SCANDINAVIAN JOURNAL OF MILITARY STUDIES

Military Innovation as the Result of Mental Models of Technology

RESEARCH ARTICLE

OLA MODIG

KENT ANDERSSON

**Author affiliations can be found in the back matter of this article*

SCANDINAVIAN MILITARY STUDIES

ABSTRACT

Heightened political tensions and advances in technological development have prompted Scandinavian countries to increase investment in military research and capability development. The aim of this study is to gain a better understanding of why actors sharing similar strategic cultures implement new technology for military purposes differently. The research is founded on a cognitive-psychological perspective comparing two cases of innovation processes: Swedish nuclear weapons development during the Cold War and developments in Swedish cyber defence during the first decades of the 21st century. The main finding is that military innovation is better explained through a consideration of shared mental models of new technology than it is through a consideration of strategic cultures. The analysis shows there are implications for capability development. First, military innovation processes are only initiated if and when new technology appears militarily relevant to an actor; thus, the ability to correctly assess the military relevance of technology at an early stage is crucial. Second, the forming of shared mental models can both contribute to and counteract military innovation and, thus, decision-makers need to be aware both that mental models can be shared and that confirmation bias affects actors on a collective level. Third, it is likely that military innovation processes benefit from mental models being challenged and from diverging mental models being made evident. Consequently, it is good practice, also from this study's perspective, to diversify and welcome different views on the use of new technology. Further studies are solicited in order to develop practical guidelines.

CORRESPONDING AUTHOR:

Kent Andersson

Swedish Defence University, SE

kent.andersson@fhs.se

KEYWORDS:

Military innovation; technology forecast; military utility; mental model; confirmation bias; strategic culture

TO CITE THIS ARTICLE:

Modig, O., & Andersson, K. (2022). Military Innovation as the Result of Mental Models of Technology. *Scandinavian Journal of Military Studies*, 5(1), pp. 45–62. DOI: *https://doi.org/10.31374/sjms.117*

INTRODUCTION

Military innovation is an appealing strategy for the development of defence capability, especially for states with a highly educated population and larger aggressive neighbours. An actor with fewer resources can still hope to deter an aggressor or win an armed conflict by being more creative in the use of technology and methods of warfare. There are many definitions of the concept in previous research, some focusing on changes in doctrine, others on changes in structure or organisation (see, for example, Farrell & Terriff, 2002; Griffin, 2017; Grissom, 2006). Many focus on the innovative use of available resources in ongoing conflicts. We believe, however, it is appropriate to align this study with a broader understanding that includes peacetime efforts to counter future military challenges (see, for example, Rosen, 1991, p. 7), and therefore choose to understand military innovation as the development of a new capability integrated into a coherent military strategy. This new capability consists in turn of a new combination of military resources, including technologies of interest and conceptual ideas for its use.

States such as the Scandinavian countries put considerable effort and funds into defence research and development. In Sweden, the research and development budget for the Armed Forces is again being increased after decades of decline following the Cold War. This is understandable considering the current pace of technological development in materials, communication, information, autonomy, and so on, and the ways in which society adapts to these technologies. Rapid advances in materiel, combined with new uses and new vulnerabilities from increased societal complexity, offer new opportunities for military innovation. Indicators of the ambition to develop capability through military innovation include, for example, a state's efforts to produce long-term technology forecasts. These aim to support decision-making in exploiting technology advancements or the preparation of adequate protection to avoid technological surprise on the battlefield (Finkel, 2011; Handel, 1987).

While predicting technological development with a 20–year horizon is not simple, research shows that, with modest expectations of precision, it can be meaningful (Kott & Perconti, 2018; Silfverskiöld et al., 2021). Nevertheless, state actors seem to implement new technology or new methods to achieve military ends with different levels of ambition and extent. If these differences are not rational, then, of course, resources could be used more efficiently. This is also why research into the implementation and driving forces behind military innovation has, in the course of more than 30 years, come to form its own multidisciplinary field. In this study, we assume credible assessments of technological development to be available. But how might findings from the field of military innovation help us understand the way in which knowledge from these assessments should be conveyed to decision-makers in the capability development process?

The first generation of research in the field dwelt on questions concerning *who* was driving military innovation – civilians or military personnel (Posen, 1984; Rosen, 1991)? The basic assumption for these researchers is that innovation is principally driven by the fear of foreign military capabilities and technological development. Nowadays, these are considered to be underlying conditions rather than causal factors (Grissom, 2006).

The second generation, the first to identify cultural aspects, moved the field into the study of drivers themselves (Griffin, 2017). In their important work of 2002, for example, Farrell and Terriff identified three main incentives for military innovation; in addition to a conscious and active change in the actor's culture, they note the imitation of the innovation of others, and a more salient, forced, change due to strategic shock.

Contemporary research, the third generation, seems to focus on understanding the *effects* of these cultural aspects in greater depth. Adamsky (2010), for example, highlights how actors perceive and implement new capabilities in different ways depending on differences in strategic culture. Our understanding of the concept of strategic culture is somewhat simplified, but close to that of Gray (1999, p. 51): an actor's military strategic preferences based on national cultural norms and traditions.

There are, however, other views (see Ångström & Honig, 2012), and researchers discussing civilian-military relations nowadays do it in terms of the meeting of two separate cultures

(Farrell & Terriff, 2002; Adamsky, 2010; Berman, 2012; Kier, 2017). Studies of the effects on military innovation, of rivalry within and between defence branches, often focus on rival organisational cultures (Hill & Gerras, 2016; Lee, 2019). Today we see different approaches to the study of the effects of cultural features on military innovation. It seems to us, however, that creativity in the operationalisation of culture makes the comparison of these studies difficult. We agree with Griffin (2017): the field seems to be fragmented or "confused."

It is more fruitful to view strategic culture as a condition underlying, rather than explaining, variations in military innovation, and we find there are basically two arguments for approaching the problem from another perspective. First, strategic culture, as an explanatory model, is of little practical use if the aim is to improve the ability to innovate. Arguably innovation processes would benefit more from identifying factors that might influence an actor's understanding of new technology or the pace of progression in innovation processes. The military actor quickest to exploit military innovation undoubtedly has the greater room for manoeuvre. Second, as shown in this study, there are examples of variations in the driving forces behind military innovation, despite the strategic culture being largely the same. We have chosen here, instead, to study military innovation processes from a cognitive-psychological perspective. Thus, the aim is to find out why actors implement new technology for military purposes differently despite sharing similar strategic cultures. The approach involves the study of military innovation from the perspective of cognitive biases at the actor level, in the form of so-called shared mental models. By taking this viewpoint, we expect to identify concrete explanatory factors helpful in developing practical military innovation processes. The results might, for example, support the actor's self-examination of capability development, including which assessments to ask for, and how to process those assessments when they are received.

Immediately below, we present the cognitive-psychological perspective on which the research design is based. We then describe the research approach, including the comparative case study method applied here. The results section that follows is divided into three parts relating to results from the two single studies and a comparison; the two subsequent sections present a discussion of the results, relating them to earlier research in the context of capability development, and final conclusions.

OUR COGNITIVE-PSYCHOLOGICAL VIEWPOINT AND CENTRAL CONCEPTS

In this study, we investigate whether an actor's initial mental models of a technology's relevance are altered with changes in the internal or external environment, or whether confirmation bias tends to leave mental models intact, and what the consequences are for military innovation processes. We find the theory of shared mental models useful because it can be operationalised to study decision-situations associated with an actor's *collective* decision-making. Similarly, we find confirmation bias a useful concept because it contributes to explaining the absence of change in shared mental models of military innovation processes.

