior expectations with respect to experienced workload, SA, task performance (problem solving) and communication. Hypotheses fall in three categories: hypotheses on individual differences in cognitive control (in general and, if applicable, for specific components of cognitive control), hypotheses on support method (i.e., digitised or paper map) and hypotheses regarding the expected interaction between individual differences in cognitive control and support method, that is hypotheses on possible advantages of the digitised support system for participants with low cognitive control (in general or for specific components of cognitive control), but not for participants with high cognitive control.

Table 1: **Hypotheses**

	Individual differences in cognitive control	Support condition	Cognitive control x Support condition	
Problem Solving	high CC > low CC	digital > paper	high CC:	digital ≈ paper
			low CC:	digital > paper
Communication				
mean duration	high CC < low CC[a]	digital ≈ paper	high CC:	digital ≈ paper
			low CC:	digital ≈ paper
rate	high CC > low CC[a]	digital < paper	high CC[a]:	digital < paper
			low CC[a]:	digital ≈ paper
SA	high CC > low CC[b]	digital > paper	high CC[c]:	digital ≈ paper
			low CC[c]:	digital > paper
Workload	high CC < low CC	digital < paper	high CC:	digital ≈ paper
			low CC:	digital < paper

Note: CC = Cognitive Control; [a]: switching component; [b]: updating component; [c]: updating and switching component.

3 Method

The experiment consisted of two main parts, of which the task(s) and procedure will be described separately. The comparison between the two ways of support, that is, radio support with either a paper map or a digitised support system (CZ-man), will be discussed and analysed in relation to individual differences in cognitive control. For more background about the military context of the experiment, further details about the support manipulation and for the requirements of the interface of the CZ-man system, the reader is referred to the CZ-man project report (Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011).

3.1 Participants

For this experiment 16 Dutch speaking participants (14 male, 2 female) were recruited, ageing from 24 - 34 (M = 27.9 SD = 3.2). Participants were selected from a participant database by TNO, so that their age, gender and education level (highest completed education HBO[4] was representative for military platoon commanders. This selection was necessary to actually be able to predict the usefulness of a CZ-man system in the context of a military operation (see also Streefkerk et al., 2011).

Participants were ascribed the role of a Field Leader (FL) being in charge of three groups of gold prospectors, each led by a Group Leader (GL), which roles were fulfilled by accomplices (2 male, 1 female) of the experiment leader. The roles of GLs were fulfilled by the same accomplices for all participants.[5]

3.2 Materials and Procedure Individual Differences in Cognitive Control

The first part of the experiment consisted of four tasks to measure/determine individual differences in cognitive control: the 2-Back task, the Number Classification task, the Stop-Signal task and finally the Stroop task. These four tasks are associated with the executive functions updating/monitoring, switching and the final two tasks with inhibition, respectively and previous research has shown their reliability (Del Missier et al. (2010); Miyake et al., 2000).

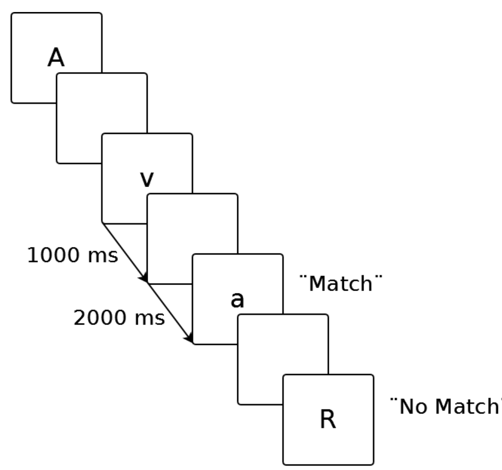


Figure 3.1: **2-Back task**

2-Back task The first task participants performed was the 2-Back task. The 2-Back task (originally formulated by Kirchner, 1958) measures working memory capabilities. Hence, this

[4] A bachelor's degree; HBO: N = 10, MBO: N = 3, VWO: N= 2, HAVO: N = 1
[5] Except for one participant, where one male accomplice was replaced by a male project team member

task is associated with the executive function of
updating and monitoring working memory. The task requires actively updating working memory and combining information from one's working memory with the presented stimulus.

In the 2-Back task participants were presented with a series of letters (upper- and lower-case) and were asked to press the left Shift-key if the presented letter matched the letter two trials back (= "Match") and the right Shift-key if it was a different letter (= "No Match"); letter case had to be ignored (see Figure 3.1). Each letter was presented for 1000 ms or until a response was given and was preceded by a blank screen for 2000 ms. The task consisted of 10 practice trials in which 3 trials contained a match. During the practice trials feedback was given at the end of the trial; a correct response was followed by the Dutch word "goed" (i.e., "good" in green font colour, for 1000 ms) and an erroneous response with "fout" (i.e., "wrong", in red font colour, for 1000 ms). After practising, participants had to run through 45 trials, of which 14 contained a match. In the test trials no feedback was given; anything else remained the same.

Dependent variable for this task is the number of correct responses.

Number Classification task The second task determines the ability to switch between different tasks and mental sets. Participants had to classify numbers as odd/even or higher/lower than 5. The classification rule that should be applied had to be derived from the number's font colour. The task is similar to the one used by Monsell, Sumner and Waters (2003), except that they used background colour or background shape as a cue for the classification rule. The task switch was unpredictable; the colour could change any trial and this change could not be predicted.

The task consisted of three blocks; each block contained a practice round, followed by a test round. In the first block, the participant was presented with a number (yellow font colour, numbers 1-10) and had to classify it as either being odd or even by pressing either the right or left Shift-key, respectively (10 practice trials and 32 test trials, equal number of even and odd trials). In the second block, participants had to indicate whether the presented number was larger than or smaller than/equal to 5 (blue font colour, equal number of larger than 5 and equal to/smaller than 5 trials).

In the third block participants had to switch between the two mentioned classification rules. Which rule should be applied had to be derived from the font colour (the cue) of the presented number. The colours corresponded to the same task as in the first two blocks, that is, yellow asked for an odd/even classification and blue for a higher/lower classification. This third and last block consisted of 64 trials (two subblocks of each 32 trials; equal number of even/odd and larger/smaller trials).

The numbers in each condition were presented until a response was given or when the maximum response time of 3000 ms was reached and each trial was followed by a 150 ms pause. Throughout the whole task, feedback was given by showing a red "X" (for 200 ms) whenever a response was wrong or when no response was given; on correct responses no feedback was given.

Dependent variables for this task are: the difference in reaction time between switch blocks (block 3) and non-switch blocks (1 and 2), henceforth: "switch effect RT", and the difference in correct responses between non-switch blocks (block 1 and 2) and switch blocks (3), henceforth: "switch effect percentage correct". These variables illustrate the task switch costs, that is, switching from one task to another is time consuming and subject to making more errors.

Stop-Signal task Performance on the Stop-Signal task (Logan, 1984) is associated with the executive function of inhibiting prepotent responses. The Stop-Signal task is the third task used for this study and arose from a combination of several previously used variants of the Stop-Signal task. The task consisted of two blocks. The first block contained 24 trials preceded by another four practice trials. In the first block a stimulus had to be classified as either being an "X" or "O" by pressing predefined keys (left Shift-key for an "X", right Shift-key for an "O") (based on Logan, Schachar & Tannock, 1997, Del Missier et al., 2010, 2011). In each trial a fixation point (+) was presented for 500 ms followed by the stimulus, which remained on the screen until a response was given or until the maximum response time of 1500 ms was reached. Participants were instructed to respond as quickly and adequate as possible.

In the second block participants were asked to classify the stimuli in the same manner, but not to respond when a beep (250 ms, 750 Hz) was presented. This beep was presented either 200 or 290 ms after the onset of the stimulus (Stop-Signal Delay or SSD) and occurred in 25 percent of the total number of 144 trials (3 sub-blocks of each 48 trials, with equal probability for the beep occurring at 200 or 290 ms, see Figure 3.2).[6] Participants were instructed to respond as quickly and adequate as possible and to withhold their response when they heard a beep. They were also told that responding quickly was just as important as withholding their response when a beep occurred and that withholding their response would not always be possible (Aron & Poldrack, 2006).

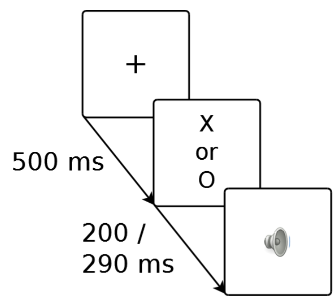


Figure 3.2: **Stop-Signal Task**

Throughout the whole task feedback was given by showing a red "X" (200 ms) whenever a wrong response was given (i.e., pressing one Shift-key when the other was required, pressing a Shift-key when a beep was presented and hence no response was required and finally when no response was given when one was required).

Dependent variable in this task is the number of correct responses in trials with a stop signal.

Stroop task The fourth and last task is associated with the executive function of inhibiting prepotent responses as well. The reason for including two tasks tapping the same executive function is because participants performed the cognitive control tasks isolated in a distinct room with no supervision of a test leader. Although it was emphasised in the instructions of the Stop-Signal task that participants should respond both fast and accurate, there was a chance that participants

[6] The Stop-Signal task used in this experiment is comparable to the one in a study with slightly easier stimuli, namely "<" ">" (Aron & Poldrack, 2006). In this study they found that the mean Stop Signal Delay (SSD) (i.e., the time between the onset of the stimulus and the stop signal) was approximately 205 ms to reach the probability of inhibiting a response, P(Inhibit) = 0.5 (median RT in trials without a beep approximately 393 ms). Therefore, an SSD of 200 and 290 ms was used; withholding a response is considered to be easier when the beep occurs at 200 ms as opposed to 290 ms.

would postpone their response pending a possible beep. Should this be the case it could not be corrected, because the test leader was seated in a different room. When participants postpone their response "on purpose", the data becomes useless. Therefore another cognitive control task tapping the inhibition component of cognitive control was added to the experiment.

Hence, the last task is the Stroop task (named after and introduced by Stroop, 1935). Participants were presented with a series of words of which they had to indicate the font colour (red, green, blue or yellow) as quickly and accurately as possible. The task consisted of 12 practice trials, followed by 36 test trials (i.e., 36 words) of which 12 were congruent, for example, the word "blue" written in blue ink, 12 were incongruent, for example, the word "blue" written in red ink and 12 served as fillers, that is, colour-unrelated words of comparable length (e.g., "hair" or "hat")[7]. A response had to be given by pressing a button with the mouse controller. There were four buttons, one button for each colour (numbered 1 to 4 and labelled by the colour name in black ink just above the button). Throughout the task an error message was given whenever a wrong response was given (the Dutch word "fout", meaning "wrong" in red ink for 400 ms). In between the trials there was a pause of 200 ms.

Dependent variable in this task is the difference in response time between the congruent and incongruent trials (known as the "Stroop effect").

Design The four tasks were presented in the same order for all participants, that is: first the 2-Back task, followed by the Number Classification task and the Stop-Signal Task and finally the Stroop task. Each task was provided with on screen instructions and a batch file of the four tasks was created so that no distraction occurred in between the tasks. During the experiment participants could choose their own pace in between the tasks, as well as during each of the tasks (i.e., between blocks and on the instruction pages preceding the tasks).

3.3 Materials and Procedure (Online) Coordination Task

The second part of the experiment consisted of an online group coordination task which was especially designed for the CZ-man project by Thales and TNO. The materials and procedure as described in this section are also described in the project report (Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011).

3.3.1 Coordination Task and Design

Coordination Task In the coordination task the participant was instructed to act as a Field Leader (FL), being in charge of three groups of gold prospectors: group Albatross, group Bear and group Camel, each led by a Group Leader (GL). The three groups had to be sent into the field to harvest gold at a goldmine and bring back as many pieces of gold as quickly as possible to the base camp. The main task for the FL was to guide each group to their goldmine via a predefined route, that is, via all way- and checkpoints. The routes were planned so that whenever incidents would occur the groups were close enough to each other to assist if necessary.

[7] "haar" and "hoed" respectively in Dutch

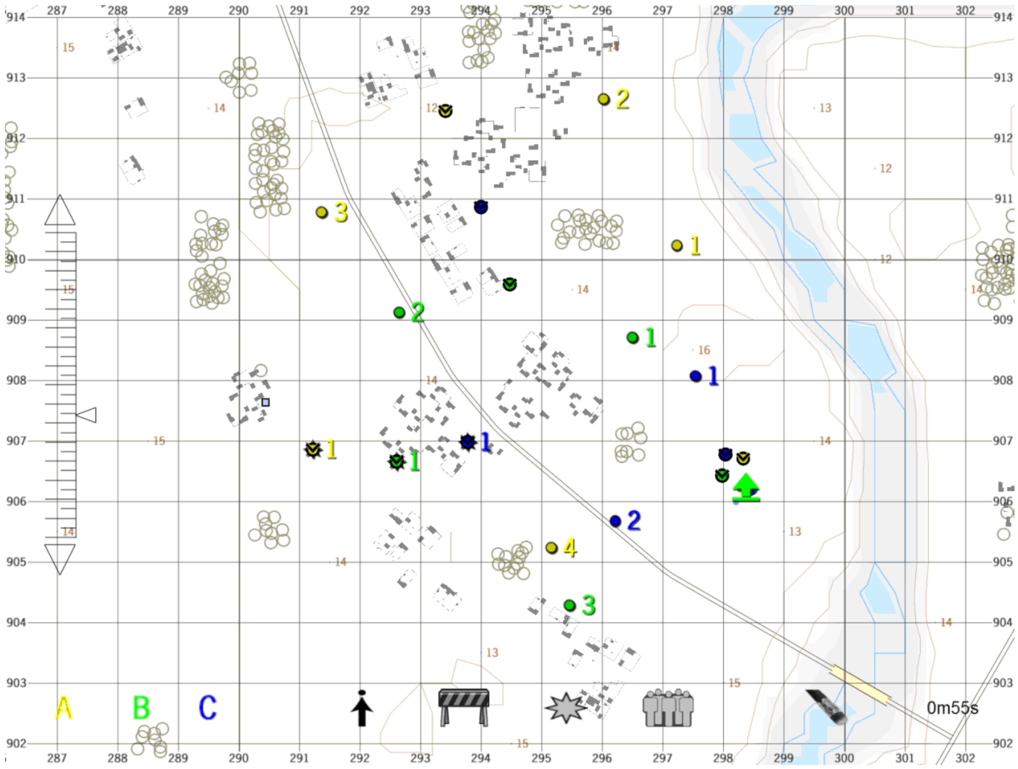


Figure 3.3: **Map of the Environment** Showing waypoints (circles), checkpoints (ticked circles), the goldmines (ticked circles with a cartel border) and at the bottom from left to right; the initials of each group with their corresponding colour; buttons for adding a waypoint, a blockade, an incident, the presence of a crowd of people, respectively, and an eraser for removing elements from the map

Routes on the (paper and digitised) map were displayed as coloured points (not connected by lines) with a different colour for each group. In both support conditions the map was provided with a grid; a point on the map could be described by an X and a Y-coordinate extended with an interpolation within the specified box in the grid (e.g., in Figure 3.3 the coordinates of the green waypoint with number 2 are X: 292.6, Y: 909.2). The participant (FL) had to keep track of the current location of each group and provide them with the correct coordinates for each new location. The numbers on the map only served as route-indicators and were only known by the FL; communication with the GLs about any location had to be done by means of the coordinate system.

As can be seen in Figure 3.3, the map shows three different signs. Circles are waypoints; whenever a waypoint was reached, the groups should be sent to the next location directly. The ticked circles are checkpoints and were included to make sure groups remained lined up and close to each other, that is, at a checkpoint each group had to wait until all groups arrived at their own checkpoint. When there were multiple checkpoints on the route, they were labelled with A, B and so on, to make clear when and where the groups should wait for each other. Again, these labels were only known by the FL and communications about checkpoints had to take place by means of the coordinate system. The ticked circles with a cartel border indicate the goldmines (one for each group).

The participant was instructed to keep the groups close to each other (i.e., when new waypoints were added to the planned route), to keep the groups moving and to solve possible incidents/obstacles the groups might encounter. It was also emphasised that groups could help each other if necessary and that new waypoints (e.g., when deviating from the predefined route), objects of interest reported by the GLs, crowds of people and blockades should be indicated on the map.

Each group started off with the same amount of gold (40 pieces) that could be supplemented by harvesting gold at the goldmine. Along the way the GLs could buy water, food or other supplies when necessary using the gold (these moments were scripted in the scenario); the participant had to indicate these changes in the amount of gold on a paper form.

