11TH ICCRTS
COALITION COMMAND AND CONTROL IN THE NETWORKED ERA

Title of Paper:
Military Self-synchronization: An Exploration of the Concept

Name of Authors:
B. J. A. van Bezooijen, P. J. M. D. Essens, A. L. W. Vogelaar

Topics:
C2 Experimentation, Network-Centric Measures

Point of Contact:
B. J. A. van Bezooijen

Name of Organization
Tilburg University

Address:
Warandelaan 2, 5037 AB Tilburg, The Netherlands

Telephone:
+31 76 527 3248

E-mail Address:
B.J.A.vanBezooijen@uvt.nl

Introduction

Literature on Network Centric Warfare (NCW) places much emphasis on self-synchronization, a term used by Alberts, Gartska, and Stein (1999) to describe the operating of entities in the absence of traditional hierarchical mechanisms for command and control. According to the tenets of NCW, self-synchronization is the link between shared situational awareness and mission effectiveness (Alberts & Hayes, 2005). The importance of the concept is further illustrated in their most recent book "Understanding Command and Control" where Albert and Hayes (2006) highlight that: "The magic of NCW is the emergence of self-synchronizing behavior" (Alberts, Gartska, and Stein 1999, p. 175, in: Albert & Hayes, 2006, p. 2). Moreover, Alberts and Hayes (2006) claim that self-synchronization leads to dramatic increases in both force agility and effectiveness (p. 2).

Given the suggested importance of the concept and the massive amount of NCW research studies contributing to the Information Age Transformation of the U.S. Military and the modernization of European militaries, one would expect that a lot of attention is devoted to the development of the concept of self-synchronization. Self-synchronization after all has been present in NCW literature since Cebrowski and Gartska (1998) introduced the concept in their classical article "Network-Centric Warfare: Its Origin and Future". However, little research has been conducted on the concept of self-synchronization in the field of command and control. The word self-synchronization gives no hits in psychological databases such as PsychInfo. Only recently a few articles explicitly take the concept into account, such as the article on cognitive readiness by Wesensten, Belenky, and Balkin (2005). The lack of empirical research may be due to the difficulties that researchers experience when they study the concept. Alberts and Hayes (2005) conclude that -similar to the related concept of shared awareness- the concept of self-synchronization is difficult to operationalize. Researchers have adopted a diverse set of approaches, ranging from no operationalization at all (Wesensten et al., 2005) to a qualitative interpretation of the conceptual definitions, such as Adkins and Kruse (2003). These authors based the findings of their exploratory case study on detailed stories from personnel of a nuclear air craft carrier during the execution of Operation Enduring Freedom (OEF). Evidence for self-synchronization is derived from the information that is obtained about the collaboration style, understanding of the commander's intent and shared situation awareness.

In short, the importance that is attributed to self-synchronization in the literature stands in sharp contrast with our knowledge of the construct. There is little quantitative evidence that self-synchronization functions in the ways it is said to function in NCW literature (see: Alberts, Gartska, and Stein, 1999; Alberts and Hayes, 2003; 2006). Building a body of knowledge on self-synchronization obliges us to go beyond mere anecdotes and qualitative findings. That there is a clear need for a more systematic approach to C2 and NCW related constructs is endorsed in publications such as Alberts and Hayes (2005) "Campaigns of Experimentation" and the Code of Best Practice (COBP) for C2 Assessment. Innovation and experimentation are necessities for military transformation (Alberts and Hayes, 2005; p. 54). This article contributes is indented contribute to a more systematic approach by elaborating the concept self-synchronization.

This article is intended to serve three goals. The first goal is to gain more insight in the concept self-synchronization. We will discuss self-synchronization as it appears in a number of research areas, and seek to apply this knowledge to a military context. The second goal is

to give an overview of the factors that influence military self-synchronization. Finally, we discuss what further research needs to be done.

What is self-synchronization?

The term synchronization is derived from the Greek words $\sigma\upsilon\nu$ (syn = common, together) and $\chi\rho o\nu o\varsigma$ (chronos = time), meaning *shared* or *common time*. The notion of two interacting systems oscillating at the same time was introduced to classical physics in the 17th century by Christian Huygens, the great Dutch astronomer, mathematician, and physicist (Blehkman, Fradkov, Nijmeijer, & Pogromsky, 1997; Blehkman, Fradkov, Tomchina, & Bogdanov, 2002; Pogromsky, Belykh, & Nijmeijer, 2003). Huygens detected that a couple of mechanical clocks hanging from a common support were synchronized, i.e. their oscillations coincided perfectly and the pendula moved in opposite directions (Pogromsky et al., 2003). When disturbed, this antiphase state was restored within a half-hour and persisted indefinitely[1].

Synchronization phenomena have been studied in mathematics, physics, biology, as well as in various fields of mechanical and electrical engineering (Blehkman, et al., 2002). The research campaigns on synchronization phenomena are at the basis of modern electronics and its importance is illustrated by the high number of scientific contributions in this field (Pogromsky et al., 2002).