SHARED MENTAL MODELS

The term "mental model" occurs in several scientific disciplines. In her study of mental models in individuals, Rook (2013) identifies cross-disciplinary similarities in the term's use; the definition she uses is a "concentrated, personally constructed, internal conception of external phenomena (historical, existing or projected), or experience, that affects how a person acts" (p. 42). Following Rook (2013), we can understand a mental model to be a form of subjective simplification or generalisation of reality, influencing behaviour and decisions. As decisions are made collectively at a more abstract level in military innovation processes, however, we find studies of so-called *shared* mental models to be most relevant. There is extensive research into the topic in strategic decision-making and management in the business sector, predominantly concerning the influence of shared mental models on effectiveness and quality. We find research into top management teams and their strategic decision-making to be particularly interesting to this study. In that context, shared mental models have been described as "organized mental representations of the key elements within a team's relevant environment that are shared across team members" (Yang et al., 2015, p. 901). Having a shared mental model of the use of a technology implies convergence between the mental models of the members in a decision-making team concerning the use of that technology. Understanding this, we contend that shared mental models facilitate military innovation – a view supported by research showing that such models facilitate problem-solving (Toader et al., 2019). The same research shows that *diverging* mental models facilitate the ability to adapt.

COGNITIVE BIASES

In 1972 Tversky and Kahneman presented the notion of cognitive bias. After extensive research in the following years, we now understand the phenomenon as causing "judgmental errors and suboptimal decision-making, which may prove to be costly at either a personal or societal level" (Weller et al., 2019). Thus, cognitive biases are psychological mechanisms subconsciously affecting how decision-makers value available information (Furnham & Boo, 2011). *Anchoring*[1] (Furnham & Boo, 2011; Hammond et al., 1998; Tversky & Kahneman, 1974) and *functional fixedness*[2] (Munoz-Rubke et al., 2018) are well-known examples, even if neither example fits well with our approach in this study. Anchoring seems too closely related to quantitative phenomena, mostly in economic contexts, while research into functional fixedness seems focused on physical objects. Instead, we have in this study based our research design on shared mental models and the cognitive bias commonly known as confirmation bias.

Confirmation bias is the collective term for a number of phenomena in psychology related to interpreting circumstances so as to enhance preconceived notions or values (Carter et al., 2007, p. 648). Although such misinterpretation is subconscious, it can, for example, lead to misguided searches for information (Nickerson, 1998, pp. 175–177). Even conscious efforts to be objective can still lead to confirmation bias (Lidén et al., 2018, p. 337). Consequently, information that contradicts a preconceived notion is ignored, and irrelevant information is given unreasonable weight (Nickerson, 1998, p. 177). A related effect is *belief persistence*, describing the phenomenon of a belief, once formed, being very persistent, even when there is convincing evidence to contradict it (Nickerson, 1998, p. 187). Thus, although confirmation bias is similar to anchoring and functional fixedness, it can be viewed from a wider perspective.

RESEARCH APPROACH

Following authors of earlier studies, we believe that causes of military innovation can be studied and generalised in theoretical models to help us understand why military innovation does or does not occur. The point of departure for this study is that generalised objective explanations for military innovation can be studied using hypotheses about plausible causes. ***Figure 1*** illustrates the bases for the case study design applied.

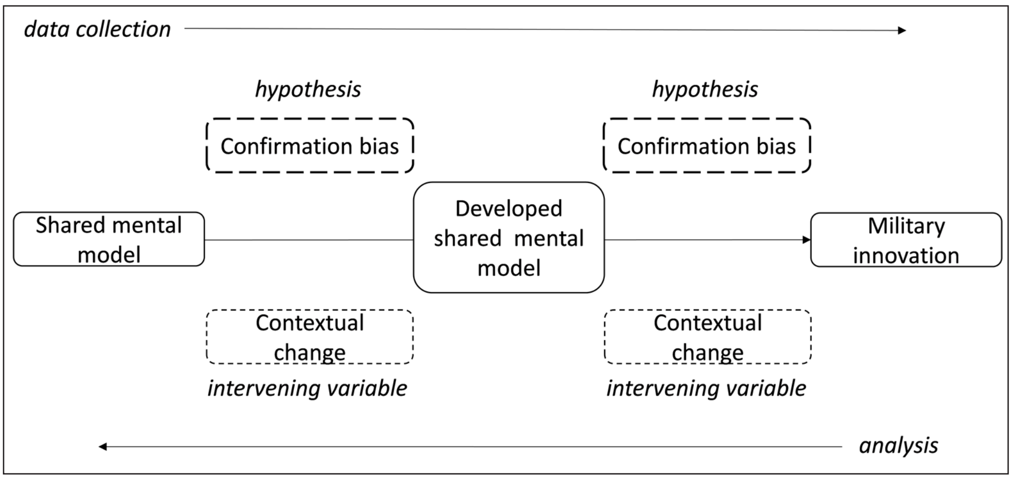

Figure 1 The Case study design, single case.

1 The disproportionate influence on decision makers to make judgments that are biased toward an initially presented value.

2 A cognitive bias that describes how previous knowledge of a tool's function can negatively impact the use of this tool in novel contexts.

HYPOTHESES

The first hypothesis is "Military innovation processes are initiated if new technology is perceived to be militarily relevant".

While we might safely assume technologies developed to support military innovations to be relevant for military operations, not all new technologies end up filling this role. There are examples of military innovation processes being initiated but later terminated. One such example is a Swedish project based on the Network-Based Defence concept. The Swedish government concluded it had been "characterised by a development process marked by technological optimism" (GoS, 2019, p. 123). Consequently, we will in this study use mental models to investigate how new technologies are perceived when military innovation processes are initiated. The hypothesis is satisfied if the actor initiates military innovation processes only if there is a shared mental model of the new technology reflecting a perception that the technology is militarily relevant.

The second hypothesis is "An actor's shared mental model of new technology as militarily relevant affects military innovation processes to a greater degree than contextual changes".

In this study, military innovation processes continue for relatively long periods of time, during which the actor can be expected to receive new information both about the technology, through research and development, and about societal and external developments. There are historical examples of military innovation processes proceeding despite information indicating that the military relevance was long gone; one such is the fortress in Karlsborg, in central Sweden, built between 1819 and 1909 to serve as the nation's auxiliary capital. On the other hand, actors also face risks if their shared mental models prevent them from exploiting technology that has proven militarily relevant. Given the aim of this study, we thus argue the second hypothesis to be relevant. It will be tested using confirmation bias as a complementary explanatory model. If the hypothesis is correct, military innovation processes are driven by preconceived notions rather than actual circumstances.

A COMPARATIVE CASE STUDY METHOD

Testing our two hypotheses requires a mode of research allowing comparison *within* cases of military innovation. The comparison needs to comprise four steps:

1. Analysis of the actor's shared mental model and its development over time.
2. Analysis of contextual change during the innovation process.
3. Analysis of when innovation processes are initiated.
4. Analysis of the actor's innovative outcome.

The first hypothesis is tested in the first step. The second hypothesis is tested by relating the result of the last step to the results of the other three.

In order to answer the overarching research question, we also find it necessary to make comparisons *between* cases of military innovation in which the strategic cultures of the actors involved are similar. The approach, further described by George and Bennett (2005, pp. 19–22), is sometimes described as a case study with a "most-similar systems design."

OPERATIONALISATION

Table 1 shows an overview of the operationalisation. The independent variable in this study is the actors' shared mental model of new technology. The dependent variable is military innovation.

