Modelling command and control: potential negative effects of transferring features of the individual to the organization

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Abstract

Both academics and professionals often claim that individuals in defense enterprises with access to the most relevant information and who possess the best situation awareness should decide upon what to do. This claim is typically interpreted as the person closest to the situation should decide, inferring that closeness automatically provides the best situation awareness. This interpretation is problematical however, partly because the term "situation" is undefined and partly because the individual would have to always be provided with information regarding the whole enterprise and also have the possibility to assimilate this information.

This interpretation is probably influenced by prevalent descriptions or models of command and control (C2). The field of C2 research has developed models of C2 covering several different perspectives. Two distinct classes of models are represented in this paper. First, models stemming from an individual perspective, typically focused on decision-making are highlighted. Second, models focused on a systemic and activities perspective on C2 are presented. We refer to these as reference models. This paper provides a relational analysis between the models of individual decision making and the C2 reference models. The analysis relates key features from the models of individual decision making to cornerstone aspects of the C2 reference models, especially aspects such as centralized/decentralized decision-rights. The discussion covers arguments to why it is important to avoid unreflected and noncritical transfer of features from one class of models to the other.

1 Comprehensive situation awareness – individual or system

On May 24, 2022, in Uvalde, Texas, 19 children in the age between 9 and 11, and two teachers, were shot and killed by an 18 years old lone gunman. The aftermath, including the results from the ongoing[1] formal investigations, will hopefully reveal more details about what happened in this awful attack. One question that has led to strong public critique, is why it took so long for the responding police force to enter the rooms where the perpetrator was resided. As it seems, the police force decided to await entering the rooms for about an hour, despite cell phone calls from students inside the rooms to 911 operators pleading for help [1], [2].

Without preceeding the formal investigations, the horrifying situation that took place in Uvalde, puts the focus on some questions with importance for C2. For example: who was in command at the scene?, What communication took place during the event and between whom? Was the necessary infostructure in place and working during the event? Did the responding team have the adequate competence for the situation? Who had access to the most relevant information and who had the best situation awareness of the ongoing situation?

Situation awareness (SA) is defined as a persons "state of knowledge", is generally stated as: "knowing about what is going on", and more specifically: "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" [3, p. 36]. The SA construct is, and has been, a significantly influential concept in both academic research literature e.g., [3], [4] and also in professional

[1] At the time of writing this paper (June 2022).

handbooks and doctrines e.g., [5, p. 2.5].

In this paper, our interest in SA derives from its connection to decision-making and hence also to C2. SA is moreover an instantiation of a model that is developed from an individual human perspective and from cognitive psychology specifically. Although humans are undoubtedly the key components in a C2 system (e.g., as decision makers and leaders), it is however the C2 system as a whole that fulfil its purpose. This claim leads to a need for an operational definition of C2 in this piece of work.

1.1 COMMAND AND CONTROL

The field of C2 research includes, or overlap, several different perspectives [6]. In turn, these perspectives have been suggested to be analyzed by a set of different fields of research [7]. C2 as an activity is one prominent view that is apparent in both videly used practical professional context (such as in military organizations, e.g., NATO) and also in more theoretic academic circumstances. This paper adopts a class of definitions that focus on C2 as an activity carried out by people within an organization or system in order to achieve that organization´s or system´s stated goal e.g., see [8, p. 4]. Further, on a systemic level, we consider the C2 system to constitute, together with an execution system, an overall mission respondent system [8, pp. 14-15].

The actual C2 process typically include varying amounts of both problem solving (generating courses of action that reduce or eliminate the differences between an initial state and a desired goal state) and decision making (choosing among the alternative courses of action) supported by appropriate methods and technology.

The types of problems that need to be handled by C2 activities can vary. Efforts have been made to classify problem types or domains. One example is the Cynefin framework [9] that includes four different problem domains: Clear (formerly named simple or obvious), complicated, complex or chaotic. Complex problems have been of particular interest, perhaps because they are the most challenging to both the scientific community and to the professional community. Yet, coping wih complexity in the military (and other) domain, is and has been, a pivotal line of investigation for C2. If the contexts, in which C2 is conducted, are influenced by complexity, how then does C2 relate to complexity?

A complex system[2] can be described as “a large number of parts that have many interactions” and “it is not a trivial matter to infer the properties of the whole” [10, pp. 183-184]. This description indicates that the sheer size of events in the outer environment[3] affects the amount or degree of complexity (see also [11, pp. 73-75] , [12, p. 131] about factors affecting complexity). If we for example compare a fire in a trash bin can with a fulblown forest fire, we can perhaps grasp the difference in the level of complexity. This leads to an answer of the question regarding why C2 is needed at all. Namely because the inner environment (in this case the C2 system) needs a proportional variety or complexity to handle the situation in the outer environment.

Naturally the level of necessary variety will vary with the scale of the situation at hand. To put out the fire limited to the trash bin would need a fire extinguisher and an operator (a fire fighter). The forest fire on the other hand would need a battery of resources including for example mobile land units, aircrafts, helicopters and fire break units. This massive collection of resources would certainly also need to be coordinated in space and time to effectively and efficiently achieve the goal – to stop the fire. Beside the direction (what to achieve/do), which in both these cases are rather straight forward (putting out the fire), the aspect of coordination (how to do it) is the difference. Hence, direction and coordination[4] are both required abstract products from the C2 process. On the concrete level of form these products would be represented by an actual order or other physical artefacts (verbal messages etc.).

With the example above we are ready to conclude there is a connection between a problematic situation in the outer environment (cf. endeavor space), with the chosen C2 approach .

1.2 C2 REFERENCE MODELS

The “cube” model (see figure 2 below) has over the years become a reference model regarding C2 approaches [13,

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[2] In this paper we apply a general definition of a system [60, p. 9]: “A combination of interacting elements organized to achieve one or more purposes”.

[3] The inner and outer environment are terms derived from Herbert Simon [10] and his overall approach focusing on design – the inner environment designs an interface (an artefact) to handle the properties of the outer environment.

[4] Coordination can also be regarded as an effect of direction. How much coordination that has to be explicit depends on the type of mission at hand. Nevertheless, the C2 process needs to provide both direction and coordination to the mission respondent system as a whole in some way.

p. 6]. It focuses on three main variables or dimensions: a) distribution of information, b) patterns of interaction, and c) allocation of decision rights[5]. In practice, these variables are regarded as inter-dependent. Allocation of decision rights shapes patterns of interaction and in turn these two variables determine the distribution of information [14, p. 39].

The C2 approach space is about structure and organization of C2. One particular merit of the C2 approach space model is its grounding in data (more than 300 variables and 3000 relationships). The model was established trough the input from 36 NATO member experts representing 9 member states and two partner countries. The C2 approach space is in turn related to a general conceptual model (process view) as shown in figure 1 below.