Incidents and obstacles were reported back to the FL (the participant) who had to solve them. Some of the incidents required deviations from the planned route (e.g., to pass a mob of people or to get water at a well), others required help from other groups and/or their assets. Each group had their own assets; Albatross drove a jeep and carried an excavator on petrol, Bear and Camel were by foot and carried dynamite and shovels, respectively. GLs would not solve incidents themselves or suggest alternative routes or solutions; they acted solely on the FL's command.

All communication went through a two-way, single channel (no shared channel for all leaders) radio and it was emphasised that a common military communication protocol was desired. To send a message, first the addressee of the message should be called. When the addressee copies the call, the message can be sent and is closed with "over" when a reply is desired and "out", when no reply is expected. For example, when the FL would like to send Albatross to their next waypoint, communication should take place as follows:

- "Field leader for Albatross, over"
- "Albatross for field leader come in, over"
- "Please, go to the next waypoint with coordinates 9102, 2972, over"
- "We will go to the next waypoint at 9102, 2972, out"

Design To compare the two ways of support, the traditional paper map and the CZ-man system, participants had to perform the described task twice (i.e., a within subject design). When using the same scenario twice, participants would know about upcoming incidents and (possibly) their correct solutions. Therefore two comparable scenarios were created: Alpha and Bravo. A practice scenario was designed as well, for the participant to get familiar with the communication protocol, the CZ-man interface and the task in general, including solving one problem. To rule out learning effects, the conditions and scenarios were counterbalanced as shown in Table 2.

Table 2: **Counterbalancing Scenario and Condition**

# Participants	Session 1	Session 2
4	Map – Alpha	CZ – Bravo
4	CZ – Alpha	Map – Bravo
4	Map – Bravo	CZ – Alpha
4	CZ – Bravo	Map – Alpha

See also Streefkerk et al. (2011)

3.3.2 Workload Manipulation

Throughout the scenario the workload for the participant was increased, by the number of concurrent problems, the difficulty of the problems the GLs encountered and the need to continue normative tasks. To increase the workload gradually and controlled, both scenarios were divided into nominal and off-nominal phases. The main task for the FL (the participant) in the nominal phase was to coordinate groups from one point to another as planned, write down changes in the stock of gold and indicate objects of interest on the map, spotted by the GLs in the environment. In the nominal phases (the first 15 minutes of the scenario and the last 10 minutes) the groups did not encounter any obstacles/incidents and deviations from the planned route were not necessary. GLs would only report passing way- and checkpoints and changes in resources (these changes were scripted in the scenario, e.g., buying a bottle of water in return for six pieces of gold).

The off-nominal phase consisted of four phases of each 5 minutes. During these phases the GLs would encounter several incidents that had to be solved by the participant. The scenario was designed in such a way that the incidents became larger across phases, in the sense that there were either multiple problems at once, the problems were interdependent or both, to gradually increase workload (see Table 3 for an overview of the workload manipulation). While solving incidents and obstacles the FL (the participant) had to continue performing the normative tasks, that is, indicate objects of interest, keep the "unharmed" groups moving and write down changes in resources which contributed to increasing the overall workload as well. The complete script of both scenarios can be found in Appendix A (in Dutch).

3.3.3 Measures

To test the hypotheses regarding the support condition and individual differences in cognitive control and the interaction between these two, we measured experienced workload, SA and performance. We also analysed the radio communications between the participant and the GLs. Each of these measures will be elucidated separately below. Throughout the experiment physiological responses were measured (Skin Conductance, Heart Rate Average, Heart Rate Variability, Respiration Amplitude, Respiration Rate, and Skin Temperature), but these measures will not be further discussed in this section nor will they be in the remainder of this thesis. Details and results regarding the different physiological measures can be found in the CZ-man project report (Streefkerk et al., 2011).

Table 3: **Phases in the Scenario**

Time (min.)	Phase	Activities and incidents groups
15	Nominal	No incidents
		Report passing waypoints, report changes in resources, report objects of interest
5	Off-nominal	One group has one individual problem
		Other groups report passing waypoints, changes in resources and/or objects of interest
5	Off-nominal	Two groups each have one individual incident
		Other group reports passing waypoints, changes in resources and/or objects of interest
5	Off-nominal	One group has one individual problem and needs the assistance of another group, who will encounter an individual incident as well.
		Other group reports passing waypoints, changes in resources and/or objects of interest
5	Off-nominal	Each group reaches their goldmine. One group has an urgent individual problem that could result in losing every piece of gold and needs assistance of other groups. Another group encounters an individual problem. All groups are busy resolving either their own or another group's incident.
10	Nominal	No incidents
		Travel back to base camp; report passing waypoints, changes in resources and/or objects of interest

Experienced Workload Throughout the experiment experienced workload was measured every five minutes by the Rating Subjective Mental Effort (RSME, Zijlstra & Van Doorn, 1985). The RSME scale was chosen because of the quick adequate assessment; the level of mental effort can be indicated in less than ten seconds.

Participants had to indicate the level of effort it took them to execute the task they had been working on, on the RSME scale, ranging from 0 to 150 of which nine ratings were accompanied with verbal statements ranging from "absolutely no effort" (just above zero) to "very much effort" (just above 110) (see Appendix C, in Dutch).

Situational Awareness The level of situational awareness (SA) was measured four times (every ten minutes). The three SA levels were measured separately by three different questions, one tapping the perception level (questions about facts, e.g., "How much gold does group Albatross have right now?"), one tapping the comprehension level (questions about the current situation, e.g., "Which two groups are closest to each other at this moment?") and one tapping the projection level (questions concerning future situations, e.g., "What if Albatross would encounter an obstacle now, would the shortest route to base camp be left or right passed the obstacle?") (i.e., twelve questions in total, four for each level, see Appendix B for all SA questions, in Dutch).

Exit Strategies During the off-nominal phases several incidents occurred that had to be solved correctly by the participant. Solving an incident properly will be referred to as a correct exit strategy. When participants did not solve the incident correctly or when the correct solution took too long, they received a penalty, by means of losing some of their gold. This will be referred to as an incorrect exit strategy. The costs of an incorrect exit strategy were determined by the three group leaders in accordance with the test leader. To measure task performance the number of incorrect exit strategies was determined for each condition.

Communication All communications between the FL and the three groups were recorded as audio wave files; one stream for each speaker (the FL and the three GLs). To extract measures from the recorded audio, the communications were annotated using a coding scheme.[8] Because of the communication protocol used during the experiment, the communications (the messages going back and forth between the FL and the GLs) had clear boundaries. This protocol served as the basis of the coding scheme for the transcription of the audio (see Appendix E for the complete coding scheme). For practical reasons, the content of the communications (uttered by the FL) was only labelled for the four off-nominal phases, moreover, no (real) performance differences were to be expected in the nominal phase. The total *number of* communications (and their *duration*) though could be calculated for *all* communications; nominal phases included. The coded communications were used to calculate the following measures: (1) General measures: the total number of communications, the total duration of all communications (sum) and the mean duration of a single communication. (2) General measures concerning incidents: the total number of communications concerning a problem and the mean and total duration of those communications. (3) Measures on problem solving: the time between the onset of the (first) problem and executing a correct solution for all problems per off-nominal phase (i.e., problem solving time), the number of communications uttered until a correct solution was executed and the total duration of those communications.

3.3.4 Set-up and Apparatus

The participant (the FL) was seated behind a desk in a room (Figure 3.4a), with the paper map or the touch screen monitor displaying the CZ-man system in front of him/her.[9] The accomplices (the three GLs and the experiment leader(s), see Figure 3.4b) were seated in an adjacent room. During the practice scenario the test leader would sit with the participant to assist if necessary. Participants could use a note block to write down any information they considered useful (e.g., coordinates reported by a GL). In addition, participants had a paper form to keep track of the

[8] Transcription was done using the XTrans Tool developed by the Linguistic Data Consortium (LDC, http://www.ldc.upenn.edu/tools/XTrans/). The tool is developed for broadcast transcription, e.g., interviews, talk shows and broadcast news, in which different speakers appear with possibly overlapping speech and was therefore particularly useful for the communication data.

[9] The physiological measurements were carried out by means of a mobile polygraph (Nexus-10, Mind Media BV, Roermond, The Netherlands). The participant carried the mobile polygraph with him/her as can been seen in Figure 3.4a.

(a) *Participant behind the desk with the touch screen interface*

(b) *Group Leaders (left) and test leaders (right)*

Figure 3.4: **Set-up** Streefkerk et al. (2011)

current amount of gold of the three groups (three columns, one for each group, showing the initial amount of gold and the assets they carried).

Headsets were used for the communication between the FL and the GLs (headphones with a microphone attached to it). The FL had an open channel (i.e., could talk freely); the three GL's communicated by means of push-to-talk".

A PDA was taped to the desk and an alarm went off every 5 minutes. The alarm had to be turned off by the FL after which a questionnaire laying on another desk had to be filled in (RSME every five minutes and a SA questionnaire was added every ten minutes, see 3.3.3). This desk was positioned so that the participant only had to spin his/her chair a quarter turn.

The CZ-man interface was developed by TNO specifically for this experiment and was programmed in the VBS2 (Virtual Battlespace2)[10] environment. In the CZ-man condition the GLs and the FL logged on to the VBS2 scenario. The GLs only had a virtual avatar (first-person viewpoint) walking through a '3D' environment. The FL could only view the map of the environment. This map

[10] Developed by Bohemia Interactive Studio, http://www.bistudio.com/

of the environment was zoomable and pannable and showed the routes of each group (the way- and checkpoints and the locations of the goldmines). The FL could keep track of the current positions of the GLs (small moving dots on the screen) and could add/remove waypoints and objects of interest to the map; Figure 3.3 shows a screenshot of the interface.

In the paper map condition a map of the environment, including the routes of the three groups, was taped to a metal board. New waypoints, objects of interest, blockades, crowds of people or incidents could be added to the map by magnets (different magnets for waypoints, blockades etc.). To keep track of the current position of each group in the paper map condition the FL could place a magnet on the map and update its position when new information was available, which information could thus only be retrieved through radio communication.

3.4 General Procedure

The entire experiment took three and a half hours including a fifteen minute break after the first test session. The general procedure was as follows (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011):

- Introduction and pre-session questionnaire concerning participant's demographics (sleep efficiency, education level, cell phone and computer experience, experience with paper map navigation and GPS car navigation systems) (5 minutes)
- Cognitive control tasks (20 minutes)
- Apply sensors to measure and monitor physiological responses (10 minutes)
- Instructions coordination task and familiarisation with the CZ-man interface (20 minutes)
- Practice session in the presence of the experiment leader (20 minutes)
- Two test sessions, one supported by the paper map, one supported by the CZ-man system (two times 45 minutes, see also Table 2 for the design)
- Post-session questionnaire concerning the participants preferences regarding the support condition and debriefing (10 minutes)

4 Results

Individual differences in cognitive control were measured by four tasks, the Stroop task, the Stop-Signal task, the Number Classification task and the 2-Back task (descriptive statistics can be found in Appendix D). How the data was modified and transformed into *cognitive control variables* will be described first, followed by the results concerning the individual differences in cognitive control and the four measures: experienced workload, SA, performance and communication. The results regarding the support method are described mainly in relation to cognitive control. A complete analysis was done in the CZ-man project by Thales and TNO and for the results regarding the support method the reader is referred to the project report (Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011).

4.1 Cognitive Control Variables

The Stop-Signal task consisted of two blocks. In the first block participants had to classify the stimulus as either being an 'X' or an 'O'. In the second block, participants had to perform the same tasks, except that they had to withhold from responding when a beep occurred. In the second block (i.e., trials in which a beep could occur) the mean response time increased with 144 ms (*SD* = 98,9 ms, with outliers of 300 ms) as opposed to the first block (i.e. trials in which no beep could occur). Hence, due to the expectation of a possible beep participants increased their response time: "a beep-effect". Moreover, one participant did the exact opposite of what was explained in the instructions and had to be excluded from the dataset. Due to the high beep-effect and the great variability in beep-effects, the results from the Stop-Signal task might not represent the ability to inhibit correctly and therefore were not used for further analyses. Hence, individual differences in inhibiting will solely be represented by performance on the Stroop task.

In the instructions of the 2-Back task it was emphasised that the first two trials could not be a match, simply because there were no previous letters to be compared with. For that reason, the first two trials (of 45 trials in total) of the 2-Back task were excluded from the analysis.

Response times below 250 ms were removed from the dataset of each task (occurred only in one trial, in the 2-Back task). From the Number Classification task and Stroop task all response times below and above three standard deviations were removed (i.e., regarding the Number Classification task: 1,6 % from the non-switch trials was removed and 1,0 % from the switch trials; regarding the Stroop task: 0,7 % was removed).

The dependent variables of the cognitive control tasks will be referred to as the cognitive control variables in the remaining of this section. The cognitive control variable for updating is the percentage *in*correct answers in the 2-Back task. The cognitive control variables for switching are the switch effect - RT and percentage correct - in the Number Classification task. The cognitive control variable for inhibiting is the Stroop effect. The cognitive control variables were used as covariates (a *high* score indicating *low* cognitive control) to provide insight about how specific components of cognitive control are related to the measures. For instance, to investigate whether the component updating is involved with SA, the cognitive control variable for updating was added as a covariate.

Furthermore, based on the cognitive control variables, participants were divided into two groups. For each cognitive control variable standardized values were calculated,[11] so that a high (positive) z-score was associated with low cognitive control and a low (negative) z-score with high cognitive control. Thereafter, the average score of the three z-scores was calculated for each participant, which determined whether they were assigned to the low cognitive control group (positive z-scores; $N = 8$) or the high cognitive control group (negative z-scores; $N = 8$). These cognitive control groups (CCgroup) were used in order to provide insight about general differences between people with low cognitive control and high cognitive control with respect to the measures. For instance, to investigate whether people with low cognitive control in general experience more workload, CCgroup was added as a between-subjects factor.

4.2 Experienced Workload and Cognitive Control

Throughout the experiment it became clear that the strict scenario timing was not always feasible and this affected the comparability of the Rating Subjective Mental Effort (RSME) scores. The questionnaires had to be filled in at the same time for each participant, however, due to several factors (mainly the rate of speech of the participant and questions about the CZ-man interface during the experiment), scenario time (in the script) did not always match experiment time. To achieve comparable RSME scores, that is, to be able to compare experienced workload relative to events in the scenario, the scores had to be synchronised with the script afterwards.

There were no prior expectations on specific components of cognitive control in relation to experienced workload, yet it was hypothesised that low cognitive control in general would result in higher experienced workload, especially in the paper map condition. Furthermore, a main effect was expected for support condition, that is, it was expected that more workload was experienced in the paper map condition as opposed to the CZ-man condition. The results partly support these hypotheses. A mixed model ANOVA on the synchronised RSME scores per off-nominal phase revealed a trend for support condition. That is, experienced workload was generally higher in the paper map condition compared to the CZ-man condition ($F(1,\ 93) = 3.43$; $p = .067$) (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011). Moreover, a significant effect was found for phase ($F(3,\ 92) = 5.10$; $p = .003$), hence, participants indeed experienced more workload as the scenario proceeded in the off-nominal phases (see also Streefkerk et al., 2011).

To investigate the effect of individual differences in cognitive control (in general) on experienced workload, a mixed model ANOVA analysis was performed with CCgroup as a between-subjects factor. Although no main effect was found for CCgroup ($F(1{,}14) = 0.01$; $p = .921$), a significant interaction was found between support condition and CCgroup ($F(1{,}86) = 4.65$; $p = .034$). That is, participants with low cognitive control (in general) experienced less workload in the CZ-man condition as opposed to the paper map condition, while participants with high cognitive control showed a minor increase in the CZ-man condition as opposed to the paper map condition, see Figure 4.1. Exploratory consecutive analyses revealed, as expected, no effects for the three components of cognitive control separately.