Given the description of central concepts above, we can hold an actor's "shared mental model" to be an organised mental representation of the key elements within a team's relevant environment shared across team members. Thus, the mental representation reflects key elements of a phenomenon, such as the character and function of a new technology, and affects the actor's actions, such as the actor's decision-making. Therefore, in this study, the actor's shared mental model is analysed by studying how the actor describes the relevant *environment*, *internal* and *external*, by studying the *function* of the technology within the source material, and by studying the actor's *decision*. The themes representing measures of

VARIABLE	THEME	EXAMPLE DATA
Shared mental model	*External environment*	*conflicts, R&D*
	Internal environment	*change in responsibilities*
	Function	*use and effects*
	Decision	*dates and new directions*
Contextual change	*External environment*	*conflicts, R&D*
	Internal environment	*societal change*
Confirmation bias	–	*earlier shared mental models analysed relative to contextual change*
Military innovation	*Conceptual ideas*	*use and integration of technology*

Table 1 Shows the operationalisation of the theory.

each variable are presented in the middle column. The right column presents examples of types of data received by interpretive analysis.

We acknowledge there is a scientific debate on how to operationalise and measure sharedness; Mohammed, Ferzandi and Hamilton's review paper of 2010 on the structure of the team mental model, for example, has been extensively cited. But we argue that the operationalisation proposed in this study is in line with that of Toader and his colleagues (2019, pp. 44–46), a strategy-outcome approach suitable for its purpose, notwithstanding its lower resolution. If an actor expresses a view on the use of the technology of interest in an official context, and if it is interpretable using the themes chosen, we find it is reasonable to assume that it reflects a shared mental model of that actor.

Similarly, contextual change during the innovation process is studied in themes of external and internal environments.

In order to be able to study confirmation bias, we have to be able to compare shared mental models before and after contextual change. This way, the later shared mental model can be interpreted as the result of either contextual change or confirmation bias. Thus, in our case study design, depicted in ***Figure 1***, we have denoted contextual change and confirmation bias as our intervening variables. Confirmation bias is also our second hypothesis.

Military innovation is operationalised as innovative outcomes in the form of conceptual ideas of how to use a technology of interest in the development of a military capability.

We have also defined three control variables in order to be able to isolate the variables of primary interest to this study: changed strategic environment; technological development pace; and strategic culture. Control variables are held constant in a comparative case study. While they might be criticised for being rather sweeping, they are considered relevant since they mirror the results of earlier research.

CASE SELECTION

Given the research design, we chose to look for cases where all control variables could be kept as constant as possible in comparison. The choice fell on two cases: the Swedish nuclear weapons project of 1945 to 1962 and the Swedish cyber defence development between 2001 and 2019. We assessed the similarities to be sufficient enough for the study to be meaningful.

The nuclear weapons case is clearly limited in time because of the ratification of the non-proliferation treaty in 1968 (Agrell, 1985). In contrast, cyber defence development is still ongoing, which is why there is no final result to investigate. Given this study's focus on the impact of shared mental models on military innovation processes, this does not present a problem – but in order to chronologically limit the case, we have chosen the period from when the word "cyber" was first used in Swedish Armed Forces policy documents (Swedish Armed Forces, 2001) until ambitions to acquire an offensive cyber capability were first explicitly expressed by a defence committee (GoS, 2019).

In each case, the strategic environment (control variable one) could be described as being in a state of low tension at the beginning (Jung, 1947, p. 60; GoS, 1999, p. 9), but changing to one of high tension towards the end (Swedish Armed Forces, 1962, p. 4; GoS, 2019, p. 107).

The pace of technological development (control variable two) can be considered high in both cases. In the nuclear weapons case, it was high due to the arms race between the Soviet Union and the United States and civilian energy requirements (Agrell, 1985). Correspondingly, the cyber domain is characterised by the rapid pace of technological development: "As recently as 2007, malicious cyber activities did not register on the Director of National Intelligence's list of major threats to national security. In 2015 they ranked first" (Nye, 2017, pp. 44–45). Since both cases in this study are Swedish, the strategic culture (control variable three) is also considered unchanged between cases (Åselius, 2005). Fundamental cultural norms and traditions such as avoiding war while defending one's territory are still valid.

Comparing the two cases, we see significant variation in the dependent variable of military innovation. In the nuclear weapons case, military strategic ideas are presented early in the process, where nuclear weapons are integrated with conventional forces ready to be used in the field. There are scenarios in which nuclear weapons are used in both supporting missions and decisive attacks. In the cyber defence case, corresponding conceptual ideas are developed relatively late, and the degree of integration with conventional forces is low. Initially, cyber defence was focused on IT security and was not an integral part of military missions. Military innovation is studied from an actor's perspective with three areas of analysis in each case: public organisations inclined towards military research; military organisations; and political leadership.

SOURCES

The main sources for the nuclear weapons case are the Swedish Armed Forces' own studies supporting periodic policy decisions about the development of Swedish defence between 1948 and 1962. These primary sources are only complemented with secondary sources in the form of dissertations and study reports to enhance technological and contextual understanding (see, for example, Agrell, 1985; Forssberg, 1987; Jonter, 2001). Cyber defence development is mainly studied through primary sources corresponding to the first case, in reports issued by defence policy commissions, and in defence bills.

The idea of interviewing central decision-makers was discarded on account of the difficulties potentially presented in finding suitable respondents for both cases. Consequently, this study approach differs from the majority of studies on shared mental models, which focus on individuals or groups of individuals directly. The validity of this study is instead based on the use of the official documents stated above and on the assumption that these represent a shared view on a strategic level in the organisation of the actor issuing them.

THE ANALYSIS INSTRUMENT

The analysis was conducted through the collection of data from sources using qualitative content analysis based on the themes defined in the operationalisation (Esaiasson et al., 2017, p. 288). The results were presented in the form of shared mental models. These shared mental models, and possible confirmation bias, were then analysed and compared between cases. At this final step of the analysis, the hypotheses could be tested. Causality between shared mental models, confirmation bias, and military innovation were analysed based on four criteria: covariation, isolation, sequence, and causal mechanism (Kellstedt & Whitten, 2013, pp. 54–56). The analysis focused on covariation and causal mechanism, as isolation and sequence were managed in the research design.

RESULTS

The results section is divided into three parts. The first two present a summary of results from the analysis of the two single cases included in the study: Swedish nuclear weapons development between 1945 and 1962, and Swedish cyber defence development between 2001 and 2019. ***Table 2*** shows a compilation of these results. The third part of the results section presents the comparative analysis.

NUCLEAR WEAPONS DEVELOPMENT, 1945–1962

The initial shared mental model spans the years 1945 to 1948. Eleven days after nuclear weapons were exploded in Japan in 1945, the Swedish Supreme Commander asked

	NUCLEAR WEAPONS DEVELOPMENT	CYBER DEFENCE DEVELOPMENT
Initial shared mental model	- *a suitable military means*	- *military IT security*
Contextual change	- *increased tension* - *nuclear weapons in vicinity of Sweden*	- *militarily integrated cyberattacks*
	- *technological possibility*	- *cyber threats related to crime* - *national research focused on information warfare*
Developed shared mental model	- *a necessary military means*	- *societal IT security*
Contextual change	- *increased number of tactical nuclear weapons*	- *intense development* - *Sweden exposed to direct effects*
	- *Swedish Armed Forces driving innovation* - *reduced political support*	- *a national cyber security strategy*
Military innovation	- *integrated to avert attack*	- *cyber defence in depth*

Table 2 Shows a compilation of results from the analysis of the Swedish nuclear weapons development, and of Swedish cyber defence development, respectively. The first column shows variables in accordance with the single case analysis approach.

Försvarets forskningsanstalt (FOA), the Swedish defence research agency of the time, to report their knowledge of the new weapon (Jonter, 2001, pp. 21–22). From that point, FOA invested considerable resources in research on the subject. The analysis shows that FOA then considered the construction and performance of Swedish nuclear weapons a main research objective (Forssberg, 1987, pp. 15–16). The Swedish Armed Forces perceived nuclear weapons technology to be primarily relevant to defensive operations in an armed conflict but unlikely to revolutionise warfare (Jonter, 2001, p. 21; Jung, 1947, pp. 75, 102). While political leadership does not seem to have actively driven development, it certainly did not oppose it (Forssberg 1987, pp. 14–28). Thus, on a collective level, while our actor of interest perceived nuclear weapons technology to be militarily relevant, it was uncertain about its proper use. In ***Table 2***, the initial shared mental model is therefore summarised as a “suitable military means.”