Blehkman et al. (2002) pointed out that synchronization processes either resulted from natural interaction or from some sort of intervention. This latter class is labelled forced, or controlled, synchronization. Anyone who observes the vibrations of a washing machine during the first seconds of wringing is familiar with controlled synchronization (Pogromsky et al., 2002). Alternatively, the synchronization of Huygens' mechanical clocks resulted from natural synchronization. Following the reasoning of Blehkman et al. (2002), self-synchronization is by definition the result of natural interaction because self-synchronization occurs when: "(…) the synchronous regime arises due to natural properties of the processes themselves and their natural interaction". When applied to a military context, we consider the distinction between controlled and natural synchronization to be similar to the distinction between pre-planned synchronization and self-synchronization, respectively. The studies that Blehkman et al. (2002) refer to may be valuable for studying self-synchronization because this research area that has a long-term, quantitative research tradition regarding synchronization phenomena.

In another field of research Triandis (1989) linked synchronization to human behavior. In his classical article on the three aspects of the self (private, public, collectivist), Triandis (1989) illustrated the impact of culture on interaction. Triandis (1989) distinguished three factors that influence interaction: personalization, synchronization, and difficulty. Synchronized interaction is considered effortless and well coordinated. Collectivist cultures are more personalized and synchronized and less difficult than individualistic cultures (Triandis, 1989). Without going into the voluminous research areas of culture and communication, Triandis' findings illustrate that synchronization phenomena can be linked to human behavior.

Complexity theory is another context in which self-synchronization is addressed (see: Atkinson and Moffat, 2005; Costanza, 2003). Alberts, Gartska, and Stein (1999) claim that: "There is ample historical precedence for the coevolution of organization, doctrine, and technology in the warfighting ecosystem (p. 3). Following the logic of complexity theory, a

[1] www.physics.gatech.edu/Schatz/clocks.html

chaotic system will self-organize into a complex system when the number of degrees of freedom increases. Atkinson and Moffat (2005) apply the principle of self-organization to the military (p. 37). The central premise regarding self-organization is that a system is 'open' (Atkinson and Moffat, 2005). This means that energy (or information) can float into or out of the system. For an ecosystem, so describe Atkinson and Moffat (2005), the number of interacting species determine whether the system is characterized by simple or linear behaviour (few interacting species) or by complex nonlinear behaviour (large number of species).

We feel that the assumption that a large number of species leads to a large number of degrees of freedom is an issue in this respect. The large number of degrees of freedom results in an equilibrium state of the system because of the emergence of ordered behaviour (for a detailed description, see Atkinson & Moffat, 2005). There is, however, a range of factors that influence self-synchronization in an operational environment that is not considered in complexity theory (units get ambushed, experience sleep and food deprivation, to name a few). The translation of the principles of complexity theory to a military context therefore may require a more delicate approach and should also consider organizational issues, command and control issues, and human factors.

A military perspective on self-synchronization.
Just as synchronization phenomena have been subject of discussion in various research areas since the 17th century, synchronization was also used in a military context far before NCW was introduced. Kaufman (2000) pointed out that synchronization has been the foundation of warfare throughout all of history because synchronized behaviours of several units make military operations effective.

The term synchronization is used in various national doctrines to describe the process of coordinating, or orchestrating units on the battlefield. The synchronization of units functions as a force multiplier, because the careful orchestrating of effects can create a synergetic effect on combat power. Operations that are specifically designed in order to create this synergy are labelled Effects Based Operations (EBO). This creation of synergy is what distinguishes synchronization from mere coordination and has become an essential part of joint doctrine (Kirin, 1996). The synchronization of effects is also formalized in the Dutch doctrine. In this doctrine the *synchronization matrix* is used for the creation of the massing of effects (e.g. Leidraad Commandovoering I, 2000).

The concept self-synchronization was defined by Cebrowski and Gartska (1998): "Self-synchronization is the ability of a well-informed force to organize and synchronize complex warfare activities from the bottom up". Although this definition is referred to in most articles on military self-synchronization unity is lacking. There is a diverse set of definitions of self-synchronization present in NCW research. Kruse and Younger (2002) referred to the coordination of activities even at the individual level, whereas Araki (1999) described self-synchronization as doing the right thing at the right time for the right reason without having to be told to do so. Ahvenainen (2003) placed self-synchronization in an organizational perspective when he defined that: "Self-synchronization is achieving the goals of the organization without or with less leaders than in a hierarchical organization." Ahvenainen (2003) emphasized that self-synchronization is about communicating information prior to the situation. This a priori knowledge enables individuals to self-synchronize because they have a shared understanding of the situation. The differences in the conceptualization of self-synchronization illustrate the broadness of the concept. The former definition focused solely

on the coordination of actions, whereas the other definitions considered individual decision making and organizational goals.