[11] For the cognitive control variables switch effect RT and switch effect percentage correct, the mean value of both

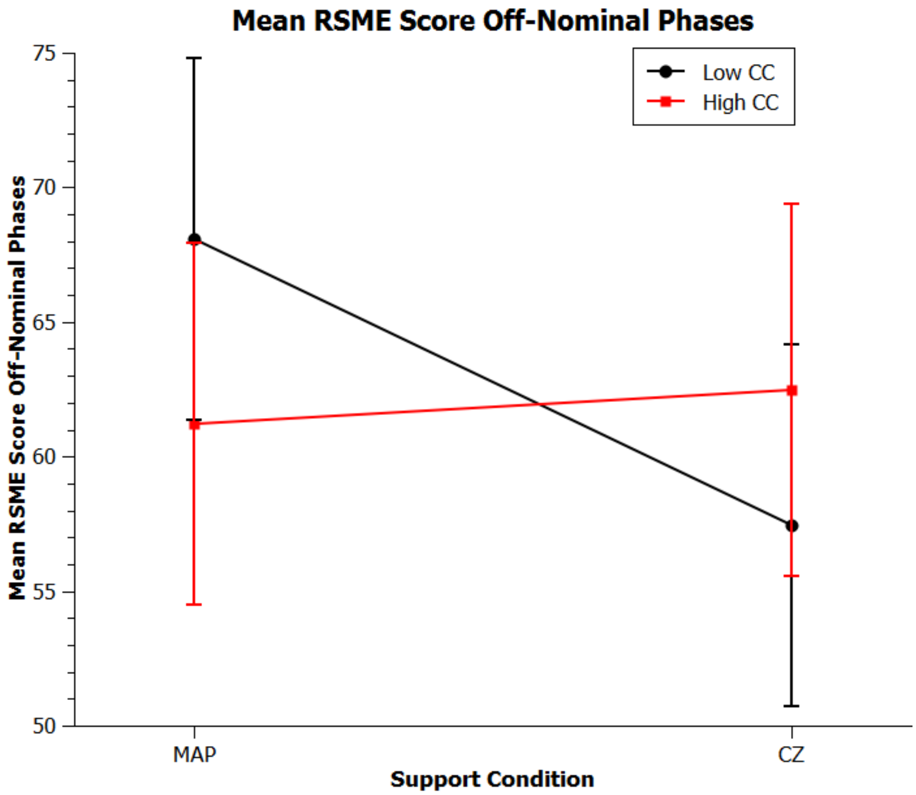


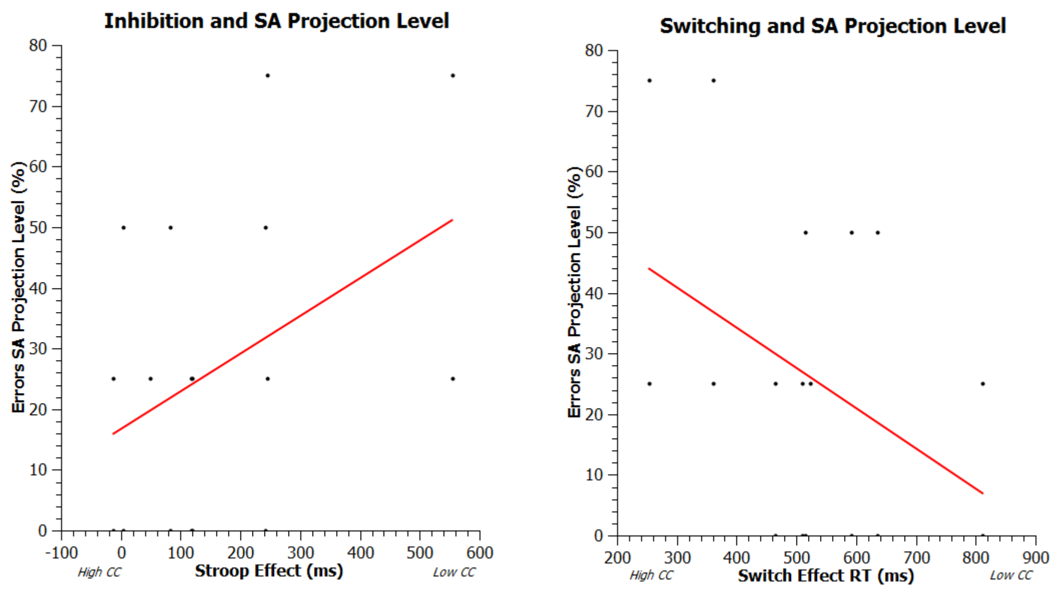
Figure 4.1: **Experienced workload** RSME mean ± SEM in the off-nominal phases for individuals with low and high cognitive control for the paper map and CZ-man condition

4.3 Situational Awareness and Cognitive Control

In the course of the experiment the true location of the groups was not recorded (the "ground truth") for seven participants. The correctness of the answers to the SA questionnaires could therefore not be verified for 7 of the 16 participants. Moreover, SA questionnaires were timed every 10 minutes and thus were not properly synchronised with events in the scenario as was the case with the RSME scores. Because of the few SA questionnaires (4 per participant, per condition) this synchronisation could not be done afterwards.

The level of SA was measured by the number of wrong answers, that is, the more wrong answers the lower SA. Repeated measures ANOVA revealed a significant main effect for support condition (CZ-man versus paper map, $F(1, 8) = 11.11$; $p = .01$), that is fewer errors were made (in general) in the CZ-man condition as opposed to the condition with paper map support (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011). Subsequent analyses for each SA level separately revealed a significant main effect for support condition in favour of the CZ-man system with regard to the projection level ($F(1, 8) = 11.26$; $p = .01$), but not for the perception level ($F(1, 8) = 3.77$; $p = .088$) and the comprehension level ($F(1, 8) = 0.10$; $p = .760$) (see also Streefkerk

standardized values was used in order to produce one score for the switching component.



(a) Scatter plot for inhibition and SA projection level; a high Stroop effect represents low cognitive control

(b) Scatter plot for switching (RT) and SA projection level; a high switch effect represents low cognitive control

Figure 4.2: **Situational Awareness** Measured by the number of wrong answers with respect to the projection level

et al., 2011).

Against prior expectations, no main effect was found for the updating component of cognitive control (i.e., the 2-Back task) in relation to SA, not for SA in general (repeated measures ANCOVA, $p = .940$) nor for the three separate levels of SA (p-values all higher than .30). Furthermore, no interaction effects were found for updating with support condition.

Exploratory consecutive analyses *did* reveal main effects for other cognitive control variables. A significant main effect for the inhibiting covariate was found with regard to the projection level of SA ($F(1, 7) = 8.75$; $p = .021$, see Figure 4.2a for a visualisation of this main effect) and a trend for SA in general ($F(1, 7) = 5.49$; $p = .052$). In both cases, participants with a high inhibiting capacity had fewer errors.

A significant main effect was found for the switching covariate (RT) with regard to the projection level of SA ($F(1, 7) = 7.74$; $p = .027$, see Figure 4.2b for a visualisation), that is participants with a high switching (RT) capacity made *more* errors. No such main effect was found for the other switching covariate (percentage correct). In accordance with prior expectations though, an interaction effect was found regarding SA in general and the switching covariate percentage correct ($F(1, 7) = 9.18$; $p = .019$) and this effect is visualised in Figure 4.3. This figure shows that a low switching capacity is associated with fewer errors in the CZ-man condition and with more errors in the paper map condition. This difference between support conditions is smaller for people with a high switching capacity.

To interpret the results correctly, it should be mentioned that the mean switch effect (percentage

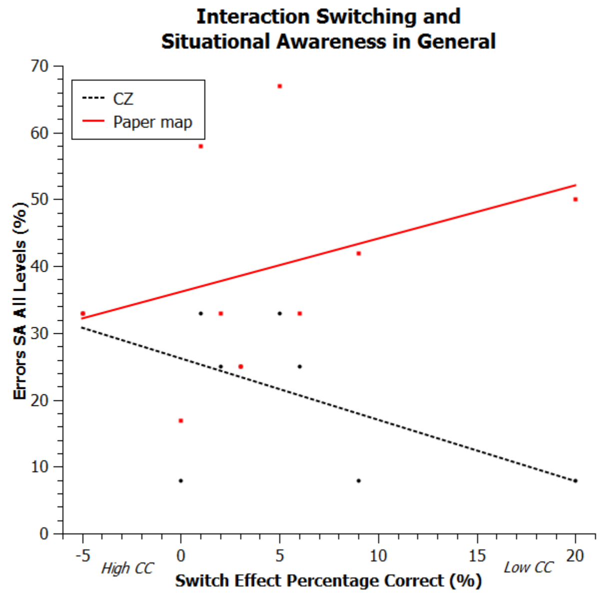


Figure 4.3: **Situational Awareness** Scatter plot for switching (percentage correct) and SA in general for the paper map and CZ-man condition

correct) amounted to 11 % and that the participants of whom the SA data could be used for analysis, all had a lower switch effect than the mean (i.e., an above average switching capacity) except for one. This effect became apparent for the other cognitive control variables as well, though to a lesser extent. Thus it appears that the SA data collected from this research do not properly represent the existing variety in the population, but rather represent individuals with a high(er) level of cognitive control.

For this reason, exploratory analyses regarding possible differences in SA in general between people with low and high cognitive control (i.e., using CCgroup as between-subjects factor) and SA were not performed. Of the nine participants, 2 were categorised as "low cognitive control" and 7 as "high cognitive control". Adding CC group as between-subjects factor would lead to (possibly) misleading and non-representative results.

4.4 Exit strategies and Cognitive Control

Incorrect exit strategies received a penalty by means of losing gold. A repeated measures ANOVA did not reveal a main effect for support condition with regard to *the number of* incorrect exit strategies ($F(1, 14) = 2.75$; $p = .120$). There were no prior expectations with regard to specific cognitive control components and the number of incorrect exit strategies, i.e., it was expected that participants with low cognitive control in general would have more incorrect exit strategies than participants with high cognitive control. The results do not support such a general hypothesis; no significant effect was found for CCgroup ($F(1, 14) = 0.97$ $p = .342$). Participants with low cognitive control had, on average, fewer incorrect exit strategies in the CZ-man condition ($M = 1.0$) as opposed to the paper map condition (M = 2.0), while the number of incorrect exit strategies remained the same across conditions for participants with high cognitive control (M = 1.1). This interaction was not significant though ($F(1, 13) = 2.70$; $p = .120$).

Preliminary correlational analyses showed promising relations for the different cognitive control components, mainly the switching and inhibiting component. Repeated measures ANCOVA indeed revealed significant main effects for the covariate switching (RT, $F(1, 13) = 14.14$; $p = .002$) and inhibiting ($F(1, 13) = 5.06$; $p = .042$). On closer inspection of the data, this effect appeared to be positive with regard to switching, that is, the lower the switching capacity the *more* incorrect exit strategies, and negative with regard to inhibiting, that is, the lower the inhibiting capacity, the *fewer* incorrect exit strategies.

4.5 Communication and Cognitive Control

Two kinds of communication analyses have been done: one concerning all communications and one concerning the communications about incidents.

4.5.1 Communication in General

In the general analysis all communications by the participant were taken into account, that is, communications about problems, about passing waypoints, opening a conversation (e.g., "Field Leader for Albatross, over"), short confirmations (e.g., "understood, out") and any other communication.

A repeated measures ANOVA revealed a significant main effect for support condition regarding the total number of communications uttered by the participant ($F(1, 14) = 11.69$; $p = .004$). As expected, more communications took place in the paper map condition (M = 253) as opposed to the CZ-man condition (M = 230). These communications took longer on average in the CZ-man condition (duration of a single communication: M = 4.04 s) compared to the paper map condition (M = 4.27 s), but this difference was only marginally significant ($F(1, 14) = 4.41$; $p = .054$). In addition, no significant effect was found for support condition with regard to the total speech time of the participant ($p > .30$).

In accordance with prior expectations, a repeated measures ANCOVA revealed a main effect for the covariate switching (percentage correct). Low switching capacity went with a higher mean duration of a single communication ($F(1, 13) = 6{,}898$; $p = .021$). Subsequent analyses (three repeated measures ANCOVA with a different cognitive control variable as covariate in each analysis) revealed no such effect for the switching RT variable nor for the inhibiting variable ($p > .50$). A main effect though was found for the cognitive control variable for updating ($F(1, 13) = 5{,}827$; $p = .031$). Low updating capacity was associated with a higher mean duration of a single communication. No interaction effects were found for support condition with cognitive control regarding the general measures.

4.5.2 Communication about Incidents

When zooming in on the communications during the off-nominal phases that concerned incidents more relations became apparent. A repeated measures ANOVA showed again a main effect for sup-

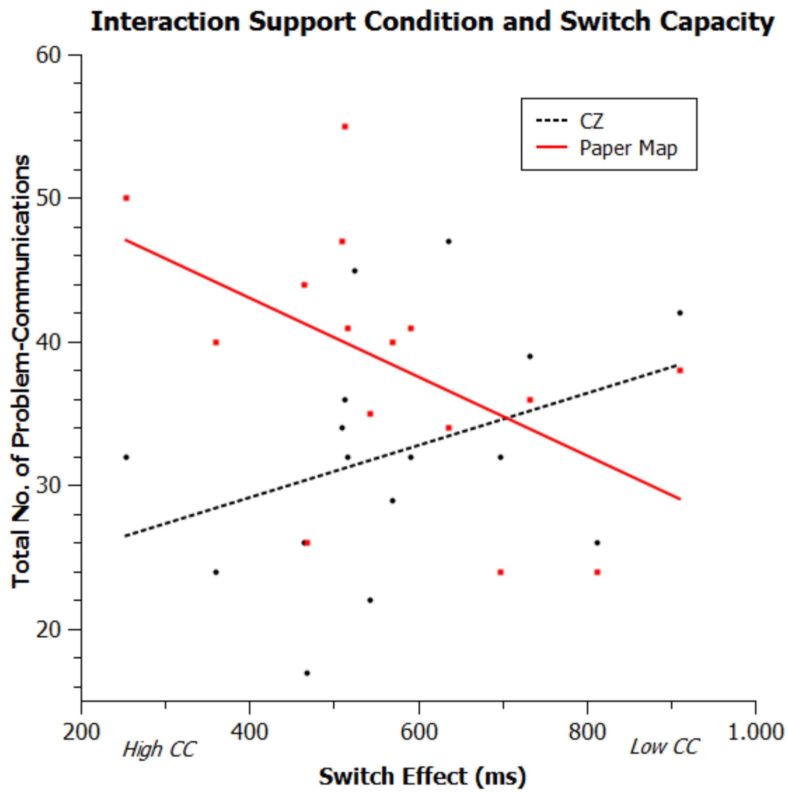


Figure 4.4: **Communication** Scatter plot for switching (RT) and the total number of problem-communications for the paper map and CZ-man condition

port condition. In the CZ-man condition the number of communications concerning a problem was significantly lower (M = 31.5 communications) than in the paper map condition (M = 38.5 communications), $F(1, 13) = 6.45$; $p = .025$.

A closer look on the three different components of cognitive control revealed a significant interaction for the cognitive control variable of switching (RT) as covariate with support condition (repeated measures ANCOVA, $F(1, 13) = 18.95$; $p = .001$) as well as a main effect for support condition ($F(1, 1) = 27.80$; $p < .001$). Figure 4.4 shows a visualisation of the interaction between support condition and switching capacity. High switching capacity (a low switch effect) is associated with a low problem-communication rate in the CZ-man condition, but this frequency increased significantly in the paper map condition, while the opposite holds, to a lesser extent, for people with poor switching capacity (a high switch effect).