Contextual Change, 1949–1954

A series of events between 1949 and 1954 may be held to characterise contextual change induced by the external environment. In 1949, the Soviet Union conducted its first plutonium-based nuclear weapons test; the United States proposed to Norway and Denmark that it might base its fighter aircraft in their territories. The Soviet Union then invested significantly in naval forces in the Baltic Sea, and the relations between the Soviet Union and Sweden deteriorated –not least due to the crisis known as the Catalina affair (Agrell, 1985, pp. 48–54).

While FOA’s research focused on the development of tactical nuclear weapons, no active measures seem to have been taken by either the Swedish Armed Forces or the political leadership to acquire them (Jonter, 2001, pp. 29–34). Hence, the contextual change following the initial shared mental model has been described as “increased tension,” the presence of “nuclear weapons in the vicinity of Sweden,” and the notion that Swedish nuclear weapons development was a “technological possibility” (***Table 2***).

Developed Shared Mental Model, 1954–1957

The analysis from the period shows that, at a collective level, the actor found the technology militarily relevant to a greater degree than it had previously. Military nuclear weapons research continued at a high pace and a nuclear test detonation was planned for 1964 (Forssberg, 1987, pp. 19–22; Jonter, 2001, pp. 37–38). Both civilian and military research focused on producing plutonium. The Supreme Commander at the time painted a gloomy military strategic situation (Swedish Armed Forces, 1954, p. 267) and argued that the most cost-effective option available to the Swedish Armed Forces was to acquire their own nuclear weapons systems to defend against an invasion (Swedish Armed Forces, 1957, pp. 279–284, 296). The government decided to increase funding and allow the import of plutonium for research purposes (Forssberg, 1987, pp. 18–23). In summary, the shared mental model developed reflects a view that nuclear weapons technology was a “necessary military means” (***Table 2***).

Contextual Change, 1958–1962

Nuclear weapons played an increasingly important role in the struggle between the superpowers in the period. At the turn of the decade, the Soviet Union had multiple nuclear carrying platforms (Agrell, 1985, pp. 49–50). In Europe, tactical nuclear weapons were deployed by NATO, and the mandate to use them was delegated to higher military commanders (Agrell, 1985, p- 50–51; DeGroot, 2004, p. 60). In Sweden, parliament postponed a decision on nuclear weapons. FOA and the Swedish Armed Forces continued to support a nuclear weapons programme, and both organisations requested increased funds for continued research into the construction of weapons (Agrell, 1985, pp. 316–320; Forssberg, 1987, pp. 38–40; Jonter 2001, p. 52). The 1958 defence development bill focused on defensive measures but also allowed continued research into nuclear weapons design (Agrell, 1985, pp. 312–313; Forssberg, 1987, p. 57; Jonter, 2001, p. 47). Therefore, contextual changes in the period have been described as an "increase in the number of nuclear weapons in the vicinity of Sweden," the "Swedish Armed Forces were now driving the innovation process, and reduced political support" (***Table 2***).

Military Innovation, 1962

Three conceptual ideas representing the resulting military innovation were identified in a report from the Supreme Commander (Swedish Armed Forces, 1962). First, nuclear weapons were seen to have operational use. They were meant to be used in national defence, for targeting concentrations of landing vessels or military units, etc. Second, nuclear and conventional weapons were seen to be synergistic. In the event of an invasion, nuclear weapons were thought to create a dilemma. Facing the threat of nuclear weapons, attacking forces were likely to spread and hence become targets for conventional weapon systems. Third, nuclear weapons were thought to be decisive. If the invasion were to be conducted using dispersed forces, Swedish conventional forces were to coerce the invading forces to concentrate and hence create a favourable situation for the use of nuclear weapons. Nuclear weapons had thus become part of joint military doctrine and conceptually integrated with conventional weapons in Swedish military strategy. In ***Table 2***, the final shared mental model of nuclear weapons technology, military innovation, is summarised as "integrated to avert attack."

CYBER DEFENCE DEVELOPMENT, 2001–2019

The initial shared mental model covers the years 2001 to 2004. In 2001, the Swedish Defence Research Agency, FOI, presented their vision of how weapons based on information technology could be used in the future (Grennert & Tham, 2001, p. 3). IT attacks would be directed at critical infrastructure, and cyber capabilities were therefore thought to produce strategic rather than military effects (Karresand et al., 2004, pp. 19–20). Defence against information warfare was acknowledged to be a fundamentally new strategic element. Cyber-related activities were mainly seen as part of information operations *supporting* military operations (Swedish Armed Forces, 2001, pp. 24, 46, 54).

The Government of Sweden depicted a period of low tension but with increased societal vulnerability because of the nature of the technological infrastructure (GoS, 2004, pp. 14–18). The Swedish Armed Forces were requested to increase their capability to counter information operations along two paths. First, to acquire the necessary materiel to develop an operational IT defence capability. This was to be used expressly in defence of Sweden's own systems, thus contributing to society's total resilience. Second, Swedish Armed Forces were requested to increase their knowledge in the conduct of offensive information operations (GoS, 2004, p. 75).

The initial shared mental model reflects a view of cyber technology as only relevant for the protection of IT systems and has hence been labelled "military IT security" (***Table 2***).

Contextual Change, 2005–2008

The first three major internationally acknowledged cyber-attacks were conducted in this period. In 2007, events in Estonia led to allegations of state-supported Russian cyber-attacks on Estonian infrastructure (Herzog, 2011). In the same year, Israel conducted offensive air operations on a presumed Syrian nuclear facility (McGraw, 2013). Syrian air defences were deactivated in a parallel cyber-attack (Brantly, 2014). Then, in 2008, Georgia was exposed to successive cyber-attacks coinciding with Russian troop movements in South Ossetia (Kastenberg, 2009). All three events can be considered examples of cyber-capability integrated into joint operations.

In Sweden, FOI issued reports in line with the 2004 policy on defence development. The aim was to increase knowledge of cyber actors and the development of theory and methods of information warfare. There seemed to be no focus on cyber warfare (Heickerö, 2006; Heickerö, 2008).

Consequently, the contextual change following the initial shared mental model can be summarised as: state-supported and "militarily integrated cyber-attacks," international "cyber threats related to crime" rather than to national security, and "national research focused on information warfare" (***Table 2***).

Developed Shared Mental Model, 2009–2013

During this period, FOI reports related to cyber warfare reflect an insight that both official agencies and private actors carry out cyber-attacks and that it is genuinely difficult to determine which actor sponsors them (Heickerö, 2010). For the first time, the Swedish Armed Forces (2013) now clearly emphasised the cyber domain and cyber capability in their study reports, arguing that Sweden should develop an offensive cyber capability. Cyber was still mainly seen, however, as being linked to information operations, and cyber security was put forward as the concept defining Swedish cyber security strategy.

At the political level, there was a new national policy decision in 2009 about defence development (GoS, 2009). However, the word "cyber" does not occur in the proposition. Ambitions were lowered in terms of cyber-related development. Since Sweden was no longer to pursue the development of a network-based defence, there was no change in direction regarding the development of a cyber capability.

To conclude, the actor studied seems to have perceived an increase in the military relevance of cyber technology but related it to the defence of information infrastructure and IT systems in society. The shared mental model developed can therefore be summarised as "societal IT security" (***Table 2***).

It should also be noted that during this period, the cyber-attack of 2010 known as Stuxnet, targeting the Iranian nuclear technology programme, took place. For the first time, a cyber-attack caused physical damage to an adversary's strategic resources. A centrifuge for uranium enrichment was destroyed through software-induced wear (Farwell & Rohozinski, 2011).