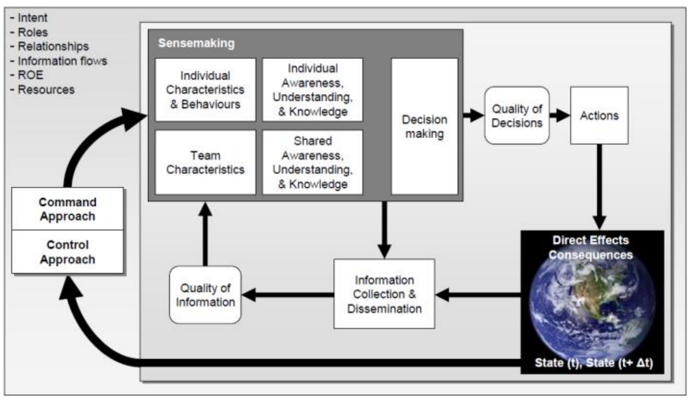


Figure 1. The conceptual model [13, pp. 7-8].

The conceptual model displays an integrated stance regarding both individual and team/group factors within the sensemaking frame. How these two different perspectices relate are however not fully understood [13, p. 3]: "Many of the concepts that apply to individuals (e.g., awareness) have a team or group counterpart (e.g., shared awareness). These team counterparts, while they are similar, are not identical to their individual partners and much work will be needed to better measure and understand them."

The three variables in C2 approach space have remained surprisingly stable over the years since introduced e.g., [14, p. 38]. However, the C2 approach space has gradually become more concerned to also include a coalition- and collectice perspective.

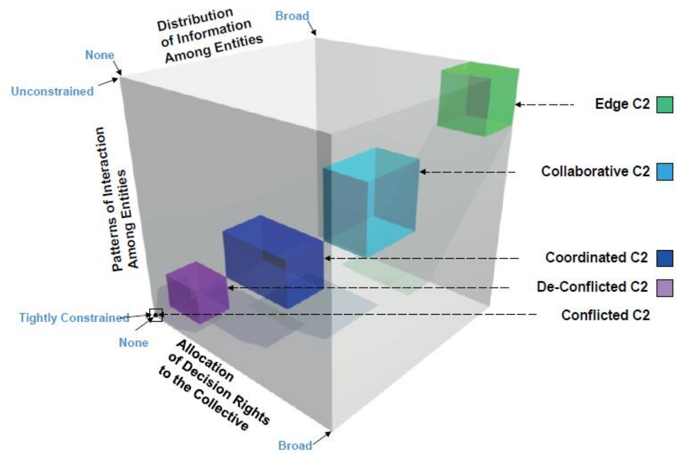


Figure 2. The C2 approach space [15, p. 2]. With permission from author.

In addition, an increasing focus on the "endeavor space" (cf. "situation" [3]) and its relation to the alternative C2 approach archetypes (conflicted, de-conflicted, coordinated, collaborative, edge) [14, p. 41], [15], [16], have occurred. The endeavor space is built up by three varibles: coupling/causality, dynamics and complexety/tractability [15, p. 6]. This need for matching between C2 approach and the endeavor space is also noticeable in the work on agility [17], [14]. Another research path investigating this relation (i.e., C2 architechture vs. various levels of complexity) is with the use of microworlds e.g., see [18]. In this paper we will mainly focus on decisions within the mission in itself. We do acknowledge that the overall decision about choosing C2 approach is certainly important, though this topic deserves a paper on it´s own right.

The generic C2 process model suggested by [19] is another influential attempt to catch and describe the key activities performed in C2. This work relies on empirical data in an even more elaborated manner than the conceptual model mentioned above. The team of researchers aggregated results from field observations covering three different domains and linked them to an overview of existing models of C2. The domains were emergency services (police- and fire services), civilian services (national grid,

[5] Allocation of decision rights have been experimentally measured as e.g., "Amount of individuals with decision rights divided by total number of individuals" [14, p. 116].

national air traffic services, and network rail) and armed services (airforce, navy and army). All instances of the services were at the tactical level. The selection of existing models of C2 consisted of: structural models (e.g., the cybernetic paradigm), network models, dynamic models, agent models and sociotechnical models.

The authors present five common features that are shared between the domains [19, p. 225]: a) “[T]he presence of a central control room that is remote from the primary operations. Data from the field are sent to displays and/or paper records about the events as they unfold over time.”, b) “[R]eliance on the transmission of verbal messages between the field and the central control room. These messages are used to transmit reports and command instructions.”, c) “[T]he planning activities occur in the central control room, which are then transmitted to the field. There are collaborative discussions between the central control room and agents in the field on changes to the plan in light of particular circumstances found in-situ.”, d) “[T]he activities tend to be a mixture of proactive command instructions and reactive control measures.”, e) “[D]ifferent social architectures are readily supported, such as centralised, split and distributed network.”

Further, the authors hypothesise that: “[T]he success or failure of a command and control system will be the degree to which both the remote control centre and agents in-the field can achieve shared situational understanding”. Beside the five common features presented, Stanton and colleagues found that task analyses from the field observations resulted in seven categories [19, p. 226]: “Receive, Plan, Reherse, Communicate, Request, Monitor, Review”. These categories are highlighted with bold text in figure 3 below.

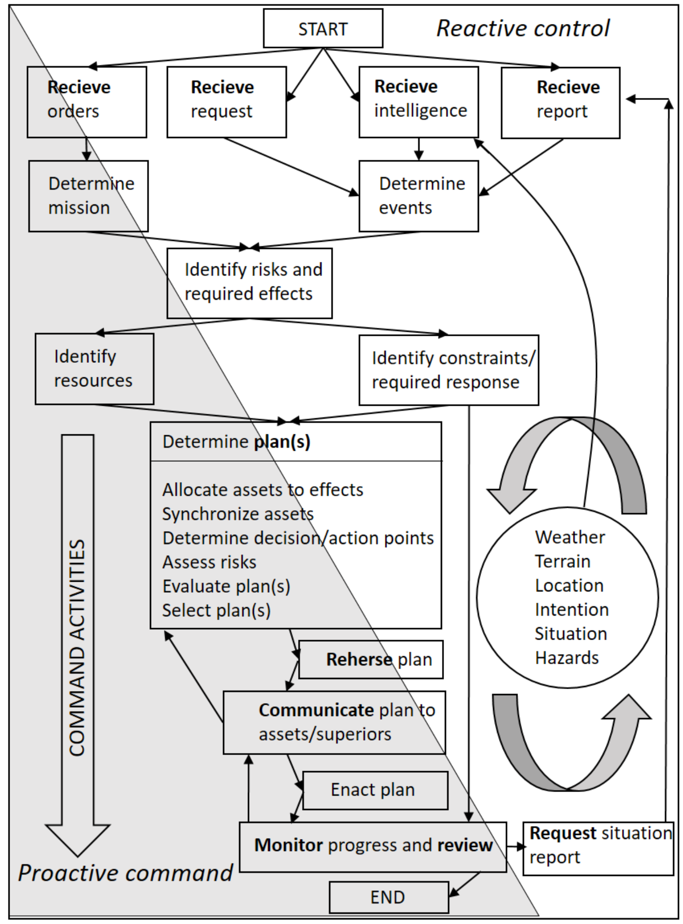


Figure 3. Generic C2 process, the seven categories marked with bold text. Adapted from [19, p. 232].