The bottom-up approach of self-synchronization that Cebrowski and Gartska (1998) described, is often illustrated with examples of self-organizing behavior of fireflies, birds, and geese (Araki, 1999; Taddiken, 2002; Wesensten, Belenky & Balkin, 2005). Wesensten, Belenky, and Balkin (2005) placed the discussion on general self-synchronization phenomena in a military perspective. These authors claim that: "Self-synchronization of individuals within groups prosecuting aggressive actions is an ancient practice, likely drawing on cognitive modules shaped by our evolutionary history of hunting and fishing in small groups" (p. 96). NCW, as is argued by Wesensten et al. (2005), enables people to use their innate talents for self-synchronization. These authors further proposed that this ability is located in the prefrontal cortex, along with other functions such as anticipation, planning, initiative, and the integration of reason and emotion. As Araki (1999) pointed out, real bottom-up self-synchronization can only occur when the "bottom" is aware of the problem. He pointed out that self-synchronization in a military context is about information flows, courses of action, chain of command, and commander's intent. These factors are absent in the examples on herding and swarming behavior.

The Stryker Brigade Combat Team case study by RAND (2005) has devoted a considerable amount of effort to self-synchronization. In this study, self-synchronization is defined as the: "Ability of a force to act in a manner coordinated in intent, time, and space with other battlespace entities, without being ordered to do so specifically; synchronization of force entities without direction from their commanders". Here, both the elements of coordination as well as decentralized execution of commander's intent are considered. Another important aspect of self-synchronization is also addressed: the distinction between pre-planned synchronization and self-synchronization. Pre-planned synchronization refers to mission design and the massing of effects. Self-synchronization is observed to work at the individual level.

Empirical research on the concept of self-synchronization.
As can be derived from the above, researchers have distinct ideas on what self-synchronization is and how it works. The question here is how this understanding of the concept was developed. In an attempt to answer this question, we studied the design of the studies and the measurement of military self-synchronization.

The first finding in this respect is rather remarkable. A considerable amount of articles, research reports and books did not actually perform any *research* on the concept. The article by Wesensten, Belenky, and Balkin (2005) is an example of this. When these authors proposed that: "Self-synchronization leads to emergent properties and efficiencies unachievable with top-down direction" (p. 96) and "These executive mental functions (integration of information, anticipating, and planning) depend on the prefrontal cortex of the brain for successful execution" (p. 104), it is not clear whether there is any evidence supporting these claims.

Some researchers applied field experiments for measuring self-synchronization. Here, a 'traditional' unit and an 'NCW' unit were given the same scenario. Performance measures and command and control measures were used in the Stryker Brigade case study (RAND, 2005) to measure self-synchronization. Performance measures that were used are mission accomplishment and the ratio of enemy to friendly force casualties. Command and control

measures are quality of situational awareness, speed of command, quality of decisions, and force synchronization. Due to both theoretical and practical problems, however, these methods did not provide the quantitative data that would allow a quantitative theoretical analysis. The research team reported that they were unable to gather quantitative data for the concepts decision synchronization and action/entity synchronization[2], concepts that were closely connected to self-synchronization. The concept of self-synchronization itself was not measured. The researchers only reported that the squadron decided to attack early, profiting from their NCW capabilities such as abbreviated collaborative planning, sending digital mission-type orders, and conducting effective brigade reconnaissance.

Other studies that used field experiments are Kruse, Younger, and Holloman (2005) and Adkins & Kruse (2003). The Global War Game 2000 was sponsored by the Naval War College and explored the impact of NCW on command and control (Morrison, in Adkins and Kruse (2003). The case study took place during the execution of Operation Enduring Freedom (OEF) aboard the USS Carl Vinson. A number of networking and collaboration tools ware tested for their impact on the planning and execution of missions.
Hutchins, Kleinman, Hocevar, Kemple, and Porter (2001) also conducted a field experiment in which forty-two individuals participated. Here, process and performance variables were measured using observations, self-reports, and log file data.

In most research studies, self-synchronization was studied qualitatively. Adkins and Kruse (2003) used interviews, documents, and physical artefacts in their case study. The interviews were exploratory and therefore open-ended. Another approach is to construct an ad-hoc analysis of an event, such as the analysis of the Battle of Trafalgar (Alberts & Hayes, 2003). The major problem of field experiments is the huge amount of effort that is needed to allow quantitative conclusions. Most field experiments, especially in the complex research area of command and control, consist of a limited amount of teams and therefore mostly lead to qualitative findings.

Fewell and Hazen (2003) acknowledged that no quantitative measure for self-synchronization is available yet. They suggested that an instrument for self-synchronization should focus on the degree of autonomy. The authors gave an example for a quantitative measure, which is the percentage of orders that do not give detailed orders at the level of the subordinate commander.

Subconclusion.
NCW literature lacks an elaborate empirical background, a remark which is stressed even by most researchers. The same conclusion applies to the concept of self-synchronization as well. There is no agreement on the definition of the concept, there are no sound measures for the concept and there have not been hardly any systematic studies.

Factors that influence military self-synchronization

Now that we have explored the concept self-synchronization and established its relevance, we turn to the question what factors are supposed to influence military self-synchronization. We analyzed the concept using a two-fold approach. We first provide an overview of the existing literature on military self-synchronization. Secondly, we held interviews with experienced

[2] We have no information whether this was due to the reported tight timelines of the study

commanders of the Dutch armed forces. In both approaches we distinguished input factors, process factors, output factors, and benefit factors of self-synchronization.