Due to some methodological complications (viz., the scenario was subject to some improvisation) not all participants had to solve a second problem in scenario Alpha in off-nominal phase 4. These participants (five) therefore had an advantage compared to those who had to solve two problems in about the same amount of time. To make sure this supposed advantage did not affect the analysis with regard to the total number of problem communications, the data from off-nominal phase 4 of the concerned participants were excluded from the dataset. Thereafter a mixed model ANCOVA

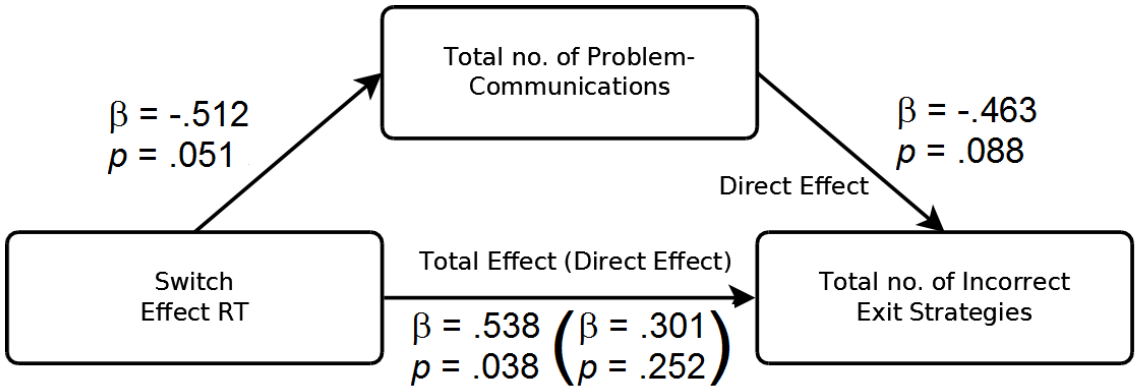


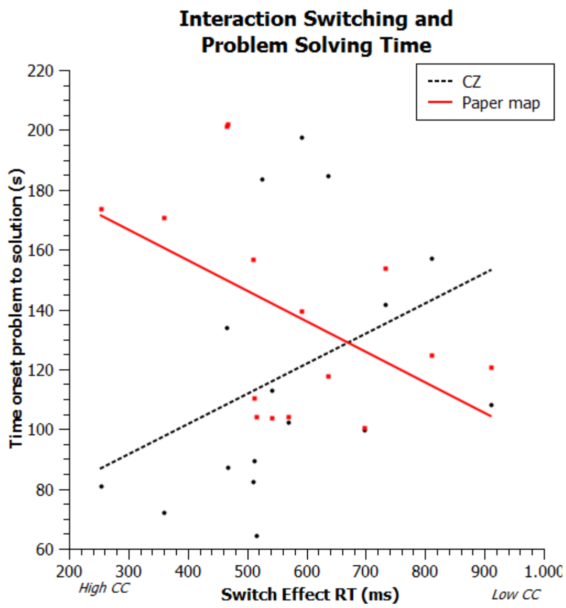
Figure 4.5: **Mediation Analysis** (Paper map condition) Coefficients for each regression analysis. "Direct Effect" is the effect adjusted for the mediator (the total no. of problem-communications), with the "Total Effect" (no adjustment for the mediator) of the switch effect RT (i.e., high switch effect = *low* cognitive control) on the total number of incorrect exit strategies in parentheses.

analysis was performed, which revealed no changes in the effects: a main effect for support condition, $F(1, 103) = 13.49$; $p = .001$ and an interaction effect for support condition and cognitive control variable switch effect (RT), $F(1, 103) = 9.85$; $p = .002$.

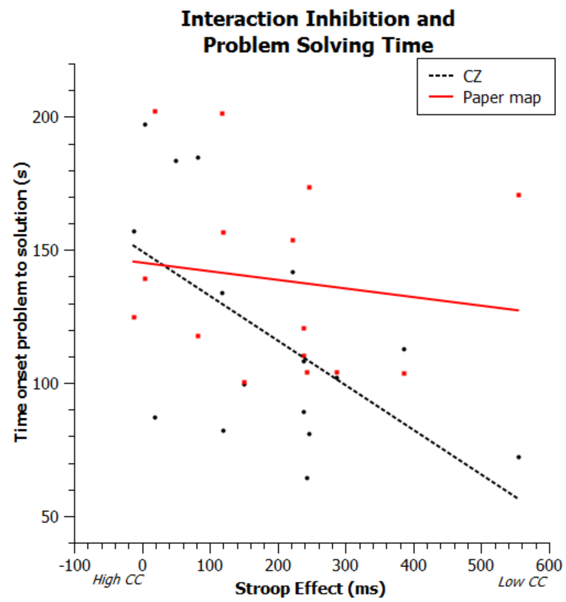
The communication findings shed new light on the previous findings regarding incorrect exit strategies. High switching capacity was associated with more problem-communications, which in turn significantly correlated with to the total number of incorrect exit strategies (in the paper map condition: $r(15) = -.618$; $p = .014$, but not for the CZ-man condition, $r(16) = .303$; $p > .20$). In addition, high switching capacity was associated with fewer incorrect exit strategies and this relation could possibly be explained by a third variable, namely by the total number of problem-communications.

A third variable that explains the relation between an independent and dependent variable is known as a mediator variable (MacKinnon, Fairchild & Fritz, 2007). To test the hypothesis that the number of problem-communications indeed serves as mediator between switching capacity and the number of incorrect exit strategies, a mediation analysis was performed[12] in line with the procedures as described by Baron and Kenny (1986). First the mediator (the total number of problem-communications in the paper map condition) was regressed on the independent variable (switching capacity, switch effect RT variable). In the second regression the dependent variable (the total number of incorrect exit strategies in the paper map) was regressed on the independent variable (= total effect). Finally, the dependent variable has been regressed on both the mediator and the independent variable (= direct effect). The obtained coefficients and significance levels of each regression analysis are shown in Figure 4.5. The four criteria that are involved with Baron and Kenny's (1986) procedure were not entirely met.[13] Nevertheless, a significant mediation effect was

[12] Using the SPSS macro written by Andrew F. Hayes, The Ohio State University, details in Preacher and Hayes (2008).
[13] Besides the direct effect between the independent and dependent variable all coefficients are supposed to be significant.



(a) Scatter plot for switching (RT) and problem solving time; a high switch effect represents low cognitive control



(b) Scatter plot for switching (RT) and problem solving time; a high Stroop effect represents low cognitive control

Figure 4.6: **Communication** Scatter plots for the (a) switching (RT) and (b) inhibiting covariates and problem solving time (data from all off-nominal phases and all participants included) for the paper map and CZ-man condition

found, 95% CI [0.0001, 0.0048].

Problem Solving In the analysis concerning the communication that related to problem solving only those communications have been taken into account that occurred before an executable solution had been put forward. As mentioned above, there were some methodological complications with regard to off-nominal phase 4. Not all participants had to solve a second problem in scenario Alpha in off-nominal phase 4 and therefore they had an advantage compared to those who had to solve two problems in about the same amount of time. Since the current analysis involves *problem solving* rather than general measures on communication, the communication measures from off-nominal phase 4 of five participants (four cases in the CZ-man condition, one case in the paper map condition) were excluded from the analysis.

Fifteen times no correct solution was put forward and/or executed (or only one of the two problems were solved). To be able to compare the performance of participants who did not come up with a solution with participants who did, their response time for executing a correct solution was timed on 300 seconds. This corresponds to the five minutes each off-nominal phase was supposed to last and thus to the time participants approximately had to solve the problems they encountered. Most importantly, no participant put a correct solution forward (and was credited as such by the group leader) after 300 seconds from the onset of the off-nominal phase, hence, 300 seconds was the maximum score for executing a correct solution to a problem.

A mixed model ANOVA revealed no main effect for support condition for any of the problem solving measures for communication, that is, (1) the time between the onset of the (first) problem and executing a correct solution for all problems per off-nominal phase (henceforth "problem solving time"), (2) the number of communications necessary before an executable solution was put forward for all occurring problems per off-nominal phase (henceforth "problem solving frequency communications" and (3) the total duration of those communications per off-nominal phase (henceforth "problem solving duration communications").

A mixed model ANCOVA did reveal an interaction effect for the switching (RT) covariate and support condition for problem solving time, $F(1, 89) = 9.63$; $p = .003$. Participants with a high switching capacity took on average longer to solve a problem in the paper map condition than in the CZ-man condition, while the opposite held for participants with a low switching capacity (see Figure 4.6a). An interaction effect was also found for the switching covariate (RT) and support condition for problem solving frequency communications ($F(1, 87) = 9.59$; $p = .003$) and problem solving duration communications ($F(1, 89) = 4.14$; $p = .045$). Participants with a high switching capacity communicated more frequent before a solution was provided and the total duration of these communications was higher in the paper map condition than the CZ-man condition, while in both cases the opposite held for participants with low switching capacity (i.e., similar interactions as Figure 4.6a).

In addition, subsequent analyses (mixed model ANCOVA) showed that participants with a low inhibiting capacity had a lower problem solving time (i.e., the time between the onset of the off-nominal phase and producing an executable solution for all occurring problems) than participants with a high inhibiting capacity ($F(1, 14) = 6.81$; $p = .021$). An interaction effect showed that this was mainly the case in the CZ-man condition. That is, participants with a low inhibiting capacity had a lower problem solving time in the CZ-man condition than in the paper map condition, while the problem solving time of participants with a high inhibiting capacity did not differ across conditions (see Figure 4.6b), $F(1, 93) = 4.02$; $p = .048$.

No interaction or main effects were revealed for the switching covariate percentage correct, for the updating covariate nor for the cognitive control group (CCgroup) for any of the measures; problem solving time, problem solving frequency communications and problem solving duration communications.

Finally, a mixed model ANOVA revealed a significant interaction effect for support condition and off-nominal phase for all measures, that is the time between the onset of the first problem and producing an executable solution for all occurring problems ($F(3, 96) = 3.28$; $p = .024$), the number of communications needed to solve a problem ($F(3, 93) = 5.34$; $p = .002$) and the total duration of those communications ($F(3, 96) = 4.15$; $p = .008$) (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011). These results were all in favour of the CZ-man condition, i.e., no differences became apparent in the first three off-nominal phases, but in off-nominal 4 problems were solved quicker, with fewer communications of which the total duration was shorter with CZ-man support as opposed to the paper map.

5 Discussion

The results ensuing from the conducted experiment will be discussed separately for experienced workload, situational awareness (SA), exit strategies and communication.

5.1 Experienced Workload and Cognitive Control

Prior expectations included the hypotheses that participants with low cognitive control would generally experience more workload as opposed to participants with high cognitive control, that participants would experience more workload in the paper map condition and that this would be especially the case for participants with low cognitive control.

The results mostly support these hypotheses. In the paper map condition more workload was experienced in general (although not significantly see also Streefkerk et al., 2011). As expected this was mainly the case for participants with low cognitive control. Low cognitive control was associated with a higher experienced workload in the paper map condition as opposed to the CZ-man condition, while the workload experience of people with high cognitive control remained stable across conditions. This strongly suggests that people with low cognitive control benefit from digitised support. The main difference between the paper map and the digitised version concerns the updated current locations in the CZ-man system. As hypothesised beforehand, the decrease in experienced workload can be explained by the presence of perceptual cues (decreasing the dependence on cognitive capacity).

In the script, incidents were strictly timed: each off-nominal phase was required to take exactly five minutes. However, as mentioned in section 4, in practice the timing proved to be infeasible and therefore the RSME questionnaires were not properly related to the events in the scenario. The questionnaires were regularly completed (nine times each scenario) and therefore they could be post-synchronised and related to the events in the scenario. Due to the post-synchronisation the RSME scores could still be compared across participants. In follow-up studies this could resolved, by having the participants complete a questionnaire at specific moments in the scenario (i.e., relative to events instead of relative to time). Hereby, the effects of slight variations in the scenario timing will be quelled.

5.2 Situational Awareness and Cognitive Control

Much was expected from the updating component of cognitive control in relation to SA. As previous research suggested, the projection level of SA depends on updating old and removing irrelevant information from working memory and retrieving information from long term memory (Baumann et al., 2008), and was therefore supposed to be closely related to the updating component of cognitive control. However, no relation was found, which contradicts the earlier research by Baumann et al. (2008). Their method though, differed from the one adopted in this study. That is, Baumann et al. (2008) loaded working memory with secondary tasks (involving updating working memory), while the participant was performing a primary task (driving). These secondary tasks interfered with constructing/updating a situation model. Since these secondary tasks required updating capacity it was argued that updating skills are involved with SA. However, it might as well be argued that switching capacity is involved: to switch between the secondary and concurrent primary task. Furthermore, one of the secondary tasks involved responding to a auditory signal as quickly as possible occurring every 1 or 2 seconds (for 20-40 seconds) and one of the dependent variables included the number of predominant responses, implicating the role of the inhibition component of cognitive control. Therefore, also inhibiting capacity might be designated as being involved in constructing (higher level) SA.

The results of the current study, in fact, revealed the involvement of the switching and inhibiting component of cognitive control. Good inhibiting capacity was associated with a higher projection level and good switching capacity (measured by switch effect RT) with a *lower* projection level. In addition, the other cognitive control variable for switching, switch effect percentage correct, interacted with support condition. A low switching capacity (measured by switch effect percentage correct) was related to a higher SA level as opposed to a high switching capacity, when supported by the digitised system, while the opposite held for the paper map.

These results were unexpected, but the reader should bear in mind that the results were based on the SA questionnaires of nine participants. In addition, SA questionnaires were required to be filled in every ten minutes and due to the previously mentioned limitation of scenario timing, they could not be directly linked to events in the scenario. Hence, it could be the case that some questionnaires were conducted when workload was relatively low (e.g., when an incident has just been solved) while others were conducted when workload was high (e.g., when an incident is not solved and other tasks have to be performed as well). As a result, the SA questionnaires are less comparable across participants and results should be interpreted with great care. In follow-up research this should be resolved by conducting the questionnaires relative to the events in the scenario rather than time.

Despite the complications, some careful suggestions could be made. Regarding the switching component of cognitive control these suggestions are rather speculative. The results were inconclusive and in addition, the nine participants on which the results were based, all had an above average switching capacity (percentage correct) and therefore the diversity in the population is not well-represented by this sample. A very cautious difference could be suggested between people who make more errors (cf. switch effect percentage correct) and people who become slower or take longer to adjust (cf. switch effect RT) when they have to switch between multiple tasks. Would this be the case, it could be possible that a higher switch effect RT is associated with a more careful/precise style of acting and that this results in better SA. A higher switch effect percentage correct could be associated with a more reckless style and the apparent benefit of the CZ-man system might quell the recklessness, because less multitasking is required with the automated support. However, this is *very* speculative and there does not appear to exist a speed-accuracy-trade-off effect between the two switch effect variants.[14] The discrepancy found in the results regarding the switch effect could be a reason for a follow-up study to investigate different coping strategies in multitasking situations.

The significant relation between inhibition and SA (projection level and a strong trend for SA in general) was not expected, however, it could be argued that people with a high inhibiting capacity

[14] The switch effect response time is (almost significantly) correlated with the switch effect percentage correct ($r(16) = .495$; $p = .051$).

are less distracted by irrelevant information or input and therefore can focus more on their task and the situation, which is likely to increase SA. In addition, inhibiting concerns one's ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary (Miyake et al., 2000) and this automatic, habitual responding is argued to be one of the major, general, factors that negatively affects SA (Endsley, 1995). Endsley (1995) argues that in a normal course of events habitual schemata are activated to deal with environmental cues in a predetermined way. Whenever the situation requires change, these habitual schemata have to be interrupted and higher-level SA has to be activated from the perception of the environmental, non-habitual cues. Hence, the significant relation between SA and inhibition confirms/is in accordance with this theory. The fact that, besides a significant relation with the projection level a strong trend was found for inhibition with respect to SA in general, strengthens the involvement of the inhibition component even more.

High inhibiting capacity appears to be associated with higher SA regardless of the support method, that is, people with low inhibiting capacity do not seem to benefit *more* from the CZ-man system than people with high inhibiting capacity. This was reflected in a general benefit of the CZ-man system; specifically regarding the projection level (see also Streefkerk et al., 2011). Hence, the results suggest that people benefit from the digitised support especially when reasoning about future situations and outcomes (based on the current perceptual input and understanding of the situation). As argued earlier, the digitised system provides the participant constantly with up to date information, mainly by showing the current location of all the groups in the field. These perceptual cues are likely to enhance comprehending/overseeing the current situation and reasoning about future situations. The paper map does not provide these up to date perceptual cues and building SA therefore requires more cognitive control.

5.3 Exit Strategies and Cognitive Control

The results concerning exit strategies will be discussed here shortly and more thoroughly in the next section in relation to communication.

It was expected that participants with high cognitive control would handle the occurring incidents better and faster than participants with low cognitive control and moreover that problems were solved quicker and better in the CZ-man condition as opposed to the paper map condition. Finally, it was hypothesised that participants with low cognitive control would benefit (more) from the digitised support system.

Only significant relations were revealed for separate cognitive control components. A high switching capacity was related to *fewer* incorrect exit strategies (i.e., the number of problems that were not solved correctly) and this relation could be explained by communication rates, which will be further discussed in section 5.4. On the contrary, a high inhibiting capacity was related to *more* incorrect exit strategies. With regard to inhibition, the same could have been expected as for SA, namely that to solve (unforeseen) problems there is need to interrupt habitual behaviour and to withhold from responding automatically. However the opposite was found, for which no straightforward explanation can be given. Possibly, the number of incorrect exit strategies was a too broad measure. For instance, the reason for receiving a penalty for not handling the incident correctly has not been taken into account although there were different reasons for receiving one. Participants received a penalty for not solving the incident, but also for not solving it quickly enough. It was not uncommon that participants did eventually come up with a good solution, but were lingering to provide it and spent too much time considering alternatives. Thus, a speculative explanation for the inhibition results could be that participants with a high inhibiting capacity do break from habitual responding, but spend too much time considering alternatives. The communication measures that concerned problem solving (section 4.5.2) indicated that the support condition had hardly an effect on problem solving time for people with high inhibiting capacity, while people with a low inhibiting capacity solved problems faster in the CZ-man condition. This suggests a benefit from the CZ-man system for participants with a low inhibiting capacity, but not for people with a high inhibiting capacity. This might be an explanation for the relation between a high inhibiting capacity and more incorrect exit strategies.