1.3 THE HUMAN ORGANISM AS A METAPHORE/ANALOGY OR BLUEPRINT FOR C2?

Further on in this paper, we will immerse in the specific theories and models based on the individual that we have chosen to relate with the C2 reference models. However, before that, an introduction to the view of the human individual as a metaphore for C2 systems can be useful.

It is no wonder that the human body/individual has been used extensively for describing functions within an organization or enterprise e.g., [20, pp. 63-69]. It is equipped with parts enabling action and motion (cf. the execution system) in the form of arms and legs, it is directed and coordinated by a central system, also known as the brain and nervous system (cf. the C2 system) and, it has the capability to sense its environment (cf. feedback control via sensors) in the form of eyes, ears, nose, mouth and skin. Coakley [21, p. 41] noted this is “the most commonly used analogy for C2”.

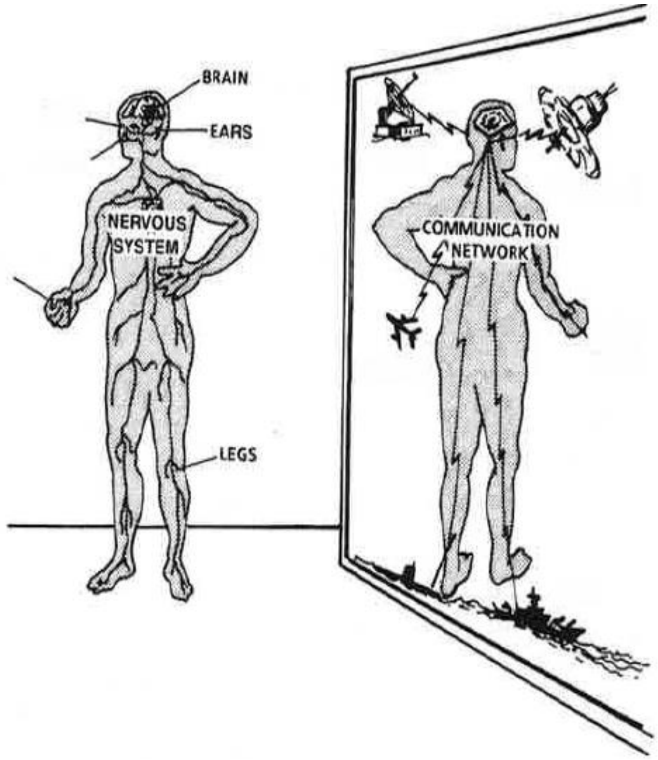


Figure 4. The human body as analogy for C2 [21, p. 41].

Even though the human analogy with a C2 system or an organization/enterprise seems to be striking in several ways, there are however some potential gaps in this line of thinking. For instance, a human being is not an organization. An organization can consist of thousands of people and it is created from the beginning with a specific purpose (what is the "purpose" of a human?) e.g., [22, pp. 4-5]. The functions (or parts, if we focus on form) of a human body/individual normally provide a unified benefit for the whole, while different functions or parts of an organization often display some level of internal conflict. You have probably never heard of discussions, negotiations or collaboration between, say a liver and a pancreas, while these activities are central to many organizations everyday existence. In humans, the decision making is completely centralized and performed by the brain.[6] In organizations, the decision making functionality can vary from highly centralized to more decentralized, which in turn admits various amounts of autonomy.

Finally, attention and awareness of an individual is not the same as in an organization or response system. Indeed a unilateral focus on individuals´ cognitive abilities, may also hamper a perspective that includes the systemic properties such as the specific situation (context), organizational aspects and the artefacts (e.g., technology and methods) which support operators in the exercise of C2 activities [11]. With other words [14, p. 37]: "This anthropomorphized view of command persists to this day as many military organizations define C2 as a commander's exercise of authority. This, of course, does not speak at all to how the function of C2 is or could be exercised and what may be appropriate or inappropriate for a given organization that has taken on a particular mission under a certain set of circumstances." Unclear approaches between the individual perspective and other levels of analysis (organizational, systemic, collective etc.) have also been noted in a related field of research – improvisation in crisis management [23, pp. 102-103].

We began this paper by introducing the key aspects of the SA model and also pointed out the fact that coordination aspects are not represented in the commonly used human-organism-metaphor for C2. Next we will explore how a set of influential models focusing on the individual, including Endsleys SA model, relate (or not) to the reference models of C2. We will concentrate on the allocation of decision rights – that is the question about the appropriate balance between centralized and decentralized organization of C2.

To conclude, the overall problem investigated in this paper, is the potential negative effects from (unreflected) transferring features of the individual to the organization in the context of C2. We will therefore strive to answer the question:

What are the potential negative effects of transferring features from models of individual decision making to models/theories of C2?

2 Individual models/theories

We have chosen to include the following theories and models as suitable for comparison with the C2 reference models presented in the introduction: a) recognition primed decision-making (RPD) by Klein [24], [25], b) situation awareness (SA) by Endsley [3], and c) observe-orient-decide-act model by Boyd (OODA) [26]. There are certainly more possible theory candidates that could have been included in our analysis, for example Brehmers dynamic decision making [27]. However, because of space

[6] We assume that decision making is a consious process which excludes for example reflexes.

limitations and perhaps less obvious impact in military handbooks, we have made this delimitation.

These three theories have the following features in common: They are all derived from an individual and applied perspective, they are all focused on, or closely related to, decision making (SA as a requisite for decision making and OODA as often described as a model of decision making), and they are all mainly process based models. Further, they are (or have been) used in military handbooks.

The comparison includes origin, descriptive or prescriptive approach, empirical grounding, main processes, factors or conditions influencing the processes, and examples of usage in military handbooks (or corresponding to handbooks). The features of these theories are then, in the following section, related to the cornerstones of the C2 reference models.

2.1 Recognition primed decision making

The RPD model [28], [29] was developed within the field of naturalistic decision making (NDM) [30]. NDM research is concerned with how people make decisions in real-world settings, in particular situations featuring for instance ill-structured problems, uncertain dynamic environments, shifting ill-defined or competing goals, and time stress [28]. NDM research has a descriptive approach and is mainly based on field studies of experts that make decisions in demanding situations, as for instance fireground commanders [28]. Expertise in this case is not refering to expertise in decision making per se, but instead expertise regarding the particular domains [31].

The NDM approach can be contrasted to more traditional decision making research which mainly is conducted in controlled settings and that investigates why people deviate from optimal decisions e.g., [32]. In the latter case, decision making is seen as selection between alternatives, whereas the NDM field concern the type of decision making that is based on categorizing situations and recognizing workable and satisficing options, cf. [33]. Situation assessment is the critical element for decision making in this case [31]. Decision making from a NDM point of view is thus closely related to intuitive decision making [34].

In the most basic variation of the RPD model the decision maker recognizes the situation at hand, including the plausible goals (what is possible to accomplish), critical cues (what information need increased attention), expectancies (what is likely to happen), and typical successful actions in such situations. In the more elaborate variation the decision maker evaluates the potential course of action by mental simulation, thus incorporating a component of analysis, before implementation [29]. Figure 5 shows an integrated view of the RPD model including both variations. Since the RPD model is based on recognition the decision maker's experiences and expertise in the domain is essential.