Literature review.
We took a bottom-up approach to the process of determining the factors that influence military self-synchronization. We selected books and articles which explicitly addressed self-synchronization in a military context and tried to identify what factors are considered to be influential (see Table 1 for an overview).

Input variables. Input variables describe what is needed for military self-synchronization; we attempted to identify the prerequisites for the process.
Fewell and Hazen (2003) demonstrated the importance of human factors. These authors showed that self-synchronizing behaviour, such as swarming, requires access to accurate and up-to-date information systems. Such an information system, however, also permits a highly centralized command and control, which is exactly the opposite of what NCW theorists propose as the appropriate command and control approach. An increase in net centricity can in this way result in an increase in centralization of command and control (Fewell & Hazen, 2003). Commanders may not be very willing to "(…) absolve themselves of accountability for lower-level actions of which they are fully aware of, and for which they are ultimately responsible" (Fewell & Hazen, 2003). The increase in centralization in command and control has been observed in Operation Enduring Freedom (Vego, in: Fewell & Hazen, 2003) and during the First Gulf War (Polk; Johnston, in: Fewell & Hazen, 2003). This tendency can be considered to be the paradox of NCW.

Therefore, trust appears to be an important factor for self-synchronization to be successful. Atkinson and Moffat (2005) highlighted the impact of increasing global uncertainty. They proposed that militaries should react to this uncertainty by organizing themselves more loosely. This should enable self-synchronized behavior. According to Atkinson and Moffat (2005), in these environments staffs have to function more autonomously. Commanders will have to rely on the confidence and competence of their staff in this respect. Albert and Hayes (2003) also emphasize the role of trust. They point out that trust in information, people, and equipment is needed for self-synchronization to work effectively. Adkins and Kruse (2003), Costanza (2003), and Hutchins, Kleinman, Hocevar, Kemple, and Porter (2001) also stress that trust is needed for commanders to give up some personal control and rely more on the staff.

The changing role of commanders and their staffs is also described in the Stryker Brigade case study (RAND, 2005). In this report, it is proposed that mission-type orders require more skill, more timely and more accurate knowledge, and greater collaboration between commanders. Leadership therefore seems to be a second factor that has a major impact on self-synchronization. Commanders need new leadership skills, according to Still (2003). Still (2003) proposed that the ability to delegate authority, the ability to clearly communicate commander's intent, and the ability to tolerate risk are the key characteristics of future commanders. A third factor that researchers consider relevant are shared mental models. The need for a commander's intent that is clear to all and having all relevant information shared is widely acknowledged.

In sum, the three factors -trust, leadership, and shared mental models- are considered very important for effective self-synchronization.

Process variables. Regarding the process of self-synchronization, the literature seems rather consistent. Two factors are considered to be important: commander's intent and coordination. The commander's intent is a crucial element in military operations today, and its importance increase when units operate more dispersed and autonomously. The changing role of the commander's intent is discussed in "Understanding command and control" (Alberts and Hayes, 2006). These authors proposed that command intent, or even just 'intent', are better terms for communicating the overall intent of an operation or a mission. Not only intent becomes more important, coordination will also become more important according to the literature. Warne, Ali, Bopping, Hart, and Pascoe (2004) and Kruse and Younger (2002) pointed out that a commander does not only have to consider the commander's intent, but also has to coordinate the efforts of his unit with the efforts of other units.

Wesensten, Belenky & Balkin (2005) describe how self-synchronization works. They propose that highly complex groups organize naturally and from the bottom-up. Here, self-synchronization refers to the nonverbal communication during the process. The authors further claim that NCW will result in a bottom-up oriented organization because the virtual line-of-sight is increased. This bottom-up organization will outperform top-down organizations when it comes to efficiency and achieving common objectives.

Outcome variables. The outcomes of successful self-synchronization processes are straightforward: higher speed of command and better adaptability. Speed of command is described extensively in NCW literature (see: Alberts, Gartska, and Stein, 1999), so we will not go over it again here. In short, self-synchronization leads to faster execution of orders, which increases the speed of command (RAND, 2005; Wesensten, Belenky, and Balkin, 2005). The second outcome of self-synchronization is also discussed extensively. Adaptability is a central theme in the 'power to the edge' approach (see: Alberts & Hayes, 2003) and originates in complexity theory (Moffat, 2003; Atkinson and Moffat, 2005).

Benefits. The benefits of self-synchronization are well-described in NCW literature. All researchers that address self-synchronization identified a higher operational tempo as the main benefit. This higher operational tempo is often linked to Boyd's 'observe, orient, decide, act'- or OODA-loop (Araki, 1999; Cebrowski and Gartska, 1998; Wesensten, Belenky, and Balkin, 2005). The general idea here is to get into the opponent's OODA-loop by taking initiatives, thereby impeding the opponent to complete their OODA-loop.