That no effects were found for support condition was unexpected, however there were some indications that there indeed existed a difference in favour of the digitised system. In general there were fewer incorrect exit strategies in the CZ-man condition (on average) and on closer inspection of the data this appeared to be only the case for participants with low cognitive control. This suggests that the CZ-man system enhanced problem solving, but this is only speculative and more research should be done, in which the focus should be primarily on problem solving and decision making. Hence, the current scenario was mainly designed to increase workload and there were too few decision making moments that required, for instance, extensive exploration of decision options, incomplete information or estimating risk level.

5.4 Communication and Cognitive Control

Beforehand it was expected that a higher communication rate would result in better performance; these communications should be kept short though, to not overshoot the mark. A higher communication rate was hypothesised to be directly associated with high cognitive control, especially with high switching capacity. Participants with high switching capacity were supposed to communicate more (for controlling purposes), but shorter as opposed to participants with poor switching skills. These hypotheses were partly confirmed by the results.

Communication in general Low switching capacity was indeed associated with a higher mean duration of a single communication as opposed to a high switching capacity, regardless of the support condition. The mean duration though, was slightly higher in the CZ-man condition than in the paper map condition, but this difference was not significant. Communication rate on the other hand, was significantly higher in the paper map condition, as expected.

The results revealed that, besides switching, a high updating capacity was also associated with a low mean duration. A possible explanation could be that people who are able to switch between tasks and mental sets with few switch costs and update working memory easily, have no trouble keeping an up to date image of the situation each group is in. This might enable them to communicate shortly and effectively without hesitation. Whether this indeed is the case could be examined by extensively analysing the content of each communication on hesitation, by for instance counting the number of utterances like "eh", long pauses or by calculating the word density.

Communications about incidents Against prior expectations, cognitive control was not related to the communication rate based on *all* communications. Yet, as was emphasised by Foushee & Manos (1981) absolute frequency is not the most important factor, type and quality of the communications are. Indeed, when focusing on the off-nominal phases and the communications that concerned an incident only, the hypotheses were confirmed. Analyses on the total number of communications concerning an incident, regardless of whether the problem had been solved or not, revealed the expected higher problem-communication rate in the paper map condition. In addition, the results revealed a relation between high switching capacity and a high problem-communication rate in the paper map condition (but not in the CZ-man condition), while the number of problem-communications for participants with poor switching skills remained nearly the same across conditions. From earlier research it already followed that a high communication rate results in better performance (Foushee & Manos, 1981; Sexton & Helmreich, 1999; Manning et al., 2001) and this same result was found with regard to the problem-communication rate and the number of incorrect exit strategies, but only in the paper map condition. The problem-communication rate served as a mediator between the switching capacity and exit strategy. That is, a high switching capacity resulted in fewer incorrect exit strategies and this was due to the problem-communication rate. In the CZ-man condition though, there was no difference between low and high switching capacity with regard to the problem-communication rate. Moreover, the causal relation between switching capacity, problem-communications and fewer exit strategies did not exist in the CZ-man condition either.

The most obvious conclusion that could be drawn is that participants with high switching capacity communicate more about incidents in the paper map condition to remain in control and up to date about the current situation. In contrast, participants with low switching capacity might simply not be able to cope with the many different tasks that have to be performed concurrently and/or subsequently when there are no perceptual cues or feedback. They might operate (undeliberately) by an "out of sight, out of mind" strategy: "out of perceptual cues, out of mind". The results could indicate that the automated support system made communicating less important, which could be beneficial for people with low cognitive control. In addition, participants with a low switching capacity did solve problems better in the CZ-man condition and thus the careful suggestion might be made that participants with low cognitive control benefit from the digitised support, while people with high cognitive control do not necessarily; they merely change their communication style.

Problem solving Analysing the response times with respect to the execution of a viable solution to incidents, revealed a difference in difficulty between the two scenarios. This mainly concerned the third off-nominal phase, which was more difficult in scenario Bravo.[15] Participants performed both

[15] In scenario Alpha participants took, on average, 98.8 seconds to find the solution that correctly solved the incident, while in scenario Bravo this took 164.6 seconds, on average. A dependent *t*-test showed that this difference was significant ($t(14)$ = -2.71; p = .017; r = .59). The same held for the number of communications needed before a correct solution was found, in scenario Bravo participants communicated more than in scenario Alpha (M(Alpha) =

scenarios and hence this difference was averaged and could do less harm with respect to the results concerning the support condition. With regard to the effect of cognitive control, this difference though could have resulted in a distorted image for the supposed benefit of the automated system. Hence, it could have been the case that the majority of participants with low cognitive control happened to perform scenario Bravo with paper map support and scenario Alpha with CZ-man support. Since scenario Bravo is a bit more difficult this could have led to misleading results in favour of the CZ-man system. A correlational analysis between CCgroup and scenario for each support condition showed that this was not the case: individuals with low and high cognitive control were evenly distributed over the scenarios and conditions.[16] Analysing the response times also revealed that the execution of the script was subject to improvisation. For instance, off-nominal phase 3 originally contained two incidents, but in practice only one incident was introduced. This was done consequently and therefore turned out not to be a problem. In the fourth off-nominal phase of scenario Alpha though, this was not the case; for five participants no second problem was introduced, while the remaining eleven did have to solve two incidents. This inconsequence turned out to have no severe effect on the results, but the data were removed in the analyses where possible and applicable.

In advance, much was expected from response times with respect to the execution of viable solutions to incidents, especially in relation to cognitive control. However, the results do not necessarily provide clarification. The results suggested that people with a low inhibiting capacity benefit from the CZ-man system, because they provided viable solutions faster in the CZ-man condition than the paper map condition. Such a benefit cannot be suggested for people with high inhibiting capacity, as their problem solving time did not decrease as much with the CZ-man support.

Beforehand it was expected that people with high cognitive control would solve problems faster than participants with low cognitive control and that, especially in the paper map condition, the switching component would be involved. As discussed above, a high switching capacity was related to better performance (fewer incorrect exit strategies), which could be explained by the number of communications that concerned an incident. Remarkably, a high switching capacity (switch effect RT) was also related to a higher problem solving time in the paper map condition than the CZ-man condition, while the opposite held for people with low switching capacity. Since the high switching capacity was related to better performance in the paper map and could be explained by the higher communication rate the "extra" problem solving time of participants with a high switching capacity might not necessarily be a bad thing. Possibly, just as suggested earlier with regard to the inhibiting capacity, the participants with a high switching capacity spent more time considering alternatives and communicated extensively to acquire a full overview of the situation and the possibilities. This would explain the higher problem solving time. It should be noted though, that although a full overview of the situation, possibilities and alternatives could be beneficial, lingering to provide a solution in critical situations might have serious consequences and is not always the best problem solving strategy.

The suggestions are only speculative and more thorough analyses of the communication data

4.73; (M(Bravo) = 8.67; $t(14)$ = -3.32; p = .005; r = .66).

[16] CZ-man = paper map condition = $r(16)$ = .00; p = 1.00, that is, exactly as many participants with low cognitive control performed scenario Bravo with the paper map as participants with high cognitive control, that is for each CCgroup, scenario and support condition combination: N = 4.

(primarily focused on the content of the messages and the problem solving strategies) should be performed to make any firm statements. It should be emphasised that the switch effect *percentage correct* was not related to any of the problem solving measures, which again shows the need to investigate the discrepancy between these two types of switch costs (time and errors).

Finally, a general advantage of the CZ-man system was found, namely a difference in the time and the number of communications (and their duration) needed to solve a problem, in favour of the CZ-man system (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011). Participants solved incidents faster, with fewer communications of which the total duration was shorter in the CZ-man condition as opposed to the paper map condition. But this effect only appeared in the fourth off-nominal phase, where subjective workload was rated highest. This indicates that when much workload is experienced the digitised system supports the operator to act quicker and more effective than the paper map. This is a very promising result for future development of support systems.

6 General Discussion and Conclusions

This final section contains a general discussion, recommendations for future research and a concluding section.

6.1 General Discussion

The results ensuing from the conducted experiment clearly show the importance of including individual differences in cognitive control in the development process of future support systems, especially for those systems which are required to support humans in critical situations. The individuals who participated in the present experiment are supposed to have had a rather high level of cognitive control, that is, they all had a good night of sleep and where not (mentally) exhausted by any other prior task. It is known that sleep deprivation, for instance, negatively affects integrative executive functioning (Nilsson et al., 2005), working memory performance (Smith, McEvoy & Gevins, 2002) and decision making, especially "[i]f there is a particular need to draw on innovation, flexibility of thinking, avoidance of distraction, risk assessment, awareness for what is feasible, appreciation of one's own strengths and weaknesses at that current time (metamemory), and ability to communicate effectively" (Harrison & Horne, 2000, p. 246). Similar results have been reported for mental fatigue. For instance, mental fatigue was found to have a negative effect on planning and flexibility (i.e., more perseverative errors) (Van der Linden, Frese & Meijman, 2003). Thus, there exist individual differences in cognitive control, but the level of cognitive control is also affected by other factors, which factors are not uncommon in critical situations. These are all the more reasons to address cognitive control in the developing process of digitised support systems, that is, addressing methods to support individuals with low cognitive control. The results from the current study provided insights with regard to the effect of individual differences in cognitive control and automated support on experienced workload, SA, performance and communication. These insights could serve as a stepping stone in the developing process.

The results suggested first, that workload is decreased with automated support (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011), which is in accordance with previous research (e.g., Thomas, 2011). However, from the current study it followed that this was mainly (even only) the case for participants with low cognitive control. This benefit can be traced back to the perceptual cues; by presenting information perceptually, less depends on cognitive controlled processes and as a result the differences (e.g., regarding experienced workload) between individuals with low and high cognitive control decrease. This result, in fact, could be compared with the inverse relation between skilled processing, that is, automatic behaviour and workload (recall the distinction between controlled processes and automatic processes, Kahneman, 2003). For instance, Young and Stanton (2007) found that novice or learning drivers experience more workload than advanced drivers. In addition, workload was decreased with automation, which in turn resulted in better performance, but in particular for novice/learner drivers. Hence, just like skilled behaviour, perception is automatic behaviour, which is less demanding of cognitive capacity and as a consequence less workload is experienced, but especially for those with low cognitive control. There was no direct causal relation between performance and workload in the present study, however, participants with low cognitive control experienced less workload and performed better with automation (not significantly), while the workload and performance of people with high cognitive control remained stable. This could indicate that automation results in decreased workload, which in turn results in better performance, but only for people with low cognitive control.

In the light of the conducted experiment it was assumed that a lower experienced workload is advantageous and there was no reason to assume otherwise, but I do not claim whatsoever that this can be blindly generalised to other tasks or situations. A certain level of (experienced) workload increases performance, for instance an approaching deadline for submitting a paper (inducing experienced workload by time pressure), might enhance performance. Put differently, underload might do as much damage as overload. As argued by Young and Stanton's MART (Malleable Attentional Resources Theory), reduced workload (e.g., as induced by automation) potentially affects a person's attentional capacity, resulting in decreased performance (Young & Stanton, 2002).

Second, it was found that people with high switching capacity communicate more (but shorter) when no digitised support is available and incidents occur, and that this results in better performance (fewer incorrect exit strategies). With an intermediate level of automation, the communication rate dropped significantly for people with high cognitive control; with CZ-man support there were no differences in communication rate between people with high and low cognitive control. Alike the decreased workload, in the discussion it was assumed that a lower communication rate, provided that support is automated, is advantageous. Hence, communicating is time-consuming and especially those messages with the sole purpose to inform about current locations can easily be taken over by automated systems, freeing the operator's resources for other tasks. However, there could be a downside to a lower communication rate, due to automated support. Throughout this thesis it has been argued that particularly people with low cognitive control benefit from the presence of relevant perceptual cues. Inherent to this benefit though, is the requirement that these cues have to be perceived, that is, operators have to divide their (full) attention to the system to detect any irregularities. And this is exactly one downside of automation for which (focal) visual attention is required: the system might fail to capture the operator's attention properly (Sarter, 2001). Therefore, distributing information across different modalities (e.g., tactile and visual feedback; focal and peripheral) could be desirable to improve the human-machine interaction (Sklar & Sarter, 1999).

Returning to the decreased communication rate in the present study, a low communication rate might thus result in worse performance. Although there was no reason to assume that the decreased communication rate in the CZ-man condition resulted in impaired performance, it is conceivable that changes in the support system might not attract the operator's attention, while regular communications do reveal possible irregularities. This might especially be the case when the operator has to perform for several hours (as opposed to the two times 45 minutes in the current study) during which hours fluctuations in attention and vigilance can be expected. Moreover, human (oral) dialogue is very rich and powerful and cannot be equalled to any other communication tool (think of tone, loudness, conversational implicatures, emotions and so on, i.e., *pragmatics*). Especially in novel situations, requiring novel sequences of actions, one vocal message might cover a whole situation and convey the appropriate actions that have to be taken. Hence, it should be emphasised that in a number of situations, human communication outperforms any other communication tool. Nevertheless, the results from the current study showed clear communicational differences between people with low and high cognitive control that should be addressed when developing an automated support system. That is, human (communicational) performance has its limits and should be complemented when necessary by automated systems.

Third, besides a general higher level of SA when supported by the CZ-man system (see also Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink, 2011), there were indications that a high inhibiting capacity is associated with a generally higher level of SA. SA requires breaking from habitual responding in non-routine situations, in order to understand the situation, as well as to anticipate on and predict future outcomes and situations. Moreover, switching capacity appeared to be involved in SA, but these results were rather inconclusive and merely based on individuals with relatively high switching capacity. The result that updating capacity was not related to SA contradicted earlier research by Baumann et al. (2008), but their method differed from the one adopted in this study and their results might point towards other components of cognitive control as well. Research on cognitive control and SA thus appears to be rather inconclusive and the present research is no exception. Nevertheless, that cognitive control somehow plays a role has become apparent and mainly the involvement of the component of inhibiting habitual or automatic responses became obvious from the present study, which is in accordance with theories on SA (Endsley, 1995). It should be noted though, that this involvement was still only based on few participants and more research should be done, primarily focused on the relationship between cognitive control and SA. Nevertheless, when developing a support system, the individual differences in cognitive control could be addressed by reducing the risk of the operator acting automatically, increasing SA.

A final general point of discussion concerns the scenario and the interface of the CZ-man system. The scenario timing was rather strict, which in the first place improved the comparability of the results across participants. However, in practice, this strict scenario timing was not always feasible, due to the participant's rate of speech, difficulties with the interface and some events taking too much time. For instance, the events in off-nominal phase 3 and 4 consequently took more time. In addition, between phase 3 and 4, the three groups arrived at their goldmines and harvested gold, which took unexpectedly much "incident/event-less" time and was rather effortless for the participant (this was reflected in the RSME scores). The difficulties with the interface were attributable to shortcomings of the CZ-man system. Participants mainly had trouble with moving waypoints. "Moving" a waypoint was only possible by removing the old and then adding a new waypoint. An intuitive touch-and-drag" mechanism was included in the requirements, but could not be implemented (see Streefkerk et al., 2011 for the requirements and the implementation). Furthermore, participants had difficulty keeping track of the planned route for each group, because the way and checkpoints were not interconnected by lines. Again this was included in the requirements but could not be implemented. The problems with respect to the usability of the interface, although attributable to limitations of the VBS2 environment, led to a less intuitive interface, especially regarding moving waypoints. These limitations did not have severe consequences for the majority of the results, yet making them explicit will ensure that in future research they can be dealt with prior to the experiment.