Klein [24] lists cases in which RPD type of decision making is less helpful; in tasks where data are abstract (e.g. alphanumerical data) instead of concerning concrete situations, in tasks requiring optimizing rather then satisficing, in tasks that requires agreement from multiple stakeholders, and in tasks when the decision makers´ level of expertise is low in that particular domain. Errors occur mainly due to lack of expertise leading to inadequate situation assessment resulting in failure to anticipate consequences of actions.

The RPD model was a result from studies of for example fireground commanders [28], tank platoon leaders [35], incident commanders managing large forest fires [29], and critical care nursing [36], employing methods such as semi-structured interviews and observations. Thus the decision makers were in these cases primarily in direct contact with the concrete events.

Althougth the RPD model was originally delveoped for describing decision making under time pressure, Klein and collegues found that even decision makers working over days or months (design engineers) often behaved according to the RPD model [29]. Thus it seems like time pressure per se is not a neccessary condition for recognitional decision making to occcur, but instead the task, an information-rich situation, and the decisionmaker´s prevous experiences and expertice seems more important.

Moreover, all these cases concerned individual decisionmakers. There have been attempts to extend the model to teams but it was concluded that the RPD model is too narrowly focused on particular aspects on decision making to be meaningfully extended to team or organizational level (see [37]). Klein [24], [38] however remarks that cohesive teams could behave according to the RPD model, for instance that options are not compared applying a satisficing criterion. For example in command and control teams at the army brigade level during planning, and incident commanders and their teams working to manage large forest fires [29, p. 98].

The RPD model was used for developing a model for military operations planning, the Recognitional Planning Model (RPM, [25], [39]). Thunholm [40] developed the

Planning Under Time-pressure model (PUT) by combining RPM and the traditional Swedish Army planning manual. PUT is currently applied in the Swedish Army at the tactical level. The RPM was based on the RPD model and on observations of command posts exercises in US Army, Navy and Marine Corps ranging from battalion to corps to Joint Force Air Component Commander [25]. The goal was to develop a model that was suitable to time-constrained situations. Moreover, these models were intended to get the commander more involved, assuming that the commander is the most experienced individual. In particular, the commander would not merely approve or disapprove, or choose among options generated by the staff, but instead be involved in the process of generating options. The PUT model [40] is broader in scope then the RPM since it also includes situation assessment. These planning models attempts to be more adapted to actual practice, in particular that a workable course of action (COA) is discovered early in the process. This is in contrast to the traditional models according to which the staff usually have to generate three options which are then deliberately compared on a set of dimensions before a choice is made by the commander.[7]

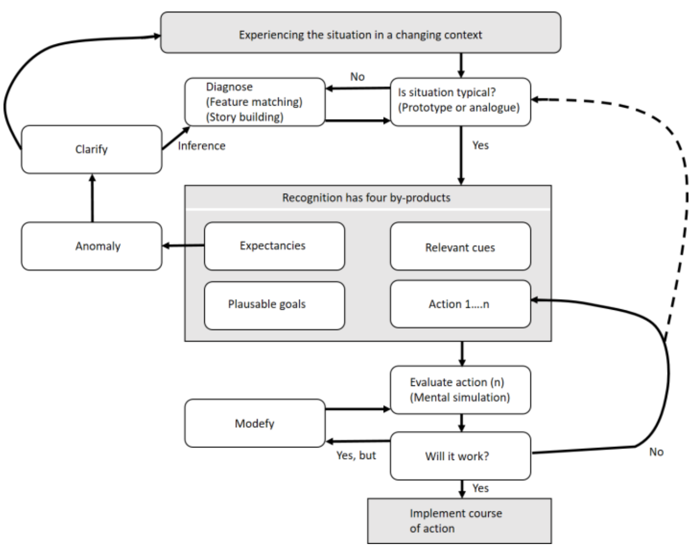


Figure 5. The recognition primed decision making model. Adapted from [29, p. 27].

2.2 Situation awareness

SA has been investgated by several researchers, see [4] for an overview. In this paper we will primarily rely on the version of SA developed by Endsley. Her work, especially [3], is by far the most cited paper in the SA field.

The origin of SA comes from military aviation, especially how the pilots perception of the environment (directly or via instruments) interplay with the pilots internal/mental models of the world around [41]. SA is both a product - a state of knowledge (situation awareness) and a process (situation assessment). As depicted in figure 6 below, it is obvious that the SA concept is an extensive model including many components connected to both the individual and the environment. At the core of SA is the hierarchical assessment process which includes three levels that together achieve SA (see definition in the introduction). Level one is about perception of elements in a current situation. Level two concerns the comprehension of current situation and level three finally is the projection of future status. Methods for measuring SA have been developed, e.g., Situation Awareness Global Assessment Technique (SAGAT) [12, pp. 259-284], although the model as a whole may be difficult to validate because of its large scope.

SA is and has been applied in military handbooks such as [5].

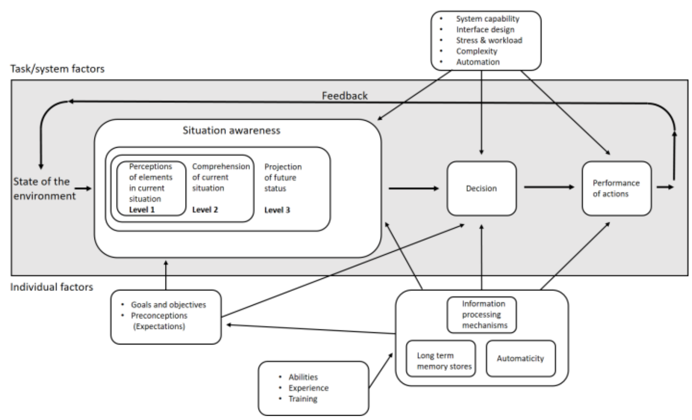


Figure 6. The situation awareness model. Adapted from [3, p. 35].

2.3 Observe-orient-decide-act

The origin of the OODA-loop model and its theoretical underpinning share part of the history with SA. It is also derived from an aviation context. The initial ideas were formed in the context of jet aircraft fighters combat in the Korean war (F 86 vs. MIG 15). Specifically air colonel John

[7] In this paper "planning" is regarded as a key activity within the C2-process.

Boyd´s experiences as a jet fighter and instructor [42] led him to suggest [43, p. 5]: "[I]n order to win, we should operate at a faster tempo or rhythm than our adversaries—or, better yet, get inside adversary´s Observation-Orientation-Decision-Action time cycle or loop." (Underlining in original.) The reason, the why, for the fighter pilot to operate as quoted is [43, p. 5]: "Such activity will make us appear ambiguous (unpredictable) thereby generate confusion and disorder among our adversaries—since our adversaries will be unable to generate mental images or pictures that agree with the menacing as well as faster transient rhythm or patterns they are competing against." (Underlining in original.) These two quotes contain the two things many people probably refer to when asked about Boyd, namely the OODA-loop and the speed factor [42, p. 6].

Even though these ideas are related to a single individual, the pilot, Boyd applied his thinking in a much wider setting, from tactical levels, via strategic levels to the national level [43, p. 141]. From this perspective Boyd could probably be regarded as a strategist as much as a creator of a well known individual decision making model.