Contextual Change, 2014–2018

As the number of sophisticated cyber-attacks both by state-supported actors and others increased significantly in the period of 2014 to 2018 (Nye, 2017, p. 44), many states adopted their own cyber security strategies (Luiijf et al., 2013). Sweden is assessed to have been exposed to state-supported attacks from China, Russia, and possibly other states, supporting industrial espionage (Svensson et al., 2019, pp. 12–14, 36). In Sweden, FOI developed concepts for civil defence, all of which included cyber operations (FOI, 2014; FOI, 2018). The Swedish Armed Forces and the Swedish Civil Contingencies Agency MSB presented a common view of the development of total defence in 2016, including a request to strengthen Sweden's capability to identify and counter cyber-attacks (Swedish Armed Forces and MSB, 2016). The following year, Sweden adopted a new information and cyber security strategy, prioritising the strengthening of military capacity to counter attacks from adversaries in cyberspace (GoS, 2017b, p. 21). The same year, the defence committee advocated an *active* cyber defence capability to secure functions critical to society (GoS, 2017a, pp. 115, 119). In sum, the contextual change from this period can be described in three phrases: "intense development"; "Sweden exposed to direct effects"; and the establishment of a "national cyber security strategy" (***Table 2***).

Military Innovation, 2019

In the strategic doctrine of 2016, the Swedish Armed Forces describe cyber capability in terms of both protection and effect (Swedish Armed Forces, 2016). In parts, cyber capability is treated equally with other forces (Swedish Armed Forces, 2016, p. 60). The overarching conceptual idea seems to be one of defensive use in total defence contexts (Swedish Armed Forces, 2016, pp. 29–30). While there is no detailed idea presented on how to integrate cyber capability with other forces, expressions like "active protection," "enabling effects," or "offensive operations against high value non-physical targets" signal offensive ambitions (Swedish Armed Forces, 2016, pp. 55–57).

In a report issued in 2018, however, the use of cyber capability has become more concrete and more tightly integrated with other forces (Swedish Armed Forces, 2018). Cyber capability is described as a prerequisite for conventional military operations (Swedish Armed Forces, 2018, pp. 5–29), thereby indicating the integration of cyber capability in a joint military strategy. Three main conceptual ideas appear in the report: to protect Sweden's own military capability and infrastructure by active outreach actions; to affect an attacker's vulnerabilities in depth at an early stage during an attack; and to contribute to cyber security in total defence. The political leadership expresses similar views. In some circumstances, it even seems cyber-attack can be equated to armed conflict (GoS, 2019, pp. 252–254). The defence committee does not, however, relate cyber capability with other military means to any great extent – something noted by the Swedish Armed Forces, who respond by saying "the function must be an integral element with other forces countering an armed attack" (Swedish Armed Forces, 2019, p. 42). Given the results, we have chosen to express the resulting military innovation in short as "cyber defence in depth" (***Table 2***).

COMPARATIVE ANALYSIS: FORMING SHARED MENTAL MODELS OF NEW TECHNOLOGY

The first of four steps in our comparative case study method requires an analysis of the shared mental models formed by our actors of interest during the innovation process. The nuclear weapons case shows that nuclear technology was regarded as militarily relevant from the outset; cyber technology, on the other hand, was regarded as militarily relevant only very late in the process. A reasonable assumption is that in the first case, the technology was introduced, or presented, in a military context, while in the second, it was introduced in a civilian context.

In the nuclear weapons case, the research interest from the Swedish Armed Forces can be described as initially very general. The study indicates instead that it was the defence research agency, FOA, who perceived the technology as militarily relevant at an early stage and that they conducted research into construction more or less out of self-interest, while the political leadership appears to have been almost uninterested. The cyber development case is different. The shared mental models of the actor studied reflects a view that cyber technology is limited to Internet and computer hackers. The only military relevance seen was the need for IT security. Gradually, this need developed to include the IT-security of the society as a whole. In fact, the shared mental model of cyber technology reflects the idea that cyber technology is militarily irrelevant in all respects until 2013/2014 when we can see this understanding change.

It seems that a central difference between the cases is that, over time, nuclear technology is related to achieving military *effect,* while cyber technology is connected with *protection*. Another difference is that nuclear technology was related to the actor's *military* capability needs, while cyber technology was primarily related to *societal* resilience. Consequently, the study indicates that shared mental models of new technology are formed on the basis of which capability the technology is perceived to contribute to, and of which organisation is perceived to have the need.

Shared Mental Models' Effect on Military Innovation Processes

The second step in the comparative analysis focuses on the effect of contextual changes during the innovation process.

In the nuclear weapons case, the shared mental model reflects military relevance from the outset. This perception is successively strengthened throughout the innovation process, which in turn successively intensifies the pace of the innovation process. Initially implicit ambitions for Swedish nuclear weapons are developed into an explicit military strategy, whereby they are ultimately considered a necessary contribution. In the cyber defence development case, it appears that no shared mental model of cyber technology was formed at all. So far, the collectively perceived military relevance relates to IT security. Analysis of the resulting military innovation expresses a current shared mental model, cyber defence in depth, indicating that the actual military innovation process has gathered pace during the recent period of contextual change. Thus, there is reason to believe the shared mental model is still developing and that the perception of cyber technology as militarily relevant is going to be further strengthened. Consequently, the analysis indicates military innovation processes are initiated when the actors' shared mental models of technology express a perception of military relevance.

The innovation processes also differ in another respect. The nuclear weapons case shows diverging views among groups within the actor studied, that is, between technology experts, the military profession, and political leadership. In the cyber defence development case, their views are similar. The former situation led to rapid technological and conceptual development, but things moved more slowly in terms of a physical capability due to political ambivalence and waning public support. In the cyber defence development case, the efforts of the different components within the actor were all aiming in the same direction. The recent acceleration in the pace of development is possibly explained by the view that the technology's militarily relevance is spreading and that this view has become a *shared* mental model.

In sum, the analysis shows that an actor's shared mental model must see a new technology as militarily relevant in order to *initiate* the innovation process and that mental models, especially if they are shared, tend to affect the *pace* and *intensity* of military innovation processes.

The Effect of Confirmation Bias on the Forming of Shared Mental Models

In the third step, sequential shared mental models are compared in relation to contextual change in order to determine whether confirmation bias has a role in their formation.

In the nuclear weapons case, the contextual change seems to be in agreement with the actor's shared mental model of the technology in question. Hence, confirmation bias cannot be detected at a collective actor level – only at a lower level. It seems the armed forces tended to ignore the challenges posed by the enormous resource requirements of a nuclear weapons programme. They continued to develop concepts comprising integrated nuclear weapons, despite fading political and public support, while continuing to follow political directives and to produce reports supporting political decision-making. We would argue that this is evidence that the Swedish Armed Forces ignored information opposing a concrete nuclear weapons programme. This is, in other words, confirmation bias: the Swedish Armed Forces' shared mental model saw nuclear technology as militarily necessary. In the case of cyber defence development, this effect is more obvious. The shared mental model of cyber technology, primarily related to IT security, appears odd when contrasted with the number of militarily integrated cyber-attacks that occurred during that same period. Thus, in this case, it seems the shared mental model developed was affected by confirmation bias, which resulted in delaying the innovation process.

To conclude, the study shows that confirmation bias has a complex effect on military innovation processes. It tends to strengthen an earlier mental model, which counteracts conditions for a shared mental model to form. On the other hand, and paradoxically, confirmation bias can also have the opposite effect. The results indicate that confirmation bias could have a positive effect on the pace and intensity of the innovation process if the model is *shared at a collective actor level*. Thus, confirmation bias in mental models can, in a best-case scenario, contribute to completing military innovations more quickly than an opponent. However, in a worst-case scenario, confirmation bias can induce a military strategic risk by inhibiting or slowing down the innovation process.