6.2 Future Research & Recommendations

Interface To start with the final point of the general discussion, the interface of the decision support system: People are nowadays used to touch screen devices (e.g., tablet-PCs, smart phones) in which 'touch-and-drag' functionalities are standard features. A decision support system should not, in any way, be inferior to these touch screen devices. To avoid any usability problems and to improve the intuitiveness of the interface in future research and the intended end product, those features should be incorporated. These features include the 'touch-and-drag' functionality but also two features that were implemented in the CZ-man system but became rather redundant. The map was zoomable and pannable, but both functionalities were rather unnecessary, because zooming in or panning the map did not provide any more detail or information. Zooming and panning could both be seen as important advantages of a digitised map, since the operator can request either more detail or more overview according to his or her needs at the very moment. Future research should investigate these supposed advantages by making these features functional.

Cognitive Control As with regard to individual differences in cognitive control, this research has clearly shown that these differences should be addressed in future development of decision support systems. For example, with respect to experienced workload the individual need for automation has been shown, in the current study, to differ across people with different levels of cognitive control. Nonetheless, there also remained some questions unanswered.

For instance, despite the complications, the SA results did point to certain directions worth going. The updating component of cognitive control appeared, against prior expectations, to be not or less involved than the inhibiting or switching component. What we might have learned is that although updating the mental image with new information is required in order to maintain SA, the ability to switch (e.g., communicating) and the ability to inhibit (e.g., break from habitual responding) are more important to acquire SA. Hence, even if you excel in updating your working memory with every new piece of information, if this new information is hard to acquire, the updating capacity will not bring you far. In future research the involvement of the different components of cognitive control should be investigated more thoroughly. For the development process of decision support system it should be known what aspects of human performance or ability needs be complemented. Complementing the human's ability to multitask or the human's ability to update its working memory will most likely result in different requirements.

As pointed out earlier in the discussion, the discrepancy that was found regarding the two switching variables (viz., switch effect RT and switch effect percentage correct) could be a reason for a follow-up study on coping strategies in multitasking situations. Where switch effect RT represents the switch costs in time (i.e., switching between tasks and mental sets takes time) and the switch effect percentage correct represents switch costs in errors (i.e., switching between tasks and mental sets results in making more errors). Hence, although both represent the negative effects associated with switching between tasks, they do not appear to go together (always). For example, only the switch effect RT was related to the higher problem-communication rate and better performance, while no relations were found for the percentage correct variant.

Another earlier mentioned suggestion for further research concerns problem solving. Previous research showed that cognitive control is involved in several decision making tasks. In this study the involvement of for instance, the switching and inhibiting component, was shown. However, since the communication analysis and the measurement concerning (in)correct exit strategies did not go "deep" enough (i.e., problem solving strategies were insufficiently addressed), there is little to say about problem solving strategies. Therefore, it remained unclear what exactly the involvement entails. In addition, as argued in section 5.3, the scenario was mainly designed to increase workload. To study problem solving strategies in future research, more decision making moments should be included that require, for instance, extensive exploration of decision options, incomplete information or estimating risk level. By including these decision making moments, the influence of individual differences in cognitive control on problem solving and the effect of support method could be investigated more effectively.

A general suggestion for further research would be to examine the relations that were found between individual differences in cognitive control and experienced workload, SA, task performance and communication in similar applied studies. Some of the relations that were found in the current study were unexpected. Although most of these relations could be explained or were in some way consistent with the other findings follow-up studies should try and replicate the findings of this rather exploratory study to provide more clarification and certainty regarding the influence of cognitive control on these measures.

6.3 Conclusion

The main goal of this thesis was to investigate whether people with low cognitive control, in general or regarding specific components, benefit (more) from automated support. To that end it was investigated how two kinds of support systems, radio communication together with either a traditional paper map or a digitised version of this map, providing more up to date information, influenced experienced workload, SA, performance and communication. As opposed to previous research on cognitive control, in this research an applied method was adopted, that is, participants had to perform a complex online group coordination task in which they had to remotely coordinate three groups of gold prospectors.

Due to the applied method, the results of the conducted experiment are supposed to be translated more easy to real life, non-routine situations. Although there were some complications/limitations, the ensuing results provided insights with regard to the effect of individual differences in cognitive control and support method. These insights clearly showed the importance of including cognitive control in future development of decision support systems, especially for those systems that are intended to support humans in critical, high workload situations.

Hence, if automated support systems are supposed to complement human performance (instead of replacing it), the differences in human abilities should be carefully addressed to optimize the support. One effective method to address these differences has been shown by the present research, namely taking individual differences in cognitive control into account.

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Appendices

A Scripts

A.1 Script Alpha

Naam Conditie: CZMan / Map **ALPHA**
Datum: PP nummer:

	Tijd (min. sec)	Field leader	A	B	C	Measures	Verwacht gedrag field leader
			Nominaal				
Verlaten veldkamp	0.00	*"Groep Albatros, jullie mogen het veldkamp verlaten"*					
			"Groep Albatros meldt zich, verlaat veldkamp"				
		Bevestig ontvangen bericht	A begint te lopen in omgeving				
		"Groep Beer, jullie mogen het veldkamp verlaten"					
				"Groep Beer meldt zich, verlaat veldkamp" B begint te lopen in omgeving			
		Bevestig ontvangen bericht					
		"Groep Camel, jullie mogen het veldkamp verlaten"					
					"Groep Camel meldt zich, verlaat veldkamp"		
		Bevestig ontvangen bericht			C begint te lopen in omgeving		
Waypoint passage	1.05		*"Groep Albatros meldt zich, waypoint 1 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend					
			"Groep Albatros hier, we gaan door naar waypoint 2"				
			Loop door naar volgend waypoint				
Resources	1.40				*"Groep Camel meldt zich, we hebben 2 flessen water voor 12 goud gekocht."*		
		Bevestig ontvangen bericht					Aantekening maken dat Camel 12 minder goud heeft
Waypoint passage	2.40			*"Groep Beer meldt zich, waypoint 1 gepasseerd"*	*"Groep Camel meldt zich, waypoint 1 gepasseerd"*		
		Bevestig ontvangen bericht Beer en geeft opdracht door te gaan naar volgend					
		Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend					
				"Hier Groep Beer, we gaan door naar checkpoint A"	*"Hier Groep Camel, we gaan door naar checkpoint A"*		
		Bevestig ontvangen bericht					
	3.40		*"Groep Albatros meldt zich, waypoint 2 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					
			"Groep Albatros gaat door naar checkpoint A"				
Checkpoint	4.10				*"Groep Camel meldt zich, we komen nu aan bij checkpoint A"*		
		Bevestig ontvangen bericht *Groep Camel, blijf op deze positie*					
		Field leader voor Groep Albatros, iets sneller naar het checkpoint A zodat jullie opgelijnd blijven met de andere groepen'					
			"Groep Albatros voor Field leader, we proberen zo snel mogelijk bij ons checkpoint aan te komen."				
		Field leader voor Groep Beer, iets sneller naar het checkpoint A zodat jullie opgelijnd blijven met de andere groepen'					
						BSMI	
				"Groep Beer hier, we proberen zo snel mogelijk bij ons checkpoint aan te komen."			
	5.30		*"Groep Albatros meldt zich, we zijn bij checkpoint A"*				
		Bevestig ontvangen bericht					
	6.00			*"Groep Beer meldt zich, checkpoint A bereikt"*			
		Bevestig ontvangen bericht *Field leader voor Groep Albatros, jullie kunnen je route vervolgen*					
			"Groep Albatros, we vervolgen onze route"				

		Field leader voor Groep Beer, jullie kunnen je route vervolgen	Verder lopen naar volgend checkpoint B				
				"Groep Beer, we vervolgen onze route" Verder lopen naar volgend checkpoint B			
		Field leader voor Groep Camel, jullie kunnen je route vervolgen					
					"Groep Camel, we vervolgen onze route" Verder lopen naar volgend waypoint		
Waypoint passage	7.25				*"Groep Camel meldt zich, waypoint 2 gepasseerd"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					
					"Groep Camel hier, we gaan door naar checkpoint B"		
Resources	8.15		*"Groep Albatros meldt zich, we hebben 1 fles water voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
OOI	8.30				Groep Camel meldt zich, object of interest gespot een autowrak op locatie xx		
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Checkpoint	9.00				*"Groep Camel meldt zich, we komen nu aan bij checkpoint B"*		
		Bevestig ontvangen bericht					
			"Groep Albatros meldt zich, we komen nu aan bij checkpoint B"				
		Bevestig ontvangen bericht					
		"Field leader voor Groep Beer, iets sneller naar het volgende checkpoint zodat jullie opgelijnd blijven met de andere groepen"					
				"Groep Beer voor Field leader, we zullen proberen zo snel mogelijk bij ons checkpoint te komen."			
				Ga sneller lopen naar checkpoint B			
				"Groep Beer meldt zich, we zijn bij checkpoint B"			
		Bevestig ontvangen bericht					
		Field leader voor Groep Albatros, jullie kunnen je route vervolgen					
			"Groep Albatros, we vervolgen onze route" Verder lopen naar volgend waypoint				
		Field leader voor Groep Beer, jullie kunnen je route vervolgen					
				"Groep Beer, we vervolgen onze route" Verder lopen naar volgend waypoint			
		Field leader voor Groep Camel, jullie kunnen je route vervolgen					
					"Groep Camel, we vervolgen onze route" Verder lopen naar volgend waypoint		
Resources	10.05			*"Groep Beer meldt zich, we hebben 1 fles water voor 6 goud gekocht."*			
		Bevestig ontvangen bericht				BSMI en SA1	Aantekening maken dat Beer 6 minder goud heeft
Waypoint passage	11.00			*"Groep Beer meldt zich, waypoint B2 gepasseerd"*			
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					
				"Groep Beer hier, we gaan door naar waypoint 3"			
passage	12.15				*"Groep Camel meldt zich, waypoint 3 gepasseerd"*		
			"Groep Albatros meldt zich, waypoint 3 gepasseerd"				
		Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend waypoint 4					

Waypoint p					*"Hier Groep Camel, we gaan door naar waypoint 4"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 4					
			"Groep Albatros gaat door naar waypoint 4"				
Resources	14.00		*"Groep Albatros meldt zich, we hebben eten voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
	15.00						
			Off-nominaal				
Incident loop 1	15.00		*"Groep Albatros meldt zich, We zijn een grote groep vijandige burgers tegengekomen. We kunnen niet onze weg vervolgen. We zijn nu op locatieXX. Aan de andere kant van deze groep is een waterput waar we water uit nodig hebben. Hoe moeten we nu verder?"*				
		Bevestig ontvangen bericht					
		Field leader moet naar een oplossing zoeken	Indien de oplossing wordt gevonden kan Albatros nieuwe events introduceren (zie hieronder) tot scenariotijd 20 minuten is.				
			"Groep Albatros meldt zich we zijn aangekomen bij de waterput, maar deze staat leeg. Is er nog een andere waterput in de buurt?"				
			"Groep Albatros meldt zich, er is een blokkade op de weg. Kunnen we ook anders lopen?"				
			"Groep Albatros meldt zich, we zijn aangekomen bij de waterput, maar er hangt geen emmer aan. "			BSMI	
Einde incident	19.40		Einde incident loop 1. Indien nog niet geeindigd kom met een exit:				
			Indien goede oplossing (naar nabije waterput sturen) kost het geen goud				
			"We hebben nu water nodig en we kunnen de waterput niet bereiken. Bewoners hier kunnen ons water verkopen, we kopen 2 flessen voor 24 goud. Helaas wel het dubbele aan kosten, maar we hebben wel water!"				
Waypoint passage	16.30			*"Groep Beer meldt zich, waypoint 3 bereikt"*			
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 4					
				"Groep Beer hier om te bevestigen dat we doorgaan naar het volgende waypoint"			
OOI	18.30			Groep Beer meldt zich, object of interest gespot een autowrak op locatie xx			
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Waypoint passage	18.25				*"Groep Camel hier, we zijn nu bij waypoint 4"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 5					
					"Groep Camel, we gaan door naar de goudmijn"		
2	19.50				*"Groep Camel meldt zich, er staat een grote groep mensen verder op in de straat, op locatie XX. We weten niet waarom ze daar staan. We weten ook niet of ze vriendelijk of vijandig zijn. Moeten we onze weg vervolgen of zullen we een andere route nemen?"*	BSMI en SA2 (na incident 1)	
		Bevestig ontvangen bericht					OoI (groep mensen) op kaart zetten

Incident loop 2	20.30			*"Groep Beer hier, door de hitte is het dynamiet te droog aan het worden. We moeten acuut naar een waterput geleid worden zodat we het goed nat kunnen maken."*			Field leader plant andere route voor Groep Camel Field leader stuurt groep Beer naar waterput
		Vraag C om info over de groep *Field leader aan Groep Camel: volg een omleiding via een nieuw waypoint…*			Desgevraagd: "*Info over groep: ze staan te joelen, Er staan mannen, vrouwen en kinderen."* Gooien met stenen Ze komen op ons af.		
		Field leader aan groep Beer: er is een waterput bij…					
Einde incident	24.40			Einde incident loop 2. Indien nog niet geeindigd kom met een exit: Indien goede oplossing (waterput) kost de exit geen goud) *"We hebben water gevonden, maar niet genoeg om alle dynamiet nat te houden. Dit kost ons 10 goud. "*	Einde incident loop 2. Indien nog niet geeindigd kom met een exit: Indien goede oplossing, omleiding, kost de exit geen goud. *"Het waren vriendelijke bewoners. We hebben ze 10 goud gegeven voor hun medewerking en kunnen onze weg vervolgen"*		
Waypoint passage	22.00		*"Groep Albatros meldt zich, waypoint 4 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 5					
			"Groep Albatros gaat door naar waypoint 5"				
OOI	23.00				Groep Camel meldt zich, object of interest gespot een lading vaten op de route, op locatie xx		
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Incident loop 3	25.05		*"Groep Albatros hier. Onze jeep zit vast in het zand en met de hand krijgen we hem niet uitgegraven"*			BSMI	
		Groep Camel de jeep laten uitscheppen					Field leader stuurt groep Camel naar groep Albatros
		Field leader voor groep Albatros, ik stuur groep Camel naar jullie toe om te helpen.				RESPONSTIJD Albatros	
		Graafmachine gebruiken	*"Dat zal niet gaan, daar kunnen we niet nauwkeurig genoeg mee werken zonder de auto te beschadigen"*				
		Field leader voor Groep Camel, jullie moeten je begeven naar groep Albatros op coordinaten…			Groep Camel gaat op weg naar Albatros, maar komt onderweg vast te zitten door een roadblock (grote kudde vijandige kamelen). *Groep Camel hier. We zijn onderweg naar groep Albatros, maar zitten vast door een roadblock. Wat moeten we doen?*		
		Field leader aan groep Camel: Jullie moeten een omleiding lopen via….				RESPONSTIJD Camel	Detour plannen op Map/ CZMan
Einde incident	29.40		Einde incident loop 3. Indien nog niet geeindigd kom met een exit: Indien goede exit (door groep Camel laten uitscheppen, kost de exit geen goud) *"Ja, de auto is los uit het zand met hulp van de bewoners! Dit heeft ons wel 1 6 goud gekost. Het is gelukt. Groep Albatros gaat vervolgt zijn route naar de goudmijn"*		Einde incident loop 3. Indien nog niet geeindigd kom met een exit: De kudde kamelen is er vandoor! We kunnen weer verder.		Field leader geeft aan Camel door dat ze terug kunnen naar hun eigen route
		Communiceren naar Groep Camel dat ze niet meer naar Groep albatros hoeven.			Als Field leader niet door geeft dat Groep Camel weer terug kan naar eigen route dan: *"Group Camel hier, we hebben begrepen dat Albatros weer verder kan, we vervolgen vanaf nu onze eigen route"*		
ge				*"Groep Beer meldt zich, waypoint 4 bereikt"*			

Waypoint passa		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 5					
				"Groep Beer hier om te bevestigen dat we doorgaan naar de goudmijn"			
Indicent loop 4	30.00				*"Groep Camel meldt zich, we komen nu aan bij checkpoint de goudmijn"*	BSMI en SA3	
		Bevestig ontvangst bericht en Groep Camel mag goud gaan delven					
				"Groep Beer meldt zich, we komen nu aan bij checkpoint de goudmijn"			
		Bevestig ontvangst bericht en Groep Beer mag goud gaan delven					
			"Groep Albatros meldt zich, we komen nu aan bij checkpoint de goudmijn"				
		Bevestig ontvangst bericht en Groep Albatros mag goud gaan delven					
					"Groep Camel meldt zich, we hebben 30 goud"		
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
				"Groep Beer meldt zich, we hebben 60 goud"			
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
			"Groep Albatros meldt zich, we hebben 50 goud"				
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
				"Groep Beer meldt zich, we worden beschoten door een grote groep bandieten we hebben assistentie nodig, we kunnen ze nog even op afstand houden door dynamiet te gooien, maar dat is bijna op."			
		Bevestig ontvangst bericht					
				Info voor vragen van field leader: > 20 bandieten > verscholen > waarschijnlijk komen de schoten uit het oosten			
		Groep Beer, blijf waar je bent en houdt ze op afstand met het dynamiet; er komt snel hulp!					
		Groep Albatros ook naar Groep Beer sturen Groep Camel via een route door of langs het ravijn sturen naar een plek ten oosten van groep B en de schutters, zodat ze hen van achteren aan kunnen vallen.					
				"Groep Beer hier, we hebben nog maar 3 stukken dynamiet, de tijd begint te dringen!"			
		Bevestig ontvangst bericht.					
					"Groep Camel hier, we zijn bij een ravijn aangekomen met vallende rotsblokken en weinig zicht, wat zullen we doen?"		
		Bevestig ontvangst bericht. Plan nieuwe route eromheen (duurt langer) of er doorheen (kost resources, want is gevaarlijk bijvoorbeeld afpakken goud door vijandelijke bewoners)					
					OF, als de route niet door het ravijn gepland was door FL *"Groep Camel hier, we zijn op de plek aangekomen"*		
		Bevestig ontvangst bericht en start de aanval					
			"Groep Albatros hier, we zijn gearriveerd bij groep Beer."				