Interviews.
As the second approach of our study we interviewed four experienced commanders. Here, we attempted to link the theorizing on self-synchronization in NCW literature to the state of today's practice. This step is based on the hypothesis that self-synchronization is present in the military today, which is also stressed by Araki (1999) and Hutchins, Kleinman, Hocevar, Kemple, and Porter (2001).
In order to familiarize the interviewees with aspects that may impact self-synchronization, we classified a number of factors in a figure and presented the figure at the start of the interview (see Figure 1). We distinguished three categories of factors: organizational, situational, and individual. Organizational factors are those factors that are directly related to the military organization. Situational factors relate to the operational situation. Individual factors are personal characteristics. Most factors, however, can not be attributed to only one category. The degree of ambiguity, for instance, is not only determined by situational factors, but it also depends on the clarity of the commander's intent (organizational factor) and the level of preparedness of the commander (individual factor).

Figure 1: Classification of factors that influence military self-synchronization.

Interviews

We conducted a series of interviews with military personnel that have recent operational experience in order to ground our notion that self-synchronization is present in the military today. Further, we wanted to establish the importance of self-synchronization in the operational field and, finally, elaborate on the factors that influence self-synchronization. Four interviews were held at various locations in the Netherlands in April 2006. The interviewees ranged in rank from commissioned officers to a lieutenant-colonel. The interviews all took about one hour and were open-ended. Two interviewees had recent operational experience in the Army, one served in the Air Manoeuvre Brigade, and one interviewee from the air force reported on a joint operation exercise.

Self-synchronization in today's military. Previously we discussed our presumption that some degree of self-synchronization is present in the military today. This is also asserted by Araki (1999) and Hutchins, Kleinman, Hocevar, Kemple, and Porter (2001). First, the interviewer elaborated on the concept of military self-synchronization and verified that all interviewees understood the concept. In this stage, we did not refer to NCW or related topics. Subsequently, we asked the interviewees whether they could come up with an example of military self-synchronization from their own experience. All four came up with one or more instances of military self-synchronization. The examples ranged from coordination in the operational field after incidents have occurred to reserving surplus resources for other nations in a joint and combined operation based on expectations about future events. All examples were characterized by the two key components of military self-synchronization, coordination of activities and the taking of initiatives in concordance with commander's intent. This finding illustrates that military personnel can relate the concept to their own behavior and, ultimately, supports our notion that the concept is present in the armed forces already. The findings indicate that military self-synchronization indeed is an 'enabling' concept, exploiting the capabilities that are present in the military today.

Importance of self-synchronization. The importance of NCW as perceived by military experts and researchers is discussed extensively in all sorts of publications and reports since the introduction of the term about a decade ago. The interviews were intended to establish the importance of self-synchronization from another perspective, that is, as perceived by the people that are out on the operational field.

All interviewees consider self-synchronizing behavior to be important for mission accomplishment. Interestingly, three interviewees refer to some kind of incident of unexpected event as the starting point of self-synchronizing behavior. All examples that came up during the interviews were about adapting to the situation at hand. One interviewee explicitly stated that self-synchronization is natural behavior, and that the organization should try to facilitate this kind of behavior as much as possible. Overall, the importance of self-synchronization was acknowledged by all interviewees. Adaptability is regarded as a prerequisite for mission accomplishment.

Factors that influence self-synchronization.
The factor that is named by all the interviewees is the commander's intent. The commander's intent functions as a guideline during operations. Importantly, two interviewees state that the commander's intent is important at all levels, and that all personnel must be able to apply the commander's intent in their behavior. A clear communication of the commander's intent therefore is crucial. Superiors have to make sure that subordinates understand the commander's intent and know in what ways they can act upon it. Commanders also have to communicate to what extent the subordinates have freedom to act autonomously.

Second, situational awareness is considered to be crucial for self-synchronization. This can take the form of having accurate and complete knowledge about other units that are present in the operational field or as being familiar with the resources and needs of coalition partners in the light of possible future events. The awareness of the capabilities and expertise of other units is important for maximizing the effectiveness and mission accomplishment according to the interviewees. The use of code words was reported as a tool for self-synchronization. Here, the overall goal of an operation was discussed before the operation took off, and different sub goals were derived and given a code word. Communicating the code words helped different units to self-synchronize their efforts based on the progression of the operation. The role of new technologies on the operational battlespace was discussed in two interviews. Both interviewees point out that NCW-technology could help to improve situational awareness by creating a better visualisation of the battlespace.

The third factor that is identified is trust. Trust is important for self-synchronization because teams function dispersed and therefore relatively autonomous. Members of military teams have to know each other well and need trust each other. The team also needs to trust other units and other personnel that are located elsewhere. According to the interviewees, trust is closely related to the situational awareness. Knowledge about the capabilities and expertise of other units is essential for self-synchronizing the efforts of the team. At the higher levels, personal contact seems to be important. Here, military personnel find themselves in a joint and combined environment. Trust in other services and coalition partners is shaped throughout the mission by personal contact. Self-synchronization here is sometimes facilitated by personal relationships. Interestingly, nationalities are claimed to differ in their trust in other nations.

Conclusions and further research

We now turn to the synthesis of this exploration of the concept. The main conclusion that can be drawn is the verification of the notion that our knowledge of military self-synchronization does not match with the importance that is given to the concept in NCW literature. Although the functioning of self-synchronization is well-established in a number of research areas, our understanding of military self-synchronization is limited.