Hypotheses Testing

We find that our first hypothesis – "military innovation processes are initiated if new technology is perceived to be militarily relevant" – to be strengthened. In the nuclear weapons case, the results show initiation happened only days after the nuclear detonations in Japan. In the cyber defence development case, initiation is not easily identified. By using shared mental models as our explanatory model, we can see that it is not the technology itself but the shared mental model of the technology as militarily relevant that triggers the military innovation process. In the cyber defence development case, the forming of a shared mental model of the technology as militarily relevant may have been delayed; but once it was formed, however, innovation started to gain pace. These results highlight the importance of studying and understanding the military potential in new technology in order for military innovation to take place.

The second hypothesis, however – "an actor's shared mental model of new technology as militarily relevant affects military innovation processes to a greater degree than contextual changes" – cannot unambiguously be dismissed or strengthened. In the nuclear weapons case, contextual change complies with the shared mental model, and in the cyber defence development case, contextual changes, related to the military relevance of the technology, coincide with Russia's annexation of Crimea.

DISCUSSION

In this study, we have examined military innovation processes from the perspectives of shared mental models and confirmation, using a comparative case study approach. The aim was to gain a better understanding of why actors implement new technology for military purposes differently despite their similar strategic cultures. We claim the results indicate that a difference in shared mental models is the better explanation; similar strategic cultures do not necessarily mean that actors cognitively create similar shared mental models of new technology. On a more detailed level, findings can be consolidated as three conclusions:

1. Military innovation processes tend to be initiated if and when the actor's shared mental model of new technology reflects military relevance.
2. The forming of shared mental models can both contribute to and counteract military innovation processes.
3. Military innovation processes likely benefit from mental models being challenged and from diverging mental models being made visible.

In what follows, the validity of these findings is first discussed in relation to earlier research. The findings are then elaborated upon in a capability development context.

As we have seen, some strands of research see military innovation to be explicable through a consideration of either the active party in the process, or of a meeting between distinct cultures. In the nuclear weapons case, for example, it seems that the military complex is the active part, in line with the arguments made by Rosen (1991). But this is not as clear in the cyber defence development case. One could also argue that different mental models are partly similar to the separate cultures theory and that shared mental models are similar to the "consensus cultures" framed by Kier (2017) or to Jensen's (2018) "new theory of victory." Nevertheless, there is a difference. They approach the phenomena from an organisation-sociological perspective rather than a cognitive-psychological perspective.

It is more difficult to disregard the explanation offered by Farrell and Terriff (2002) that military innovation arises from strategic shock or a sudden change in the strategic environment. There were external shocks in both cases studied (the bombs dropped on Japan and extensive cyber-attacks, respectively). Where Farrell and Terriff (2002) argue that shock induces a fear which in turn drives innovation, however, this study finds innovation to follow the attainment of insight into the potential of a new technology. There is a difference in nuance, suggesting both perspectives contribute to increased knowledge.

Others, among them Adamsky (2010) and Lee (2019), claim that strategic culture, rather, provides the best explanation. While we agree in principle, following earlier research, we assume that shared mental models of new technology provide a more accurate explanation of military innovation than strategic culture alone. Studies of risk management (Bessette et al., 2017) and learning organisations (Bahar Aşı et al., 2016) support a notion of shared mental models as a more tangible expression of an actor's strategic culture. We claim that the results of this study support this assumption and corroborate earlier research. While the collective actors in the two cases studied are very similar in terms of strategic culture, the military innovation processes differ significantly in their intensity and in the resulting perception of new technology. Hence, the study highlights a difference between strategic culture and shared mental models and suggests that a cognitive-psychological perspective on military innovation can provide new insights into its dynamics.

If we put the three conclusions about mental models above into a capability development context, we argue that, with further work, they can be operationalised into recommendations. The overarching idea, presented in the introduction, is that the actor who is able to exploit military innovation the quickest has the advantage of greater room for manoeuvre.

The first finding highlights the need to identify the potential military relevance of the new technology and to make it visible to decision-making groups. Until this happens, military innovation is unlikely to gain pace. Consequently, there is a need for further studies into how to formulate and effectively convey assessments in technology forecasts to decision-makers in the military capability development process. Undoubtedly, there is a range of issues in the process involving aspects of human communication, including mechanisms and the different roles and interests of recipients. Thus, a logical next step for the research project would be to explore how best to benefit from knowledge on processes favourable for increasing sharedness in mental models. Although we believe that our rather coarse operationalisation was sufficient to make an effect probable, we suspect that this continued study will require a more rigorous treatment of shared mental models specific to the technology forecast context.

The second finding above underlines the dangers of either over or underestimating uncertainties in assessments of new technology. If a technology, later shown to have disruptive potential, is wrongly assessed to have no military relevance at an early stage, confirmation bias will preserve this shared mental model, and necessary military innovation will be delayed. On the other hand, if it is wrongly assessed to have potential, there is a great risk of wasting resources. Consequently, there is obviously a need both to communicate assessments and to effectively communicate uncertainties – and of course, to continuously work on reducing them.

Finally, and from the viewpoint of this study, the third finding implies it is good practice to diversify study groups and to make differences in mental models visible. Technological experts and military and political leaders, we find, can be made aware of the effects of mental models and confirmation bias, which will allow them to take part in innovation processes with a healthy level of self-criticism. However, self-critical reasoning should also be stimulated. Understanding from earlier research that confirmation bias can be counteracted if challenged with diverging ideas, three recommendations easily come to mind: first, stimulate innovation endeavours in cooperation with civilian companies and universities (we have highlighted that contemporary technology developments are driven by commercial actors and, like security political actors, they are also exposed to a competitive environment); second, conduct experimental exercises in joint settings to increase the probability of representatives of different mental models meeting: third, ensure that younger professionals from within the collective actor are invited to play an active role in the innovation process. With the high tempo of commercially driven technological development today, it is the authors' experience that younger people have different mental models of the use of technology to those of senior decision-makers.

CONCLUSIONS

The cognitive-psychological approach used in this study contributes to the understanding of military innovation processes. The broadly accepted explanation based on differences in strategic culture is further developed. The results show that looking to shared mental models of new technology resolves questions of military innovation more accurately than a simple consideration of strategic culture.

Three conclusions were drawn from a comparative case study of Swedish nuclear weapons development through the 1950s and 1960s and the Swedish cyber defence development that has taken place during the last two decades:

- Military innovation processes are only initiated if and when new technology appears militarily relevant to an actor; thus, the ability to correctly assess and understand the military relevance of technology is crucial to timely capability development.
- The forming of shared mental models can both contribute to and counteract military innovation processes; hence, decision-makers in the capability development process need

to be aware that cognitive-psychological phenomena, such as mental models, can be shared and that confirmation bias affects actors at a collective level.
- Military innovation processes likely gain from mental models being challenged and from diverging mental models being made observable; consequently, the results support research from other perspectives and the idea that it is good practice to diversify and welcome different views on the use of new technology for effective capability development.

More studies are needed to take further advantage of knowledge in the field. This study highlights a need for the exploration of processes favourable for the augmentation of sharedness in mental models of the use of technology in capability development decision-making teams. One aim is to more effectively further military innovation by contributing to the preliminary guidelines on how technology assessments should be performed and communicated.

ACKNOWLEDGEMENTS

This paper was developed, based on the master's thesis, *Militär innovation som resultat av aktörers mentala modeller av ny teknologi* (in Swedish). The authors are very grateful to Mr Stephen Henly for proofreading the manuscript. The research was partly funded by Swedish Armed Forces R&D.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Ola Modig did the conceptualization, research design, validation, formal analysis, investigation, and the writing of the original report. Kent Andersson wrote the journal manuscript, provided scientific supervision, and did the project administration.