Einde incident		Bevestig ontvangst bericht NB!!!! het incident is alleen opgelost alsgroep Beer en groep Camel de aanval heeft ingezet! UITLOOP LAATSTE INCIDENT EN OVERGANG NAAR NOMINAAL Het goud wordt verzameld door Albatros die het in de jeep laadt en terug brengt naar het kamp. Op de terugweg moeten ze opgelijnd blijven, dus de jeep zal soms moeten wachten.					
	35.00		exit Indien goede oplossing: hulp van andere groepen dan kost de exit geen goud.	exit Indien goede oplossing: hulp van andere groepen dan kost de exit geen goud. We hebben de bandieten kunnen wegsturen met 40 goud	exit Indien goede oplossing: hulp van andere groepen dan kost de exit geen goud. We zien hier een paadje wat we kunnen nemen langs het ravijn, (de tol is 10 goud).		
			Nominaal				
Waypoint passage	35.00		*"Groep Albatros meldt zich, waypoint 5 gepasseerd"*			BSMI	
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend					
			"Groep Albatros hier, we gaan door naar waypoint 6" Loop door naar volgend waypoint				
Resources	36.40				*"Groep Camel meldt zich, we hebben 2 flessen water voor 12 goud gekocht."*		
		Bevestig ontvangen bericht					Aantekening maken dat Camel 12 minder goud heeft
OOI	37.15		Groep Albatros meldt zich, object of interest gespot een hoop bouwmateriaal op de route, op locatie xx				
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Waypoint passage	37.40			*"Groep Beer meldt zich, waypoint 5 gepasseerd"*	*"Groep Camel meldt zich, waypoint 5 gepasseerd"*		
		Bevestig ontvangen bericht Beer en geeft opdracht door te gaan naar volgend Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend					
				"Hier Groep Beer, we gaan door naar waypoint 6"	*"Hier Groep Camel, we gaan door naar waypoint 6"*		
		Bevestig ontvangen bericht					
	38.40		*"Groep Albatros meldt zich, waypoint 6 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 7					
			"Groep Albatros gaat door naar checkpoint C"				
Waypoint passage	40.25				*"Groep Camel meldt zich, waypoint 6 gepasseerd"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 7			*"Groep Camel hier, we gaan door naar chekcpoint C"*		
				"Hier Groep Beer, waypoint 6 gepasseerd"			
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend checkpoint C				BSMI en SA4	
				Hier Groep Beer, we gaan naar Checkpoint C			
Resources	41.15		*"Groep Albatros meldt zich, we hebben 1 fles water voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
	42.00				*"Groep Camel meldt zich, we komen nu aan bij checkpoint C"*		
		Bevestig ontvangen bericht					

			"Groep Albatros meldt zich, we komen nu aan bij checkpoint C"				
		Bevestig ontvangen bericht					
		"Field leader voor Groep Beer, iets sneller naar het volgende checkpoint zodat jullie opgelijnd blijven met de andere groepen"					
				"Groep Beer voor Field leader, we zullen proberen zo snel mogelijk bij ons checkpoint te komen."			
				Ga sneller lopen naar checkpoint C			
Checkpoint	42.30			*"Groep Beer meldt zich, we zijn bij checkpoint C"*			
		Bevestig ontvangen bericht					
		Field leader voor Groep Albatros, jullie kunnen je route vervolgen					
			"Groep Albatros, we vervolgen onze route"				
		Field leader voor Groep Beer, jullie kunnen je route vervolgen	Verder lopen naar volgend checkpoint D				
				"Groep Beer, we vervolgen onze route"			
		Field leader voor Groep Camel, jullie kunnen je route vervolgen		Verder lopen naar volgend checkpoint D			
					"Groep Camel, we vervolgen onze route" Verder lopen naar volgend checkpoint D		
				Groep Beer hier, object of interest gespot een auto wrak.			
OOI		Bevestig ontvangen bericht					Geef OOI aan op map/ CZMan
	44.00		*"Groep Albatros meldt zich, wij zijn aangekomen bij het veldkamp, checkpoint D"*				
		Bevestig ontvangen bericht					
				"Groep Beer meldt zich, wij zijn aangekomen bij het veldkamp, checkpoint D"			
		Bevestig ontvangen bericht					
					"Groep Camel meldt zich, we zijn aangekomen bij het veldkamp, checkpoint D"		
Checkpoint	45.00	Bevestig ontvangen bericht					
Experiment leider geeft einde scenario aan							

Adopted from Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink (2011)

A.2 Script Bravo

Naam handlanger: Conditie: CZMan / Map **BRAVO**
Datum: PP nummer:

	Tijd (min. sec)	Field leader	A	B	C	Measures	Verwacht gedrag field leader
			Nominaal				
Verlaten veldkamp	0.00	*"Groep Albatros, jullie mogen het veldkamp verlaten"*					
			"Groep Albatros meldt zich, verlaat veldkamp"				
		Bevestig ontvangen bericht	A begint te lopen in omgeving				
		"Groep Beer, jullie mogen het veldkamp verlaten"					
				"Groep Beer meldt zich, verlaat veldkamp"			
		Bevestig ontvangen bericht		B begint te lopen in omgeving			
		"Groep Camel, jullie mogen het veldkamp verlaten"					
					"Groep Camel meldt zich, verlaat veldkamp"		
		Bevestig ontvangen bericht			C begint te lopen in omgeving		
Waypoint passage	1.05		*"Groep Albatros meldt zich, waypoint 1 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 2					Passage waypoint aangeven op map/ CZMan
			"Groep Albatros hier, we gaan door naar waypoint 2"				
			Loop door naar volgend waypoint				
Resources	1.40				*"Groep Camel meldt zich, we hebben 2 flessen water voor 12 goud gekocht."*		
		Bevestig ontvangen bericht					Aantekening maken dat Camel 12 minder goud heeft
Waypoint passage	2.40			*"Groep Beer meldt zich, waypoint 1 gepasseerd"*	*"Groep Camel meldt zich, waypoint 1 gepasseerd"*		
		Bevestig ontvangen bericht Beer en geeft opdracht door te gaan naar volgend waypoint 2					Passage waypoint aangeven op map/ CZMan
		Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend waypoint 2					
				"Hier Groep Beer, we gaan door naar Checkpoint A"	*"Hier Groep Camel, we gaan door naar checkpoint A"*		
		Bevestig ontvangen bericht					Passage waypoint aangeven op map/ CZMan
	3.40		*"Groep Albatros meldt zich, waypoint 2 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					Passage waypoint aangeven op map/ CZMan
			"Groep Albatros gaat door naar Checkpoint A"				
Checkpoint	4.10				*"Groep Camel meldt zich, we komen nu aan bij checkpoint A"*		Aangeven dat C checkpoint heeft bereikt
		Bevestig ontvangen bericht *Groep Camel, blijf op deze positie*					
		Field leader voor Groep Albatros, iets sneller naar het checkpoint A zodat jullie opgelijnd blijven met de andere groepen'					
			"Groep Albatros voor Field leader, we proberen zo snel mogelijk bij ons checkpoint aan te komen."				
		Field leader voor Groep Beer, iets sneller naar het checkpoint A zodat jullie opgelijnd blijven met de andere groepen'					
				"Groep Beer hier, we proberen zo snel mogelijk bij ons checkpoint aan te komen."			
	5.30		*"Groep Albatros meldt zich, we zijn bij checkpoint A"*			BSMI	
		Bevestig ontvangen bericht					Aangeven dat A checkpoint heeft bereikt
	6.00			*"Groep Beer meldt zich, checkpoint A bereikt"*			
		Bevestig ontvangen bericht *Field leader voor Groep Albatros, jullie kunnen je route vervolgen*					Aangeven dat B checkpoint heeft bereikt
			"Groep Albatros, we vervolgen onze route"				
		Field leader voor Groep Beer, jullie kunnen je route vervolgen	Verder lopen naar volgend checkpoint B				

		Field leader voor Groep Camel, jullie kunnen je route vervolgen		*"Groep Beer, we vervolgen onze route"* Verder lopen naar volgend checkpoint B			
					"Groep Camel, we vervolgen onze route" Verder lopen naar volgend waypoint		
Waypoint passage	7.25				*"Groep Camel meldt zich, waypoint 2 gepasseerd"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					Passage waypoint aangeven op map/ CZMan
					"Groep Camel hier, we gaan door naar checkpoint B"		
Resources	8.15		*"Groep Albatros meldt zich, we hebben 1 fles water voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
OOI	8.30				Groep Camel meldt zich, object of interest gespot een autowrak op locatie xx		
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Checkpoint	9.00				*"Groep Camel meldt zich, we komen nu aan bij checkpoint B"*		
		Bevestig ontvangen bericht					Aangeven dat C checkpoint heeft bereikt
			"Groep Albatros meldt zich, we komen nu aan bij checkpoint B"				
		Bevestig ontvangen bericht "Field leader voor Groep Beer, iets sneller naar het volgende checkpoint zodat jullie opgelijnd blijven met de andere groepen"					Aangeven dat A checkpoint heeft bereikt
				"Groep Beer voor Field leader, we zullen proberen zo snel mogelijk bij ons checkpoint te komen." Ga sneller lopen naar checkpoint B			
				"Groep Beer meldt zich, we zijn bij checkpoint B"			
		Bevestig ontvangen bericht *Field leader voor Groep Albatros, jullie kunnen je route vervolgen*					Aangeven dat B checkpoint heeft bereikt
			"Groep Albatros, we vervolgen onze route" Verder lopen naar volgend waypoint 3				
		Field leader voor Groep Beer, jullie kunnen je route vervolgen					
				"Groep Beer, we vervolgen onze route" Verder lopen naar volgend waypoint 3			
		Field leader voor Groep Camel, jullie kunnen je route vervolgen					
					"Groep Camel, we vervolgen onze route" Verder lopen naar volgend waypoint 3		
Resources	10.05			*"Groep Beer meldt zich, we hebben 1 fles water voor 6 goud gekocht."*			
		Bevestig ontvangen bericht				BSMI en SA1	Aantekening maken dat Beer 6 minder goud heeft
Waypoint passage	11.00			*"Groep Beer meldt zich, waypoint 2 gepasseerd"*			
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 3					Passage waypoint aangeven op map/ CZMan
				"Groep Beer hier, we gaan door naar waypoint 3"			
Waypoint passage	12.15				*"Groep Camel meldt zich, waypoint 3 gepasseerd"*		
			"Groep Albatros meldt zich, waypoint 3 gepasseerd"				
		Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend waypoint 4					Passage waypoint aangeven op map/ CZMan
					"Hier Groep Camel, we gaan door naar waypoint 4"		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 4					Passage waypoint aangeven op map/ CZMan
			"Groep Albatros gaat door naar waypoint 4"				

Resources	14.00		*"Groep Albatros meldt zich, we hebben eten voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
	15.00						
			Off-nominaal				
Incident loop 1	15.00		*"Groep Albatros meldt zich, we hebben water nodig, maar de waterput op onze route is leeg. Is er een andere waterput in de buurt?"*				
		Bevestig ontvangen bericht Field leader moet naar een oplossing zoeken	Indien de oplossing wordt gevonden kan Albatros nieuwe events introduceren (zie hieronder) tot scenariotijd 20 minuten is.				
			"Groep Albatros meldt zich er is een blokkade op de weg, kunnen we er op een andere manier komen"				
			"Groep Albatros meldt zich, we zien de waterput, maar de route er naar toe wordt verhinderd door een kudde kamelen"				
			"Groep Albatros meldt zich, we zijn aangekomen bij de waterput, maar er hangt geen emmer aan. "			BSMI	
Einde incident	19.40		Einde incident loop 1. Indien nog niet geeindigd kom met een exit:				
			Indien goede oplossign (naar waterput) kost de exit geen goud.				
			"We hebben nu water nodig en we kunnen de waterput niet bereiken. Bewoners hier kunnen ons water verkopen, we kopen 2 flessen voor 24 goud. Helaas wel het dubbele aan kosten, maar we hebben wel water!"				
Waypoint passage	16.30			*"Groep Beer meldt zich, waypoint 3 bereikt"*			
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar de goudmijn					
				"Groep Beer hier om te bevestigen dat we doorgaan naar de goudmijn"			
OOI	18.30			Groep Beer meldt zich, object of interest gespot een autowrak op locatie xx			
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Waypoint passage	18.25				*"Groep Camel hier, we zijn nu bij waypoint 4"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 5					
					"Groep Camel, we gaan door naar het volgende waypoint 5"		
Incident loop 2	*19.50*			*FL hier Groep Beer, over.*			
		Groep Beer hier FL, over.				BSMI en SA2 (na incident 1)	
				"Groep Beer hier, er staat een groep midden op de weg, misschien is er een ongeluk gebeurd, maar het zou ook een barricade kunnen zijn? We kunnen het niet goed zien! Moeten we onze weg vervolgen of een andere route nemen? over"			
		Bevestig ontvangen bericht					
			FL hier Groep Albatros, over.				
		Groep Albatros hier FL, over					
	20.30		*"Groep Albatros hier, we zitten zonder benzine. We hadden een extra tank, maar deze zijn we onderweg ergens verloren. Is er een dorp dichtbij, zodat we kunnen tanken? Over."*				
		Vraag B om info over de groep					

Einde incident				Desgevraagd "*Info over groep: het lijken alleen mannen te zijn en ze zijn erg rumoerig.*"			
		Beslissing nemen over te volgen route Group Beer en dit mededelen					
	24.40		Einde incident loop 2. Indien nog niet geeindigd kom met een exit: *FL hier Groep Albatros, over.*	Einde incident loop 2. Indien nog niet geeindigd kom met een exit:			
		Groep Albatros hier FL, over					
			Indien goede exit (naar dichtsbijzijnde dorp) kost de exit geen goud. "*We van een bewoner benzine gekregen. We kunnen dus weer verder. We hebben ze 10 goud moeten betalen. Over en uit.*"	Indien goede exit (omleiding) kost de exit geen goud.			
				FL hier Groep Beer, over.			
		Groep Beer hier FL, over.		*"De groep mensen kwam op ons af, heeft 10 goudstukken van ons gestolen, maar is daarna weggerend. We kunnen dus weer verder. Over en uit."*			
Waypoint passage	22.00				"Groep Camel meldt zich, waypoint 5 gepasseerd"		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar de goudmijn					Passage waypoint aangeven op map/ CZMan
					"Groep Camel gaat door naar de goudmijn"		
OOI	23.00				Groep Camel meldt zich, object of interest gespot een lading vaten op de route, op locatie xx		
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Incident loop 3	25.05				*"Group Camel meldt zich, er heeft een lawine plaatsgevonden en de weg is geblokkeerd. We kunnen het puin zelf niet opruimen, omdat er grote rotsblokken inzitten die we niet kunnen verschuiven."*	BSMI	
		Groep Beer naar Camel sturen met het dynamiet					
				Groep Beer gaat op weg naar Camel maar komt onderweg vast te zitten.			
							Detour plannen op Map/ CZMan
		Stuur Groep Camel naar een nabijgelegen paadje			*"Group Camel hier, daar kunnen we ook niet langs, alles is onbegaanbaar."*		
				Komt roadblock tegen en route moet herpland worden.			
Einde incident	29.40			Einde incident loop 3. Indien nog niet geeindigd kom met een exit:	Einde incident loop 3. Indien nog niet geeindigd kom met een exit: Indien goede exit (hulp van Beer) kost exit geen goud. "*Met de hulp van omstanders hebben we de grote rotsblokken weg kunnen duwen. Dit heeft ons wel 12 goud gekost*" Groep Camel vervolgt zijn weg naar Waypoint X.		
		Communiceren naar Groep Camel dat ze niet meer naar Groep albatros hoeven.		Als Field leader niet door geeft dat Groep Beer weer terug kan naar eigen route dan: Group Beer hier, we hebben begrepen dat Camel weer verder kan, we vervolgen vanaf nu onze eigen route			
nt passage	27.00		*"Groep Albatros meldt zich, waypoint 4 bereikt"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 5					Passage waypoint aangeven op Map/ CZMan