We consider this limited understanding of military self-synchronization to result from the relatively small amount of scientific contributions to this research area. Only a few studies explicitly address the concept. Researchers who do consider military self-synchronization use a number of indirect measures. To our knowledge, no researcher has developed a measure for the concept yet. The development of measures for command and control variables may take some time to develop, as was pointed our by Alberts and Hayes (2005). As the development of NCW technologies continues, the need for experimentation on the concept becomes more important.

Experimentation on the concept should enhance our knowledge in a number of domains. Military self-synchronization is a broad concept, and is claimed to be relevant for collaborative issues, trust, and situation awareness. The concept will also be relevant for sensemaking (the transformation of raw experience into intelligible world views (Weick, 1987). This relationship has received little consideration so far. Knowledge of military self-synchronization is especially relevant for joint and combined missions. The factors that seem to influence self-synchronization will absolutely be affected by cultural differences.

References

Adkins J., and Kruse, M. (2003). Case study: Network Centric Warfare in the U.S. Navy's Fifth Fleet. Obtained from: http://www.oft.osd.mil/initiatives/ncw/docs/CTF50_NCW_Case_Study.pdf, 12 April 2006

Ahvenainen, 2003. Backgrounds and Principles of Network-Centric Warfare. Obtained from http://personal.inet.fi/koti/sakari.ahvenainen/index/semi_SAb.pdf, 11 April 2006

Alberts, D. S., Gartska, J. J., and Stein, F. P. (1999). *Network Centric Warfare: Developing and Leveraging Information Superiority.* 2nd Edition (Revised). Washington, DC: CCRP Publication series.

Alberts, D. S., and Hayes, R. E. (2003). *Power to the Edge. Command and Control in the Information Age.* Washington, DC: CCRP Publication series.

Alberts, D. S., and Hayes, R. E. (2005). *Campaigns of Experimentation.* Obtained from http://www.dodccrp.org/html2/pubs_pdf.html, 16 February 2006.

Alberts, D. S., and Hayes, R. E. (2006). *Understanding Command and Control.* Obtained from http://www.dodccrp.org/html2/pubs_pdf.html, 12 April 2006.

Araki, L. M. K. (1999). Self-synchronization: What Is It, How Is It Created, and Is It Needed? *Working paper*. Naval War College, Newport, RI.

Atkinson, and Moffat (2005). *The Agile Organization*. Obtained from http://www.dodccrp.org/html2/pubs_pdf.html, 12 April 2006.

Blehkman, I. I., Fradkov, A. L., Nijmeijer, H., and Pogromsky, A. Yu. (1997). On Self-synchronization and Controlled Synchronization. *Systems & Control Letters, 31*, 299-305.

Blehkman, I. I., Fradkov, A. L., Tomchina, O. P., and Bogdanov, D. E. (2002). Self-synchronization and Controlled Synchronization: General Definition and Example Design. *Mathematics and Computers in Simulation, 58, 367-384.*

Cebrowski, A. K. & Gartska, J. J. (1998). Network Centric Warfare: Its Origin and Future. Obtained from http://www.usni.org/Proceedings/Articles98/PROcebrowski.htm, 16 February 2006.

Costanza, C. D. (2003). Self-synchronization, the future force and the United States army's objective force. *Working paper.* US army school of advanced military studies. USA, KS, Fort Leavenworth.

Fewell, M. P. and Hazen, M. G. (2003). Cognitive Issues in Modelling Network-Centric Command and Control. *Research report defence science and technology organization,* DTSO-RR-0293

Hutchins, S. G., Kleinman, D. L., Hocevar, S. P., Kemple, W. G., and Porter, G. R. (2001). Enablers of Self-synchronization for Network-Centric Operations: Design of a Complex Command and Control Experiment. *Proceedings of the 6th international command and control research and technology symposium, CCRP, Annapolis, MD.*

Kaufman, A. (2000). Curbing Innovation. How Command Technology Limits Network Centric Warfare. Australia, Canberra: Argos Press.

Kirin, S. J. (1996). The Art of Synchronization. Obtained from http://www.nwc.navy.mil/press/Review/1996/autumn/sync-a96.htm, 16 Febraury 2006.

Kruse, J. Younger, M., and Holloman (2005). Network Centric Warfare in the U.S. Navy's Fifth Fleet. *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, obtained from http://doi.ieeecomputersociety.org/10.1109/HICSS.2005.453, 12 April 2006.

Moffat, J. (2003). *Complexity theory and Network Centric Warfare*. Obtained from http://www.dodccrp.org/publications/pdf/Moffat_Complexity.pdf, 16 February 2006.

Pogromsky, A., Belykh, V. N., and Nijmeijer, H. (2003). Controlled Synchronization of Pendula. *Proceedings of the 42nd IEEE conference on decision and control, Maui, Hawaii USA.*

Gonzales D., Johnson, M., McEver, J., Leedom, D., Kingston, G., and Tseng, M. (2005). Network-Centric Operations Case Study. The Stryker Brigade Combat Team. USA, CA: RAND.

Still, B. C. (2003). The Role of Leadership in Self-Synchronized Operations- Implications for the U.S. military. Research report, Naval War College, RI, Newport.