AUTHOR AFFILIATIONS

Ola Modig
Swedish Armed Forces, SE
Kent Andersson *orcid.org/0000-0001-6104-5788*
Swedish Defence University, SE

REFERENCES

Adamsky, D. (2010). *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel*. Stanford, US: Stanford University Press. DOI: *https://doi.org/10.1515/9780804773805*

Agrell, W. (1985). *Alliansfrihet och atombomber* (1:1 ed.). Stockholm, Sweden: Liber Publishing.

Ångström, J., & **Honig, J.** (2012). Regaining Strategy: Small Powers, Strategic Culture, and Escalation in Afghanistan. *Journal of Strategic Studies, 35*(5), 663–687. DOI: *https://doi.org/10.1080/01402390.2012.706969*

Åselius, G. (2005). Swedish Strategic Culture after 1945. *Cooperation and Conflict, 40*(1), 25–44. DOI: *https://doi.org/10.1177/0010836705049732*

Bahar Aşcı, H., Zehra Tan, F., & **Altıntaş, F.** (2016). A Strategic Approach For Learning Organizations: Mental Models. *Procedia - Social and Behavioral Sciences*, *235*, 2–11. DOI: *https://doi.org/10.1016/j.sbspro.2016.11.002*

Berman, L. (2012). Capturing Contemporary Innovation: Studying IDF Innovation against Hamas and Hizballah. *Journal of Strategic Studies, 35*(1), 121–147. DOI: *https://doi.org/10.1080/01402390.2011.608933*

Bessette, D., Mayer, L., Cwik, B., Vezér, M., Keller, K., Lempert, R., & **Tuana, N.** (2017). Building a Values-Informed Mental Model for New Orleans Climate Risk Management. *Risk Analysis, 37*(10), 1993–2004. DOI: *https://doi.org/10.1111/risa.12743*

Brantly, A. F. (2014). Cyber Actions by State Actors: Motivation and utility. *International Journal of Intelligence and CounterIntelligence, 27*(3), 465–484. DOI: *https://doi.org/10.1080/08850607.2014.900291*

Carter, C., Kaufmann, L., & **Michel, A.** (2007). Behavioral supply management: a taxonomy of judgement and decision-making biases. *International Journal of Physical Distribution & Logistics Management, 37*(8), 631–669. DOI: *https://doi.org/10.1108/09600030710825694*

DeGroot, G. (2004). The bomb, a life. *The RUSI Journal, 149*(3), 58–63. DOI: *https://doi.org/10.1080/03071840408522950*

Esaiasson, P., Gilljam, M., Oscarsson,, H., Towns, A., & **Wängnerud, L.** (2017). *Metodpraktikan* (5th ed.). Stockholm, Sweden: Wolters Kluwer Sverige AB.

Farrell, T., & **Terriff, T.** (2002). *The Sources of Military Change: Culture, Politics, Technology*. Boulder, Colorado: Lynne Rienner Publishers.

Farwell, J., & **Rohozinski, R.** (2011). Stuxnet and the Future of Cyber War. *Survival, 53*(1), 23–40. DOI: *https://doi.org/10.1080/00396338.2011.555586*

Finkel, M. (2011). *On Flexibility - Recovery from Technological and Doctrinal Surprise on the Battlefield*. Stanford, California: Stanford University Press. DOI: *https://doi.org/10.1515/9780804777155*

FOI. (2014). *Hotbildsunderlag i utvecklingen av civilt försvar*. Stockholm, Sweden: Totalförsvarets forskningsinstitut – FOI.

FOI. (2018). *Typfall 5: Utdragen och eskalerande gråzonsproblematik*. Stockholm, Sweden: Totalförsvarets forskningsinstitut – FOI [the Swedish Defence Research Agency].

Forssberg, O. (1987). *Svensk kärnvapenforskning 1945–1972*. Stockholm: Regeringskansliets offsetcentral [Office of the Government of Sweden].

Furnham, A., & **Boo, H. C.** (2011). A literature review of the anchoring effect. *The Journal of Socio-Economics, 40*(1), 35–42. DOI: *https://doi.org/10.1016/j.socec.2010.10.008*

George, A. L., & **Bennett, A.** (2005). *Case Studies and Theory Development in the Social Sciences*. Cambridge, Massachusetts: MIT Press.

GoS. (1999). *Europas säkerhet - Sveriges försvar*. Stockholm, Sweden: försvarsdepartementet [department of defence].

GoS. (2004). *Vårt framtida försvar*. Stockholm, Sweden: Regeringen [Government of Sweden].

GoS. (2009). *Ett användbart försvar*. Stockholm, Sweden: Regeringen [Government of Sweden].

GoS. (2017a). *Motståndskraft; Inriktningen av totalförsvaret och utformningen av det civila försvaret 2021–2025*. Stockholm, Sweden: Regeringskansliet [Office of the Government of Sweden].

GoS. (2017b). *Nationell strategi för samhällets informations- och cybersäkerhet*. Stockholm, Sweden: Regeringskansliet [Office of the Government of Sweden].

GoS. (2019). *Värnkraft - Inriktningen av säkerhetspolitiken och utformningen av det militära försvaret 2021–2025*. Stockholm, Sweden: försvarsdepartementet [department of defence].

Gray, C. S. (1999). Strategic Culture as Context: the First Generation of Theory Strikes Back. *Review of International Studies, 25*(1), 49–69. DOI: *https://doi.org/10.1017/S0260210599000492*

Grennert, J., & **Tham, M.** (2001). *Att påverka konflikter med IT-vapen; Icke-statliga aktörers möjligheter till inverkan på konfliktförlopp*. Stockholm, Sweden: Totalförsvarets forskningsinstitut – FOI [the Swedish Defence Research Agency].

Griffin, S. (2017). Military Innovation Studies: Multidisciplinary or Lacking Discipline? *Journal of Strategic Studies, 40*(1–2), 196-224. DOI: *https://doi.org/10.1080/01402390.2016.1196358*

Grissom, A. (2006). The future of military innovation studies. *Journal of Strategic Studies, 29*(5), 905–934. DOI: *https://doi.org/10.1080/01402390600901067*

Hammond, J. S., Keeney, R. L., & **Raiffa, H.** (1998). The Hidden Traps in Decision Making. *Harvard Business Review, 76*(5), 47-58.

Handel, M. I. (1987). Technological surprise in war. *Intelligence and National Security, 2*(1), 1–53. DOI: *https://doi.org/10.1080/02684528708431875*

Heickerö, R. (2006). *Informationskrig i cyberrymden. Elektronisk och digital krigföring i en breddad hotbild*. Stockholm, Sweden: Totalförsvarets forskningsinstitut – FOI [the Swedish Defence Research Agency].

Heickerö, R. (2008). *Utveckling av strategier och förmåga till informationskrigföring och informationsoperationer i Kina*. Stockholm, Sweden: Totalförsvarets forskningsinstitut - FOI.

Heickerö, R. (2010). *Emerging Cyber Threats and Russian Views on Information Warfare and Information Operations. Avdelningen för försvarsanalys*. Stockholm, Sweden: FOI, Totalförsvarets Forskningsinstitut [the Swedish Defence Research Agency].

Herzog, S. (2011). Revisiting the Estonian Cyber Attacks: Digital Threats and Multinational Responses. *Journal of Strategic Security,* 4(2), 49–60. DOI: *https://doi.org/10.5038/1944-0472.4.2.3*

Hill, A., & **Gerras, S.** (2016). Systems of Denial: Strategic resistance to military innovation. *Naval War College Review, 69*(1), 109–132.