Boyd regards the human life in an uncertain and everchanging environment as "conflict, survival and conquest". Therefore it is not surprising that he was inspired by evolution and natural selection and advocated the necessity of a broad repertoire of rapid responses, cooperation and action [43, pp. 10-12]: "[V]ariety, rapidity, harmony, initiative (and their interaction) seem to be key qualities that permit one to shape and adapt". (Underlining in original.) Further, the umbrella title of the main part of Boyd´s work (four presentations and an essay) is: "A Discourse of Winning and Losing", perhaps an indication of the overall focus on survival.

With reference to the German "Blitzkrieg" tactics and their "mission concept" (cf. mission command e.g., [44], [45, pp. V 14-21]) during World War II, Boyd points out [43, p. 74] that a "common outlook" has the implication of: "a unifying theme that can be used to simultanously encourage subordinates inititive yet relize superior intent". A common outlook is in turn based on officers having the same training, tactical education, way of thinking and speech. Even though Boyd states the relevance of the mission concept for achieving higher tempo and rhythm at the tactical level (in harmony with slower tempo and rhytm at higher levels), he also highlights the limitation [43, p. 76]: "[I]t does not suggest ways to coordinate or harmonize activities among many superiors and subordinates as a collective group".

In [46, pp. 15-16] it is clear that orientation is the key product in the OODA-loop. It shapes how we observe, decide and act. Orientation as a view or impression of the world is shaped by "genetic heritage, cultural tradition, previous experiences and unfolding cicumstances". (Underlining in original.) These features in turn are shaped by the process of "many-sided implicit cross-referencing process of projection, empathy, correlation, and rejection." (Underlining in original.) These activities are interactions needed for balancing the two pairs of variety/rapidity and harmony/initiative (see above).

To Boyd, the OODA-loop *is* the command and control-loop. It is about shaping and adapting to cicumstances. While command give direction about what to do and interact with the system in terms of shaping it (to realize what to do), control assess and ascertain what is being done without interacting or interfering with the system. Boyd suggests that the terms command and control are altered to leadership and appreciation, possibly because he reckoned that C2 at the time, did not mean what he thougt it should mean [46, pp. 31-32]. It is clear, already in the introduction to [46, p. 2], that Boyd wants to reduce the importance of hardware in C2 (sensors, communications, computers, displays, satellites etc.) in favor of the "implicit nature of human beings".

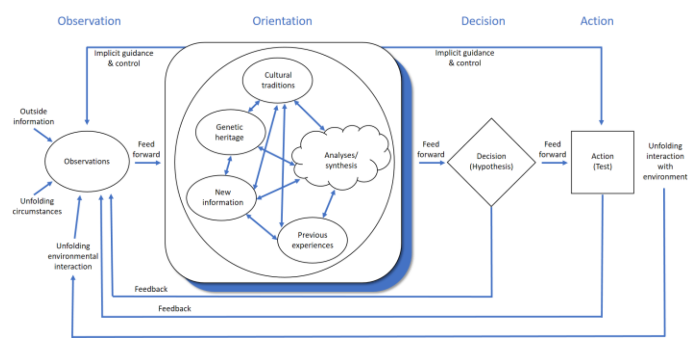


Figure 5. The complete OODA-loop. Adapted from [26, p. 4].

The only visual representation or model of the OODA-loop that Boyd did appears in [26, p. 4]. One peculiar circumstance is that the three other components of the OODA-loop beside orientation, (observation, decision and action) is not described by Boyd in any detail.

Boyd´s thougts have been influential in shaping several doctrines [42, p. 4] and in military education overall. This fact makes it relevant to include this material in our paper even though it is not alway easy to relate to this unpublished material that has not passed through traditional scientific review. There are however several other authors in the scientific community that have contributed with insightful interpretations of the material, which together helps in the interpretation process [42], [47], [48], [49].

Table 1: A model comparison

Categories\Models	RPD	SA	OODA
Presciptive/descriptive	Descriptive	Descriptive	Prescriptive
Type of model	Process	Process (structure)	Process
Origin	Firefighting	Aviation	Aviation
Key author	Klein G.	Endsley M.	Boyd J.
Key reference	1998	1995	1996
Reseach field	Cognitive psychology	Cognitive psychology	Mix
Theoretical core	Recognition of situation. Mental simulation.	SA assessment level 1-3 (perception, comprehension, projection).	"Common outlook" "Mission concept" "Rapidity" "Orientation"
Measures	Semistructured interviews	SAGAT	No
Military application	PUT [40]	COPD [5]	MCDP-1 [42, p. 4]

3 INDIVIDUAL DECISION MAKING MODELS RELATION TO C2 REFERENCE MODELS

3.1 RPD RELATION TO THE C2 REFERENCE MODELS

The RPD model is a descriptive model of the decision making process occurring among experienced decision makers. RPD is thus not a model of C2 but the model has been used as a basis for prescriptive planning models (RPM [25] and PUT [40]).

If we relate the RPD model to the C2 approach space, the variable concerning allocation of decision rights is obviously of particular interest. Although decisions in the C2 approach space is defined as choices between alternatives, RPD type of decisions are also covered by the C2 approach space [50, p. 83].

How would the RPD model relate to allocation of decision rights? If we consider one of the endpoints of this variable, total centralization, the highest commander could, in theory, have acquired such a level of expertise to be able to arrive to a decision based on recognition in a specific situation. This presumes however that information about the situation is somehow perceptually available. Perhaps we stretch the RPD model slightly, but we believe that it is not necessary to be physically submerged in the situation. Instead, mediated information such as conveyed by stories, maps, videos or livestreams, may as well function as a basis for recognitionally based decisions. Recognition is a cognitive process that needs to be supported by suitable information that, if it is mediated, represents relevant aspects of the situation for patterns to be discovered. However, the combinatorial[8] character of decision tasks that a centralized decision maker is likely to face, would probably require more analytically based decisionmaking [38, p. 5].

Likewise if considering the other endpoint of the variable, total decentralization, decision tasks for decision makers may have less combinatiorial character and therefore be more suitable for RPD. Klein and colleagues based the RPD model on studies of decision making during time stress and other complicating conditions, such as ill-structured problems, uncertain dynamic environments, shifting ill-defined or competing goals. Such circumstances could prevail for decision makers in an organization irrespectively whether the decision rights are centralized or decentralized, although these circumstandes may be more likely to occur for decision makers in direct contact with concrete events. Although, what is important is whether the decision maker has the domain-specific expertise and access to adequate information.

Regarding the variable "distribution of information" in the C2 approach space, it is relevant that the decision maker have access to perceptually available and high quality information relative to the task at hand. It is likely that a broad distribution of information yields access to a richer picture supporting specific decisions. Likewise, unconstrained "patterns of interaction" could in this case be seen as a means for providing information for a specific decision maker.