Taddiken, B. C. (2002). The Cultural Challenges of Joint Self-synchronization. *Working paper.* Research Report, Naval War College, RI, Newport.

Triandis, H. C. (1989). The Self and Social Behavior in Differing Cultural Contexts. *Psychological Review, 96,* 269–289.

Warne, L., Ali, I., Bopping, D., Hart, D., and Pascoe, C. (2004). *The Network Centric Warrior: The Human Dimension of Network Centric Warfare*. Defence Science and Technology Organisation. Research report DSTO-CR-0373, obtained from http://www.dsto.defence.gov.au/publications/3430/DSTO-CR-0373.pdf, 16 February 2006.

Weick, K.E. (1987). Theorizing About Organizational Communication. In: F.M. Jablin, L.L. Putnam, K.H. Roberts & L.W. Porter (eds.). *Handbook of organizational communication: An interdisciplinary perspective*, pp.97-122. Newbury Park CA: Sage.

Wesensten, N. J, Belenky, G., and Balkin, T. J. (2005). Cognitive Readiness in Network-Centric Operations. *Parameters,* Spring 2005, pp. 94-105.

Table 1: Analysis of literature on military self-synchronization

Reference	Definition	Input	Process	Outcomes	Benefits	Research design	Measures
RAND "Network-Centric Operations Case Study: The Stryker Brigade Combat Team"	Ability of a force to act in a manner coordinated in intent, time, and space with other battlespace entities, without being ordered to do so specifically; synchronization of force entities without direction from their commanders (p.117)	Mission-type orders, these orders require more skill, more timely and more accurate knowledge of the battlespace, and greater collaboration between commanders (p.34	Mission-type orders provide clear command intent and mission objectives and less detailed descriptions of the means to achieve those objectives (p.34)	Subordinates can understand their implications correctly and execute the orders effectively (p.34)	Higher speed of command, better and faster implementation of decisions (p.95)	NCW vs. niet-NCW team, oefening	interviews; herinterpretatie van interviews van een ander onderzoek (p. xxiv), missionm accomplishment, C2 COBP (p.9)
Proceedings of Systems Science Conference 2002, Kruse & Younger	Self-synchronization is the coordination of activities to the lowest organizational level, even to individuals (p.3)	SSA, common understanding of CI, and decentralized execution of plans (p.3)	Coordinating the execution of plans with that of other subordinate commanders or team leaders (p.3)	Rapid situation assessment and decision processes	Higher operational tempo that is more effective than opponent's	NCW vs. niet-NCW team, oefening	
JFQ, article by Kaler, Riche, & Hassell (2000)		Hardware + SSA	Elements of self-synchronization are robust networked entities sharing awareness information and a rule set to operative interactively (p.68)	Self-synchronization goes beyond SA to a point where weapons and sensors receive information information (…) of every element (p.68)	Higher operational tempo because shifting in air and missile defense		
U.S. Navy's 5th Fleet case-study (University of Arizona)	cf. Alberts, Gartska, & Stein (1999)	CI on strategic and tactical goals, trust				interviews met staf leden, operationele gebruikers, en gebruikers met weinig bandbreedte. All interviewees were asked for verifiable evidence to support an "End-to-End" story, to tell us about the dramatic successes with NCW, a typical day using NCW capab	open-ended exploratory interviews on informant's opinion on events and facts, speed of command niet gespecificeerd
S. Ahvenainen (2003). Backgrounds and principles of Network-Centric Warfare. National Defence College, Finland.	"Self-synchronization is achieving the goals of the organization without or with less leaders than in a hierarchical organization."	1. SS is based on pre-information before the situation occurs and it is based on knowledge of the neighbouring leaders. The parts of the system have to have some kind of model in their heads to self-synchronize their actions meaningfully. 2. SS is based o					
H.S. Marsh (2000). Beyond situational awareness: The battlespace of the future. Office of Naval Research.	a. consistent, shared perception of the situation b. consistent, shared processes for understanding the situation c. common appreciation of the situation d. common doctrine and techniques, tactics, and procedures for taking action e. common training to en	Distributed SS is a form of centralized command and decentralized execution. When the enabling criteria (input) are satisfied, it becomes possible to execute under a commonly understood action plan even when the distributed elements of the force do not re					
N.J. Wesenstein, G. Belenky, T.J. Balkin (2005). Cognitive readiness in Network-Centric Operations. Parameters, Spring, 94-105.		Shared mental models of the current situation and of the desired end-state (commander's intent, object of the operation). A group having information in common and adopting a common mental model of what constitutes a successful outcome and working in conce	Highly complex groups organize naturally (and optimally) from the bottom up. It refers to coordination without verbal or written communication.	By enabling more extended SS, NCO are likely to change the balance between bottom-up initiative and top-down directive in favour of bottom-up initiative. NCO is a means to reinstall the virtual line-of-sight that makes it possible to know what others are			
Moffat, James, Complexity theory and network centric warfare. CCRP, DoD. Washington, DC, USA	(…) Within a broad intent and constraints available to all the forces, the local force units self-synchronise under mission command in order to achieve the overall intent.	Local coevolution: units linking up with other units, which are either local in a physical sense or local through (for example) an information grid or intranet (self-synchronisation). Trust is essential factor.	cf. Alberts, Gartska, and Stein (1999).	Self-organization: there is no master "oracle" dictating the actions of each and every combatant. Adaptation: Combat forces must continually adapt and coevolve in a changing environment.	Emergent		