Jensen, B. M. (2018). The role of ideas in defense planning: revisiting the revolution in military affairs. *Defence Studies, 18*(3), 302–317. DOI: *https://doi.org/10.1080/14702436.2018.1497928*

Jonter, T. (2001). *Försvarets forskningsanstalt och planerna på svenska kärnvapen*. Stockholm, Sweden: Statens kärnkraftinspektion [Swedish Radiation Safety Authority].

Jung, H. (1947). *Vårt framtida försvar: Överbefälhavarens förslag*. Stockholm, Sweden: P. A. Norstedt & Söners Publ./Stockholm in cooperation with Centralkommittén Folk och Försvar.

Karresand, M., Persson, M., & **Lindahl, D.** (2004). *Scenarion och trender inom framtida informationskrigföring ur ett tekniskt perspektiv*. Linköping, Sweden: Totalförsvarets forskningsinstitut - FOI [the Swedish Defence Research Agency].

Kastenberg, J. (2009). Non-Intervention and Neutrality in Cyberspace: An Emerging Principle in the National Practice of International Law. *The Air Force Law Review, 64*.

Kellstedt, P. M., & **Whitten, G. D.** (2013). *Fundamentals of Political Science Research*. Cambridge, UK: Cambridge University Press. DOI: *https://doi.org/10.1017/CBO9781139104258*

Kier, E. (2017). *Imagining War: French and British Military Doctrine Between the Wars*. Princeton, New Jersey: Princeton University Press. DOI: *https://doi.org/10.1515/9781400887477*

Kott, A., & **Perconti, P.** (2018). Long-term forecasts of military technologies for a 20–30 year horizon: an empirical assessment of accuracy. *Technology Forecasting Social Change, 137*, 272–279. DOI: *https://doi.org/10.1016/j.techfore.2018.08.001*

Lee, C. (2019). The role of culture in military innovation studies: Lessons learned from the US Air Force's adoption of the Predator Drone, 1993–1997. *Journal of Strategic Studies*. DOI: *https://doi.org/10.1080/01402390.2019.1668272*

Lidén, M., Gräns, M., & **Juslin, P.** (2018). The Presumption of Guilt in Suspect Interrogations: Apprehension as a Trigger of Confirmation Bias and Debasing Techniques. *Law and Human Behaviour, 42*(4), 336–354. DOI: *https://doi.org/10.1037/lhb0000287*

Luiijf, E., de Graaf, P., & **Besseling, K.** (2013). Nineteen National Cyber Security Strategies. *International Journal of Critical Infrastructure Protection*, *9*(1-2), 3–31. DOI: *https://doi.org/10.1504/IJCIS.2013.051608*

McGraw, G. (2013). Cyber War is Inevitable (Unless We Build Security In). *Journal of Strategic Studies, 36*(1), 109–119. DOI: *https://doi.org/10.1080/01402390.2012.742013*

Mohammed, S., Ferzandi, L., & **Hamilton, K.** (2010). Metaphor No More: A 15-Year Review of the Team Mental Model Construct. *Journal of Management, 36*(4), 876–910. DOI: *https://doi.org/10.1177/0149206309356804*

Munoz-Rubke, F., Olson, D., Will, R., & **James, K. H.** (2018). Functional fixedness in tool use: Learning modality, limitations and individual differences. *Acta Psychologica, 190*, 11–26. DOI: *https://doi.org/10.1016/j.actpsy.2018.06.006*

Nickerson, R. (1998). Confirmation Bias: A Ubiquitous Phenomenon in Many Guises. *Review of General Psychology, 2*(2), 175–220. DOI: *https://doi.org/10.1037/1089-2680.2.2.175*

Nye, J. S. (2017). Deterrence and Dissuasion in Cyberspace. *International Security, 41*(3), 44–71. DOI: *https://doi.org/10.1162/ISEC_a_00266*

Posen, B. R. (1984). *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*. Ithaca, New York: Cornell University Press.

Rook, L. (2013). Mental models: a robust definition. *The Learning Organization, 20*(1), 38– 47. DOI: *https://doi.org/10.1108/09696471311288519*

Rosen, S. P. (1991). *Winning the next war: innovation and the modern military*. Ithaca, New York: Cornell University Press.

Silfverskiöld, S., Andersson, K., & **Lundmark, M.** (2021). Does the method for Military Utility Assessment of Future Technologies provide utility? *Technology in Society, 67*. DOI: *https://doi.org/10.1016/j.techsoc.2021.101736*

Svensson, E., Magnusson, J., & **Zouave, E.** (2019). *Kryptomaskar och deras konsekvenser (*FOI-R—4774—SE). FOI, Försvarsanalys.

Swedish Armed Forces. (1954). *Alltjämt ett starkt försvar: riktlinjer och kostnader* (Kontakt med krigsmakten, Year X(9–1)). Sweden: Försvarsstaben [the defence staff of SwAF].

Swedish Armed Forces. (1957). ÖB-utredningarna 1957 (Kontakt med krigsmakten, Year XIII(10– 12)). Sweden: Försvarsstaben [the defence staff of SwAF].

Swedish Armed Forces. (1962). *ÖB 62: riktlinjer för krigsmaktens fortsatta utveckling*. Stockholm, Sweden: Försvarsstaben [the defence staff of SwAF].

Swedish Armed Forces. (2001). *Försvarsmaktsidé och målbild; Årsrapport från Perspektivplaneringen 2000–01*. Stockholm, Sweden: Försvarsmakten [Swedish Armed Forces].

Swedish Armed Forces. (2013). *Försvarsmaktens redovisning av perspektivstudien 2013*. Stockholm, Sweden: Försvarsmakten (Swedish Armed Forces).

Swedish Armed Forces. (2016). *Militärstrategisk doktrin - MSD 16*. Stockholm, Sweden: Försvarsmakten [Swedish Armed Forces].

Swedish Armed Forces. (2018). *Tillväxt för ett starkare försvar*. Stockholm, Sweden: Försvarsmakten [Swedish Armed Forces].

Swedish Armed Forces. (2019). *Försvarsmaktens underlag för försvarspolitisk proposition 2021–2025*. Stockholm, Sweden: Försvarsmakten [Swedish Armed Forces].

Swedish Armed Forces and MSB. (2016). *Sverige kommer att möta utmaningarna*. Stockholm. Sweden: Försvarsmakten och Myndigheten för samhällsskydd och beredskap [Swedish Armed Forces and the Swedish Civil contingencies Agency].

Toader, A., Cantner, U., & **Kessler, T.** (2019). The Effect of Team Mental Models Divergence on Creative Performance During Situational Changes. *Creativity Research Journal, 31*(1), 40–51. DOI: *https://doi.org/10.1080/10400419.2019.1577206*

Tversky, A., & **Kahneman, D.** (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124–1131. DOI: *https://doi.org/10.1126/science.185.4157.1124*

Weller, J., Ceschi, A., Costantini, A., Sartori, R., & **Di Fabio, A.** (2019). Dimensions of decision-making: An evidence-based classification of heuristics and biases. *Personality and Individual Differences, 146*, 188–200. DOI: *https://doi.org/10.1016/j.paid.2018.07.033*

Yang, Y., Narayanan, V., Baburaj, Y., & **Swaminathan, S.** (2015). Team mental model characteristics and performance in a simulation experiment. *Management Research Review, 39*(8), 899–924. DOI: *https://doi.org/10.1108/MRR-02-2015-0036*

TO CITE THIS ARTICLE:
Modig, O., & Andersson, K. (2022). Military Innovation as the Result of Mental Models of Technology. *Scandinavian Journal of Military Studies*, 5(1), pp. 45–62. DOI: *https://doi.org/10.31374/sjms.117*

Submitted: 27 September 2021
Accepted: 31 January 2022
Published: 14 April 2022

Scandinavian Journal of Military Studies is a peer-reviewed open access journal published by Scandinavian Military Studies.