If we consider the generic process model of C2 described by Stanton and colleagues [19], the activities that perhaps could be related to the RPD model are "receive", "determine plan", and "evaluate plan". In the RPD model the process of arriving to a decision is a cognitive activity based on recognition thus the steps between "receive" and "determine plan" in figure 3 would be superfluous. The "evaluate plan" may be related to the activity "mental simulation" in the RPD model. In the model by Stanton and colleagues, it is not indicated who does these

[8] We refer to "combinatorial character" as the combination of a large number of time-frames, organizational units and possible actions etc. that the decision-maker needs to consider.

activities. Thus, it is silent regarding the involvement of the commander, or the cognitive or experiential requirements that would facilitate a recognition primed decision. Moreover, in the model activities such as "Identifying risks and required effects" and "Identifying resources/constraints/required response" point to a traditional mode of planning, which apparently is not based on recognition. Naturally, the cases studied by Stanton and colleagues may have been following a traditional type of planning method in which such steps are prescribed, or the cases studied may have been unsuitable for recognition based decisions.

In all, the RPD model concern cognitive processes, which are not easily observed, whereas the C2 model by Stanton and colleagues concern observable activities on the group level. To create a model of cognitive aspects, for all individuals involved in the C2 process, at the same level of detail as the RPD model, would be a formidable task.

3.2 SA relation to C2 reference models

SA relates to the allocation of decision rights in that decision rights regulate what decisions an individual have the mandate to make. We assume these decisions in turn are directly related to specific tasks and goals. Tasks and goals affect a persons mental models that directs attention of what elements, in a volume of time and space, that need to be perceived. Hence, the allocation of decision rights has a strong linkage to SA and its corresponding assessment process.

If this line of reasoning is valid, then the formulation of specific tasks may be the key to a more elaborated understanding of the term "situation" in the SA framework. Even though the term "situation" is part of the actual construct "situation awareness", it is not, to our awareness, described in Endsleys work with great extent. It is partly defined within the formal definition of SA (see introduction) as: "the elements in the environment within a volume of time and space". Endsley suggests that what constitutes relevant elements are dependent on the operators specific role, task and goals (cf. a pilot, a tactical commader, a manufacturing system operator or an automobile driver). Further, time matters as SA is built up over time and the spatial dimension is important for categorizing different elements in relative relevance, e.g, distance and velocity for enemy aircrafts when you are a fighter pilot [3, pp. 36-38].

A general reflection when considering the relation between SA and the distribution of information dimension is the overall design approach within the SA framework. Endsley has a developed view on for example display design in order to facilitate the achievement of SA [12]. Hence the connection between SA and the distribution dimension is established.

SA originates and focuses on the individual. However, Endsley also presents how SA can be viewed in a more collective sense, i.e., shared or team SA. Endsley acknowledges that an individual in a team may require partly the same SA as other team members. The resulting overlapping requirements, that in turn are based on individual responsibilities, demands coordination – a sharing process. Endsley suggests that sharing can be accomplished by for example verbal exchange, by common information in displays, or by having shared mental models. Shared mental models may in turn reduce the need for communication with verbal exchange [3, pp. 38-39]. Hence, team and shared SA seem to be important in relation to the dimension pattern of interaction. What kind of pattern (amount of interaction) may vary according to Endsley. Since the sharing process sometimes need explicit communication, this also indicates linkage to the distribution of information dimension.

SA relates to the five common features and seven categories found by [19] as follows: SA is obviously needed by individuals in both the control room and in the field. We therefore assume that SA in the control room setting primarily is achieved by assessing the displays and verbal messages. SA in the field is probably to a greater extent achieved by assessing the "particular circumstances found in-situ" [19, p. 225] in combination with the command messages received. Overall it seems that to achieve SA, and situational understanding as expressed by Stanton and colleagues, the generic C2 process model (see figure 3) depends more on explicit communication between command levels than on shared mental models and/or a shared commander´s intent. In contested information environments this explicit communication may be hampered, thus deteriorating situational understanding. Naturally, contested information environments can also affect the variable "distribution of information" in an obstructive manner.

Further, our impression is that SA perhaps has a stronger linkage to the right side representing reactive control with an emphasize on the categories receive, monitor, review and request. One, possibly obvious, reason for this tilt towards control, is that the SA framework is not focusing on decision making per se. Decision making is more prominent in the left section of the model (figure 3) and connected to the "determine plan(s) activity".

3.3 OODA relation to C2 reference models

The OODA-model is the only one, out of the three, that is directly comparable to C2 according to the author himself.

The thougts of Boyd implies, in respect to the distribution of information dimension in the cube model, that this distribution is of less importance. This is reasonable since Boyd rather prioritizes implicit knowledge which is independent of for example a robust network enabling information distribution. The only key piece of information, that is severely important according to Boyd, is the overall or superior intent. Boyd does not however touch upon how this intent should be distributed.

The ideas behind the OODA-loop relate to the dimension pattern of interaction by focusing on, among other things, collaboration and initiative. This in turn indicates patterns of interaction that should not be limited. On the other hand one might wonder how interaction should be performed without the support of infostructure?

At the heart of Boyd´s reasoning is the promotion of the mission concept that supports high tempo and rhythm. This is a distinct sign of that allocation of decision rights is a prioritized matter and should be generally decentralized.

The matching between C2 approach and the endeavor space as suggested by the reference model [13] is not apparent in the OODA material. As we understand Boyd´s reasoning, his recommendations are more general and are supposed to be valid under all circumstances. However, another angle is that the matching mentioned above is related to the strive for agility. Agility in turn is closely connected to adaptation which, as has been presented above, is a very central statement in Boyds reasoning.

The OODA material relates to the five common features presented by [19] in the following way: the presence of a remote control room that receives data from the field is in line with Boyd´s view on control/appreciation - assess and ascertain what is being done. How data are transmitted from the field to higher levels is not accounted for by Boyd though.

Regarding the transmission of verbal messages between the field and the central control room for transmitting reports and command instructions, the OODA model relates as above. That is, the need for information distribution and transmission should be reduced in favor of implicit knowledge about the overall mission and intent. On the other hand, both clear direction and clear control/appreciation should still be performed – a little bit contradictory perhaps?

Stanton et al. [19] also found that planning occurred in the control room followed by transmisson to the field. Planning activities include collaboration between levels so that local circumstances can change the plan. Even though collaboration is also promoted by Boyd we interpret this to be primarily alluding to collaboration between units locally. Discussions between levels should not be necessary because there should be a clear intent to guide actions according to Boyd. Hence the need for transmission is reduced and rapid action is enabled.

More overall observations in [19] is the prevalence mixture of proactive command instructions and reactive control measures and that different social architectures are readily supported. Neither of these characteristics are much supported by the OODA material. Stanton et al. noted extensive communication between levels, Boyd instead proposed a mission concept in order to, among other things, reduce vertical communication. Finally Boyd seems to advocate a general social architecture (based on primarily local interaction), not different types.

4 Discussion and conclusions

4.1 Coping with complexity

All three models (RPD, SA and OODA) share the standpoint that experience, in sufficient amount leading to expertise, is a key factor for decision making, situation assessment, awareness, and orientation. We do not dispute this claim when tasks and situations are characterized by normality (cf. the clear domain [9]). Indeed, sometimes the normal or "business as usual", perhaps receives insufficient attention in organizational design and research efforts, given the amount of time organizations usually spend in that domain.