Atkinson, S. R. and Moffat, J. (2005). The agile organization. CCRP, DoD. Washington, DC, USA.	The essential idea is that of a force structure which allows the 'edge' self-synchronization of autonomous units in the battlespace, in order to achieve specific mission objectives.	Driven by the same underlying forces of increasing global uncertainty and transition to the information age, it is not surprising that the armed forces should consider more loosely based federations of functions to perform a mission in a self-synchronous	The nature of Network Centric Warfare for such future Information Age forces can be outlined as: within a broad intent and constraints available to all the forces, the local force units self-synchronize under mission command in order to achieve the overal	This in turn leads to emergent behavior and effects in the battlespace.			
Alberts & Hayes (2003). Power to the edge. CCCRP DoD. Washington, NC, USA	The DoD Transformational Planning Guidance issued in April 2003 defines self-coordination as an effort to "increase freedom of low level forces to operate near-autonomously and re-task themselves through exploitation of shared awareness and commander's in	However, the assumptions for selfsynchronization make it clear that the result will not be chaos in the battlespace. They are: • Clear and consistent understanding of command intent; • High quality information and shared situational awareness; • Competenc	However, a network topology alone will not achieve the desired result; it does not create the conditions necessary to achieve productive self-synchronization. To complete the package, a suitable approach to command and control must be developed to leverag		The Network Centric Warfare concept of self-synchronizing forces is a statement of the requirement for massive improvements not only in flexibility but also in adaptability.		
Alberts, D. S., Gartska, J. J., and Stein, F. P. (1999). Network centric warfare. CCRP DoD. Washington, NC, USA	Selfsynchronization is a mode of interaction between two or more entities.	The key elements of self-synchronizationare : two or more robustly networked entities, shared awareness, a rule set, and a value-adding interaction	The key elements of self-synchronizationare : two or more robustly networked entities, shared awareness, a rule set, and a value-adding interaction			Outcome measures: shared situational awareness, achievements, operational speed.	I At the tactical level, the U.S. Navy's Fleet Battle Experiment Series has demonstrated that combat power can be significantly increased through the ability of tactical units to self-synchronize operations based on a shared combat operational picture and
Araki, L. M. K. (1999). Self-synchronization: what is it, how is it created and is it needed? Naval War College, Newport, RI, USA	cf. Cebrowski & Gartska (1998). Simply put self-synchronization is doing the right thing at the right time for the right reason without having to be told by someone higher in the chain of command.	Creation of battlefield vision and empowerment leadership.	Bottom-up; replacing the attitude of 'it is easier to beg for forgiveness, then ask for permission' for facilitating creativity and innovation.	The goal is to have the right action taken so quickly the opponent is always in the observation phase, never gets oriented, and thus can never make a decision and an never act (OODA-loop).	higher speed of command, getting into opponents OODA-loop		
Still, B. C. (2003). The role of leadership in self-synchronizaed operations - implications for the U. S. Military. Naval War College, Newport, RI, USA	cf. Cebrowski & Gartska (1998)	Leadership skills: ability to delegate authority, ability to clearly communicate CI, ability to tolerate risk					
Taddiken, B. C. (2002). The cultural challenges of joint self-synchronization. Naval War College, Newport, RI, USA		COP and CEC (Cooperative Engagement Capability) (joint component synchronizing tool)	Forces act on own iniative based on loose guidelines set forth by the higher commander	Higher speed of command			
Costanza, C. D. (2003). Self-synchronization, the future joint force and the United States Army's objective force. Naval War College, Newport, RI, USA	cf. Cebrowski and Gartska (1998)	cf. Alberts (2002): two or more networked systems, shared awareness, a rule set, and value adding interaction. Based on Navy experiments: commonality in operating framework, COP, Trust, Empowerment, CI	Self-synchronization does not mean autonomous operations. It is ability to control "bottom-up' emergent behavior within bounds which include commader's intent doctrine, and anything that contributes to a common understanding of feedback. Integration of se		AC2 Study by Chief of Naval Operations, Spring 2001on U.S.S. Enterprise		
Warne, Ali, Bopping, Hart, Pascoe (2004). The network centric warrior: the human dimension of network centric warfare. DTSO, Australia		High-capability network, clearly understood CI, effective liason staffs and a sufficient background of personal contact between officers of the various nations.	In our view, this concept does not require every unit com-mander to draw identical conclusions from the available information, so as to ensure robot-like lock-step action. Rather, it means that the theatre commander's promulgated common intent, in concert	Higher speed of command			A metric for it must distinguish it from agility and the ability to amass effect under centralised command; in effect, the synchronisation aspect has been ad-dressed already under ability to mass effects. Hence, metrics suggested here (degree of autonomy