Waypoi			*"Groep Albatros hier om te bevestigen dat we doorgaan naar de waypoint 5"*				
Waypoint passage	28.00		*"Groep Albatros meldt zich, waypoint 5 bereikt"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint de goudmijn					Passage waypoint aangeven op Map/ CZMan
			"Groep Albatros hier om te bevestigen dat we doorgaan naar de goudmijn"				
Indicent loop	30.00				*"Groep Camel meldt zich, we komen nu aan bij de goudmijn"*	BSMI en SA3	
		Bevestig ontvangst bericht en Groep Camel mag goud gaan delven					
				"Groep Beer meldt zich, we komen nu aan bij de goudmijn"			
		Bevestig ontvangst bericht en Groep Beer mag goud gaan delven					
			"Groep Albatros meldt zich, we komen nu aan bij de goudmijn"				
		Bevestig ontvangst bericht en Groep Albatros mag goud gaan delven					
					"Groep Camel meldt zich, we hebben 50 goud"		
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
				"Groep Beer meldt zich, we hebben 60 goud"			
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
			"Groep Albatros meldt zich, we hebben 30 goud"				
		Bevestig ontvangst bericht en Groep Camel mag terug op weg naar field camp gaan					
				"Group Beer meldt zich, er komt een enorme zandstorm opzetten. We kunnen weinig zien en onze voortgang is te langzaam om op tijd op het field camp te zijn. Op deze manier verliezen we onze goudstukken!"			
		Bevestig ontvangst bericht Groep Beer, blijf waar je bent en bescherm het goud; er komt snel hulp!		*Groep Beer meldt zich, de zandstorm zorgt er voor dat onze goudstukken kwijt raken! Komt de hulp snel?!* *We zien geen hand voor ogen! Waar blijft de hulp!?*			
		Groep Ablatros, ga naar locatie XX om Groep Camel te helpen bij het vervoer van hun goud.					
			"Groep Albatros hier, wij gaag Groep Beer helpen"				
					Groep Camel meldt zich, 1 van onze groepsleden heeft een zonnesteek, we kunnen niet verder lopen en we hebben water nodig.		
		Bevestiging ontvangst bericht Groep Camel, leg de zieke op een stretcher					
					Groep Camel hier, dat doen we.		
		Groep Camel voor water moeten jullie naar loctie XX, loop met de stretcher daar heen.					
					Groep Camel hier, dat doen we, de zieke is dan wel geholpen maar op deze manier zijn we niet op tijd op de field camp met ons goud!		
		Groep Albatros, kunnen jullie nadat jullie Groep Beer uit de zandstorm hebben gehaald, hen afzetten op een locatie waar geen storm is en dan de zieke ophalen?					
			Groep Albatros hier, dat kunnen we doen.				
			Indien tijd tot 35 min. nog niet vol: Roadblock tegen komen *Indien goede exit (Beer en Camel helpen) kost exit geen goud.*	Dekking zoeken en Albatros maar niet kunnen zien Indien goede exit (hulp van Albatros) kost exit geen goud.	Te langzaam vooruit gaan met zieke op stretcher Indien goede exit (naar Albatros toe) kost exit geen goud.		

Einde incident	35.00		Groep Albatros hier, we zijn zo snel gereden, dat we 12 goud kwijt zijn.	Exit: Groep Beer hier de storm is voorbij! We zijn wel 12 goud kwijt geraakt.	Exit: Groep Camel hier, we hebben water gekocht voor 6 goud, en met het groepslid gaat het gelijk beter, we zijn op weg naar het field camp.		
			Nominaal				
Waypoint passage	35.00		*"Groep Albatros meldt zich, waypoint 6 gepasseerd"*			BSMI	
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend waypoint 7					Passage waypoint aangeven op map/ CZMan
			"Groep Albatros hier, we gaan door naar waypoint 7				
			Loop door naar volgend waypoint 7				
Resources	36.40				*"Groep Camel meldt zich, we hebben 2 flessen water voor 12 goud gekocht."*		
		Bevestig ontvangen bericht					Aantekening maken dat Camel 12 minder goud heeft
OOI	37.15		Groep Albatros meldt zich, object of interest gespot een hoop bouwmateriaal op de route, op locatie xx				
		Bevestig ontvangen bericht					Op CZMan/ Map aangeven dat OOI is gespot
Waypoint passage	37.40			*"Groep Beer meldt zich, waypoint 4 gepasseerd"*	*"Groep Camel meldt zich, waypoint 6 gepasseerd"*		
		Bevestig ontvangen bericht Beer en geeft opdracht door te gaan naar volgend checkpoint D					Passage waypoint aangeven op map/ CZMan
		Bevestig ontvangen bericht Camel en geeft opdracht door te gaan naar volgend waypoint 7					
				"Hier Groep Beer, we gaan door naar checkpoint C"	*"Hier Groep Camel, we gaan door naar waypoint 7"*		
		Bevestig ontvangen bericht					Passage waypoint aangeven op map/ CZMan
	38.40		*"Groep Albatros meldt zich, waypoint 7 gepasseerd"*				
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend Checkpoint C					Passage waypoint aangeven op map/ CZMan
			"Groep Albatros gaat door naar waypoint Checkpoint C"				
Waypoint passage	40.25				*"Groep Camel meldt zich, waypoint 7 gepasseerd"*		
		Bevestig ontvangen bericht en geeft opdracht door te gaan naar volgend checkpoint C					Passage waypoint aangeven op map/ CZMan
					"Groep Camel hier, we gaan door naar checkpoint C"	BSMI en SA4	
Resources	41.15		*"Groep Albatros meldt zich, we hebben 1 fles water voor 6 goud gekocht."*				
		Bevestig ontvangen bericht					Aantekening maken dat Albatros 6 minder goud heeft
Checkpoint	42.00				*"Groep Camel meldt zich, we komen nu aan bij checkpoint C"*		
		Bevestig ontvangen bericht					Aangeven dat C checkpoint heeft bereikt
			"Groep Albatros meldt zich, we komen nu aan bij checkpoint C"				
		Bevestig ontvangen bericht "Field leader voor Groep Beer, iets sneller naar het volgende checkpoint zodat jullie opgelijnd blijven met de andere groepen"					Aangeven dat A checkpoint heeft bereikt
				"Groep Beer voor Field leader, we zullen proberen zo snel mogelijk bij ons checkpoint te komen." Ga sneller lopen naar checkpoint C			
	42.30			*"Groep Beer meldt zich, we zijn bij checkpoint C"*			
		Bevestig ontvangen bericht *Field leader voor Groep Albatros, jullie kunnen je route vervolgen*					Aangeven dat B checkpoint heeft bereikt
			"Groep Albatros, we vervolgen onze route" Verder lopen naar volgend checkpoint D				
		Field leader voor Groep Beer, jullie kunnen je route vervolgen					

OOI		Bevestig ontvangen bericht		Groep Beer hier, object of interest gespot een auto wrak.	*"Groep Camel, we vervolgen onze route"* Verder lopen naar volgend checkpoint D		Geef OOI aan op map/ CZMan
Checkpoint	44.00		*"Groep Albatros meldt zich, wij zijn aangekomen bij het veldkamp, checkpoint D"*				
		Bevestig ontvangen bericht					
				"Groep Beer meldt zich, wij zijn aangekomen bij het veldkamp, checkpoint D"			
		Bevestig ontvangen bericht					
					"Groep Camel meldt zich, we zijn aangekomen bij het veldkamp, checkpoint D"		
	45.00	Bevestig ontvangen bericht					
	Experiment leider geeft einde scenario aan						

Adopted from Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink (2011)

B Situational Awareness Questionnaire

VRAGEN SCENARIO ALPHA.

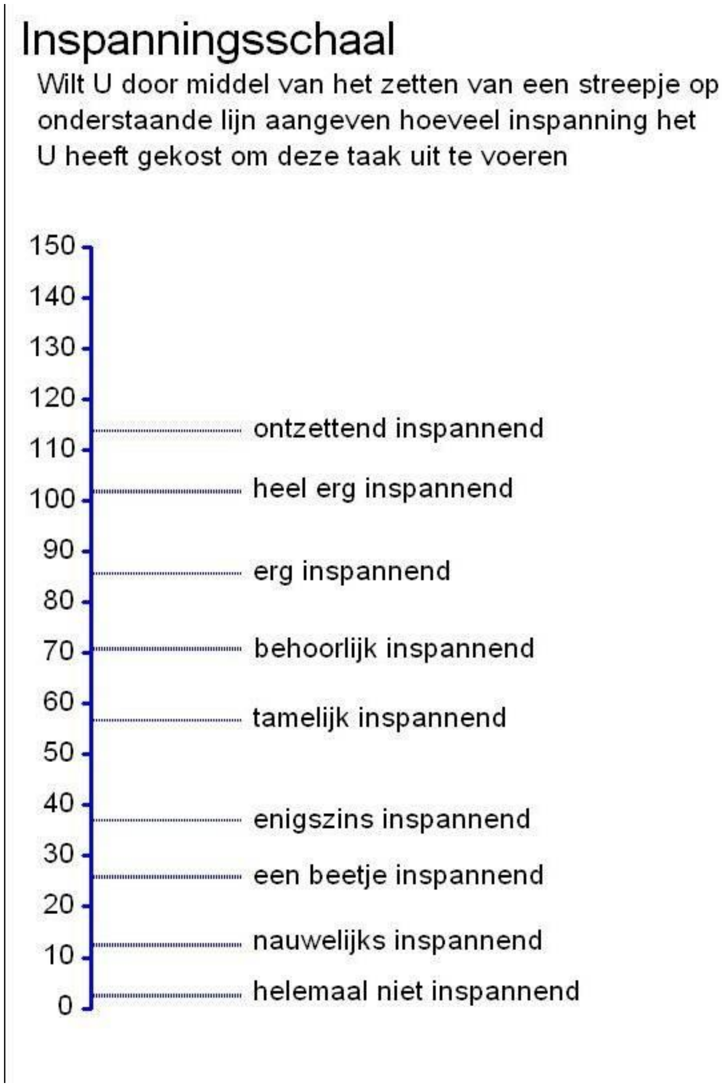
Niveau	Vraag	Antwoord
Perception	1. Hoeveel goud heeft groep Albatros nu?	
Comprehension	2. Welke twee groepen zijn nu het dichtstbij elkaar?	
Projection	3. Als groep Camel nu een blokkade tegenkomt, is de kortste route naar de goudmijn dan naar links of rechts?	
Perception	4. Welk incident is groep Beer nu in betrokken?	
Comprehension	5. Welke twee groepen zijn nu het dichtstbij het veldkamp?	
Projection	6. Stel dat groep Camel nu een incident tegenkomt, welke groep is dan het dichtstbij hen?	
Perception	7. Welk incident is groep Camel nu in betrokken?	
Comprehension	8. Welke twee groepen zijn nu het dichtstbij elkaar?	
Projection	9. Stel dat groep Albatros nu een incident tegenkomt, welke groep is dan het dichtstbij hen?	
Perception	10. Welk incident is groep Albatros tegengekomen?	
Comprehension	11. Welke twee groepen zijn nu het dichtstbij de goudmijn?	
Projection	12. Als groep Beer nu een blokkade tegenkomt, is de kortste route naar het veldkamp dan naar links of rechts?	

VRAGEN SCENARIO BRAVO

Niveau	Vraag	Antwoord
Perception	1. Hoeveel goud heeft groep Camel nu?	
Comprehension	2. Welke twee groepen zijn nu het dichtstbij elkaar?	
Projection	3. Als groep Albatros nu een blokkade tegenkomt, is de kortste route naar de goudmijn dan naar links of rechts?	
Perception	4. Welk incident is groep Beer nu in betrokken?	
Comprehension	5. Welke twee groepen zijn nu het dichtstbij het veldkamp?	
Projection	6. Stel dat groep Camel nu een incident tegenkomt, welke groep is dan het dichtstbij hen?	
Perception	7. Welk incident is groep Camel nu in betrokken?	
Comprehension	8. Welke twee groepen zijn nu het dichtstbij elkaar?	
Projection	9. Stel dat groep Albatros nu een incident tegenkomt, welke groep is dan het dichtstbij hen?	
Perception	10. Welk incident is groep Albatros tegengekomen?	
Comprehension	11. Welke twee groepen zijn nu het dichtstbij de goudmijn?	
Projection	12. Als groep Beer nu een blokkade tegenkomt, is de kortste route naar het veldkamp dan naar links of rechts?	

Adopted from Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink (2011)

C Rating Subjective Mental Effort (RSME) Questionnaire



Adopted from Streefkerk, Smets, Jansen, Varkevisser, Marcelis & Besselink (2011)

D Descriptive Statistics Cognitive Control Tasks

Table 4: **Descriptive Statistics**

Tasks and Measures	N	Range	Min.	Max.	Mean	SD	Variance	Skew.	Kurt.
2-back									
RT (ms)[a]	16	497,34	582,66	1080	850,56	164,33	27005,24	0,008	-1,269
Correct (%)	16	0,42	0,53	0,95	0,75	0,13	0,02	-0,054	-0,933
Incorrect (%)	16	0,42	0,05	0,47	0,25	0,13	0,02	0,054	-0,933
Number Classification									
RT non-switch (ms)[b]	16	244,2	486,77	730,97	588,11	76,1	5791,82	0,385	-0,683
RT switch (ms)[c]	16	723,47	780,36	1503,82	1156,81	182,65	33362,38	0,164	0,273
Correct non-switch (%)	16	0,11	0,89	1	0,96	0,04	0,001	-0,876	-0,224
Correct switch (%)	16	0,45	0,53	0,98	0,84	0,12	0,025	-1,158	1,151
Switch effect RT (ms)[d]	16	656,41	253,85	910,26	568,7	163,21	26635,95	0,313	0,514
Switch effect correct (%)[e]	16	0,45	-0,05	0,41	0,12	0,12	0,014	0,901	0,651
Stroop									
RT congruent (ms)	16	267,85	912,25	1180,1	1032,45	74,33	5524,89	0,467	-0,216
RT incongruent (ms)	16	558,75	1007,42	1566,17	1216,29	177,41	31475,68	0,862	-0,087
Stroop effect (ms)[f]	16	566,24	-12,25	553,99	183,84	150,31	22594,02	0,873	1,043

[a] RT: Response Time
[b] Non-switch: trials in which only one classification rule had to be applied
[c] Switch: trials in which two classification rules had to be applied
[d] Switch effect RT: difference in response time between the switch and the non-switch trials
[e] Switch effect correct: difference in the percentage of correct trials between the switch and the non-switch trials
[f] Stroop effect: difference in response time between the incongruent and the congruent trial

E Communication Coding Scheme

Labels Communications	Description
General	
o	Opening a conversation by calling the addressee of a message/responding to the opening of a conversation
c	Very short confirmation (e.g., “copy that”, “understood”)
p [+ no. of the problem]	A message concerning a problem
a	A message that does not concern a problem or that concerns an ended problem (SUCCESS/EXIT)
Field Leader	
SOL+/- p[+ no. of the problem]	A proposed correct (+) or incorrect (-) solution (SOLution) to a problem
SOLEX +/- p[+ no. of the problem]	The execution of a proposed correct (+) or incorrect(-) solution (SOLution EXecuted) to a problem
Group Leader	
INIT p[+ no. of the problem]	Initiate/report a problem
SUCCESS p[+ no. of the problem]	Report a problem being solved successfully by executing the FL’s proposed solution
EXIT p[+ no. of the problem] (minus # gold)	Report a problem being solved (with possibly additional costs)

Table 5: **Coding scheme communications**