However, when coping with complex problems that include difficulties in predictability because of the occurrence of unexpected events (cf. high levels of complexity/intractability in the endeavor space [15, p. 6]), then expertise may sometimes even be detrimental. Contexts in which C2 is conducted will be unpredictable and infested with unexpected events. This is the nature of antagonistic threats where a human opponent will strive for deception and surprise. Expertise may even be a contradiction in terms when referred to coping with complexity. The reason is that when you think you know what constitutes relevant "perception of the elements in the environment within a volume of time and space" [3], your attention span will focus and narrow according to the present state of expectations, goals and mental models. This in turn is likely to affect your ability to notice unexpected events (e.g., [51], [52]). See also confirmation bias [53].

We consider there is still hope however when coping with complexity. In order to reduce the probability for experiencing unexpected events (thereby also coping with complexity), we lean on the fact that organizations, or mission respondent systems, consist of more then one individual. This gives the opportunity to increase internal variety [54] (of the organization) by affecting factors important for cognitive capabilities (in individuals within the organization/system) such as experience and training. That in turn builds mental models that guide attention and hence the selection of relevant (?) elements in the environment. In other words, people with different experiences and training will attend different elements. This leads to a potential of more universal SA within the organization. It is also important to mention other types of internal variety, beside the cognitive aspects, when it comes to organizational design. The formation of various divisions that contain the required specialized competences is naturally another powerful tool for coping with complexity. However, just as cognitive variety often needs more coordination, the same goes for the specialized competences within departments.

However, for this to occur, SA has to be achieved on a organizational level by a sharing process. This is not a trivial step and it will not happen automatically (cf. "A robustly networked force improves information sharing. Information sharing and collaboration enhance quality of information and shared situational awareness. Shared situational awareness enables collaboration and self-synhronization" [55, pp. 152-154]). When considering a coalition or a collective perspective (i.e., multiple organizations), the notion of shared SA becomes even more intricate. We have presented that SA is dependent on goals and objectives. Since different organizations have different goals and objectives, shared SA in a coalition or interorganizational sense is not possible to achieve, unless the actors have agreed on a new common goal or objective. However, in an event where several actors´ tasks coincide in time and space, they will at least have to be aware of each others´ intended actions in order to enable coordinated behavior.

One recognized component of complexity is dynamics, i.e, the environment changes over time. Time aspects in relation to C2 are therefore an established theme e.g., [8]. All the presented models (RPD, SA, OODA) highlight the "need for speed" within respective process. The means for achieving adequate speed (faster then the opponent) are for example to go with the first solution that appears in the mind and that survives mental simulation [24].

Further, the SA model suggests that SA is built up over time and that expertise facilitates this build up (achieves SA faster). Endsley also highlights the need for SA in dynamic and time-critical situations.

Finally, the OODA model relies heavily on the proposed need for observing, orienting, deciding and acting faster than an opponent (even though other aspects, as presented above, also have significant importance).

To summarize, both variety and speed are needed to cope with complexity. There is a probable trade-off between necessary variety, which likely requires relatively more centralization[9], and the need for speed, which probably requires more decentralization. This is so because increased internal variety will increase the need for communication and coordination which in turn takes time. This is important when designing for effective and efficient C2. The required (cognitive) variety within an organization/system is not apparent when focusing on an individual – the focus must be on individuals working together with each other and with the supporting technology.

This strive for balance between competing requirements was noted by Herbert Simon over half a century ago regarding the advantages of centralization [56, pp. 321-322]: "We may conclude, then, that some measure of centralization is indispensable to secure the advantages of organization: coordination, expertise, and responsibility." Simon continues with some possible downsides: "Facilities for communication must be available, sometimes at considerable cost. The information needed for a correct decision may be available only to the subordinate. Finally, centralization leaves idle and unused the powerful coordinative capacity of the human nervous system, and substitutes for it an interpersonal coordinative mechanism".

[9] The relation between centralization/decentralization and allocation of decision rights are perhaps always not totally clear. If for example one level of command woud be removed from an organization, one possible effect could be that some decision rights (and power) would spill down the chain of command, but at the same time it is equally possible that decision rights would also bubble upwards to the top of the organization [59, pp. 114-115].

4.2 The commander who has the most relevant information should decide what to do?

What is the most relevant information in a given situation, and indeed what constitutes a "situation"? We have so far provided results that indicates a rather unspecified approach towards the term "situation". This applies to all three of the models/theories we have audited. The SA framework points out that SA assessment level one ("the perception of the elements in the environment within a volume of time and space") is guided by a combination of individual factors such as goals, expectations and experiences, and also by factors related to task/system such as complexity. In a team or shared SA context, responsibility is also mentioned as a key factor.

From an organizational or C2 viewpoint, who has the most relevant information then? We propose that "situation" is primarily defined by the problem at hand and the misson/task assigned. A problem can be defined as the difference between an initial state and an desired state of the environment. A mission/task should include the answers to the basic questions of what, why, when and where (and to a certain degree also how, depending on type of mission and chosen C2 approach). Hopefully, this line of thought can bring a little more precision into the term "situation" and the related "a volume of time and space". Hence, the most relevant information is defined by it´s relevance to the received mission or task and in relation to the problem at hand.

If we try to relate this reasoning with the more extreme versions of mission command (e.g., Boyd), then commanders throughout the defence organization would need to attend and perceive elements relevant to only an overall intent (fictitious example: "we shall have full control of our own territory within six months"). Would this intent suffice to determine who has the most relevant information. Our answer is no.

On the other hand, if we consider a traditional C2 structure where mission and tasks are sequentially broken down between the organizations levels of command, then each task is part of the task at the command echelon above. If we for example assume that a company has been assigned the task to secure a specific area of responsibility (AOR), during war conditions, and that company notices a limited enemy force, the commander has to make a decision on how to respond (to attack or await etc.), and probably has to do so rather rapidly too.

At the same time, the battalion to which the company belongs, has received UAV reconnaissance information stating that a major hostile force is attacking within the battalion´s AOR, yet outside "our" company´s AOR. The battalion commander must make a fast decision to whether the battalion´s resources should be assigned a new task, meaning several companies in a concerted effort should engage the emerging threat. The two decisions, the company commander´s and the battalion commander´s, are naturally not independent of each other. If the company chooses to engage the minor enemy force, less resources will be available to cope with the more substantial hostile threat within the battalion AOR.

Now, who has access to the most relevant information and who has the best situation awareness? The information from the UAV is likely to be the most relevant, given the potential deleterious effects on the overall mission. There are at least two possible options at hand. Either this crucial information can result in a new task from the battalion to the companies as described above. Or, the information could be transmitted directly to the companies (or even the platoons) given an adapted infostructure. This would imply however, that each unit, company or platoon, must have the required assets in terms of competence and overall capability to monitor and receive the information from the UAV, interpret and understand the meaning of it in relation to an overall mission intent. Further, the units must be able to communicate and reach an agreement on what to do and how to respond to the severe enemy attack, i.e., collaborate or even self synchronize.

We will not delve into the question on what option is the most effective and efficient here. Yet, we will state that this fictitous example, together with the one regarding the Uvalde shooting in the beginning of the paper, shows that it´s not always obvious who has access to the most relevant information and have the best situation awareness in an organizational context. Nor is it trivial to decide, or even define, who is closest to the "situation". Although we argue that decision rights should in principal be allocated to the individual who has access to the most relevant information, and thereby likely has an adequate SA, it could be problematic to determine who actually has access to the most relevant information in a specific situation. This claim is relevant not least in a contested information environment.

Sometimes the question is not even about *who* has access to the most relevant information. Instead, we should maybe ask *what* has access. This relates to the systemic approach of SA promoted by for example [11], [4].

Extreme variants include sensor-to-shooter systems where SA and decision-making are reduced to a "if-then" application, promoting the speed-factor above every other considerations. This view certainly raises questions about allocation of decision rights, not least on an ethical level of analysis [57].

4.3 Conclusions

In the introduction we posed the question: *What are the potential negative effects of transferring features from models of individual decision making to models/theories of C2?*

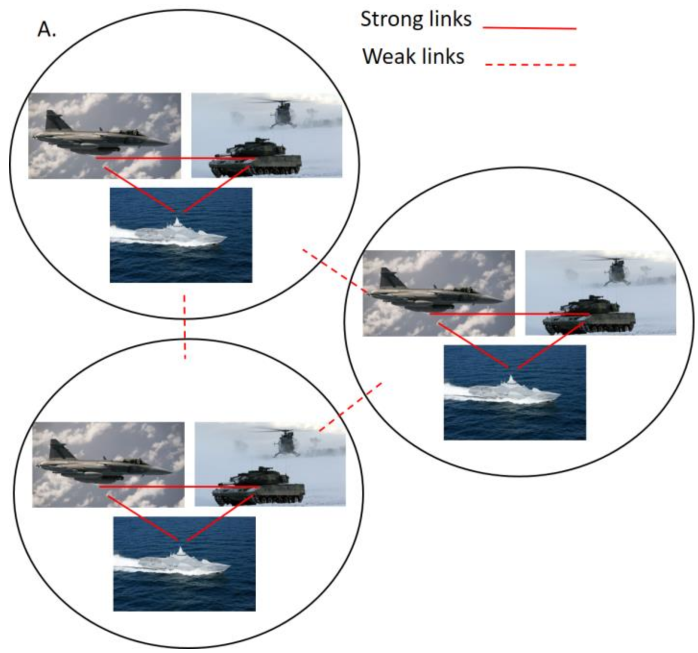
We have compared a selection of very influential models and theories of individual decision making (or closely linked to decision making) with C2 reference models (a combination of [13] and [19]) in order to investigate the research question. We conclude that:

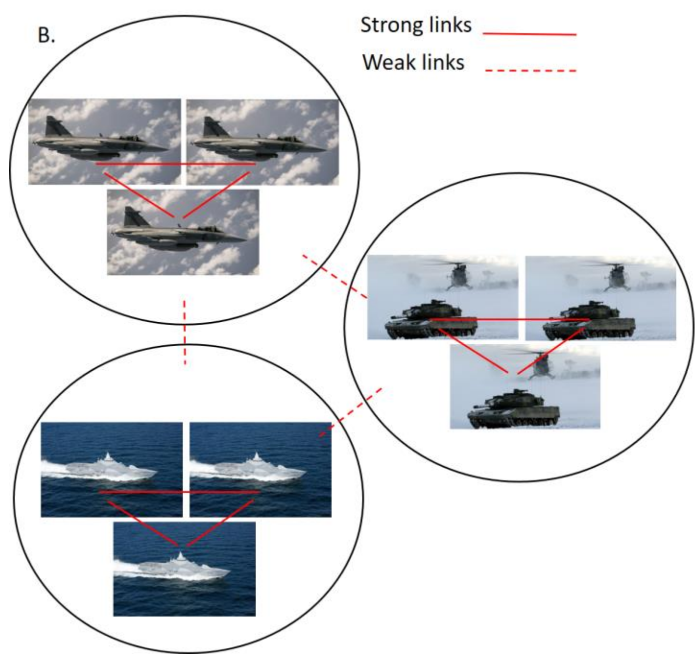
- There is a risk when applying models of individual decision making, as if they were descriptions of a complete C2 process, in that activities necessary for achieving the purpose of C2, are left out. Examples from our investigation include a) the activities regarding observation, decision and acting in the OODA-loop are not described, b) the communication and its necessary infostructure needed for transmitting command intent and control assessment are not described in neither of the models (although touched upon in in terms of team/shared SA), and c) variety aspects needed at the organizational level are not described. Hence, an individual perspective on decision making is useful as a limited part of the C2 process, yet it is not to be mixed up with the complete C2 process.
- To cope effectively with complex problems, a C2 system within a mission respondent system or defence organization, should be able to balance requirements on high tempo with those on requisite variety.
- Allocation of decision rights should be coupled to the received mission or task and to the problem at hand, granted access to relevant information. This applies to both individuals and parts of an organization or system (units, departments etc.).

4.4 Proposal for future research

One urgent research inquiry would be to operationalize variety (functional teams/divisions and cognitive etc., see figure 6A, B, C) and experimentally investigate team or system performance under different conditions, in a microworld or other type of platform, with varying levels of complexity. The complexity variable, in turn, needs to include not just varying dynamics and number of elements, but also a certain proportion of unusual and unexpected events (see figure 7).

We also suggest that the relation between allocation of decision rights, accessible information, and SA merits further research, especially when the quality of information changes during a mission.





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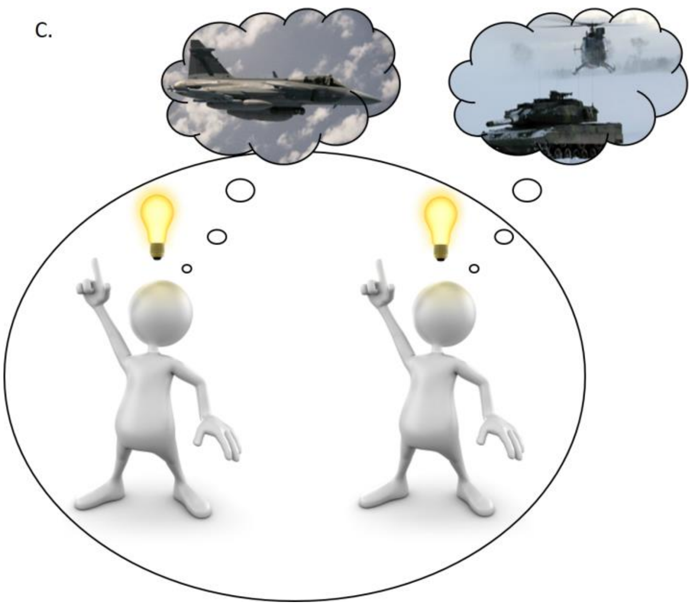

Figure 6a, b, c. Functional variety displayed at the level of teams (variety within) and divisions (variety between) including strong and weak links (see e.g., [10, p. 197] about "nearly decomposable systems"). In addition cognitive variety is displayed at the individual level.

Figure 7. Inattentional blindness occurring in connection to unusual and unexpected events [58].

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