Communication submitted to the organization of the
13th ICCRTS – June 2008 – Bellevue, WA, USA
"C2 FOR COMPLEX ENDEAVORS"

Sharing awareness and problem solving: introducing the concepts of embodied knowledge, epistemic and pragmatic action.

Conference Draft

Dr David W VERSAILLES
Research center of the French Air Force

Contact and corresponding author:

Lt-Col Dr David W Versailles, director
CReA – Centre de recherche de l'Armée de l'air
[Research Center of the French Air Force]
French Air Force base 701
13661 Salon Air
France

tel (office): +33 (0)4 90 17 83 30
fax (office): +33 (0)4 90 17 81 89 (new!!)
cell phone: +33 (0)6 09 52 54 56
eMail: dversailles@cr-ea.net

Topic:
Track 4 – Cognitive and social issues

This contribution is respectfully dedicated to the memory of my friend and Doktorvater Pr Dr Gerhard Radnitzky Me 262 squadron leader and epistemologist.

The ideas developed in this contribution are those of the author and can neither commit the French ministry of Defense nor the French Air Force.

The author would like to thank the participants to the Workshop on knowledge theory organized in Salon de Provence at CReA in January 2007. The author is highly grateful to Prof. Max Boisot for fruitful discussion and the insight for elements of this contribution.

This contribution will elaborate on the interpretation of shared awareness on the basis of the asymmetry between information and knowledge. It will sketch the main elements associated to the implementation of knowledge computation in the C2 cycle on the basis of the aspects associated to knowledge assets codification and contextualization.
Even though the concepts of situation awareness and shared awareness have become now a commonplace in the scientific literature, the concept of awareness remains often considered as a "buzzword" labeling a range of cognitive processes. Relevant definitions may be divided into two classes corresponding to State vs. Process duality. Endsley's conceptual contribution focuses on individual appreciations and confronts "situation awareness" to "situation assessment". Defining and modeling SA has recently evolved to take into account team cognition specificities and to consequently build up team situation awareness (TSA). Teamwork requires information gathering, information sharing, knowledge mobilization and team convergence toward a concrete action. Networking and computational capabilities available at all levels of the military systems on a battlefield and in the C2 chain have come to a turning point where creation, formalization, and distribution of information may be assessed as problem solving features and integrated into a broader investigation of decision making.

Our purpose in this contribution is twofold: on the one hands, we clearly demarcate information sharing from knowledge sharing; on the other hands, we intend to investigate the specific framework of team interaction. The importance of teamwork is recognized, but not traditionally addressed in cognitive and managerial sciences: team related variables such as communication, shared information, and coordination are too often discarded in the analysis. This communication will focus on knowledge-based mechanisms associated to the notion of "shared-ness" within command and control processes. Knowledge results from the interpretation of a proposition regarding a subject in a given context; knowledge truth-status is related to trial and errors processes confronting hypotheses with reality. Opportunities associated to the new computational capabilities associated to the various nodes of the Command and control network do not only refer to information sharing and to the corresponding information transfer mechanisms.

Efficiency in command intent transmission refers to the mobilization of information databases, understood here as a set of common references pushed into the system or picked up at specific times by the various actors. Awareness accommodates a wide range of activities and handles both different timescales and different command layers. Various people committed to the same situational problem will react according to their own perspectives on the situation, which spans the perception of elements in the environment, the comprehension of their meaning and the projection of their status in the next future. "Shared" awareness therefore depends at the same time on individual situation awareness capacities, on team performance and on the architectures present in the weapons systems in order to prepare the individuals' computation. In this contribution

I will follow the lines developed in Popperian knowledge theory and, more specifically, elaborate on the results of Max Boisot's contributions to the issue. This contribution will develop a description of individual computation based upon perception, mental representation and critical elaboration of knowledge which borrows from Boisot's elaboration on Popper's knowledge theory.

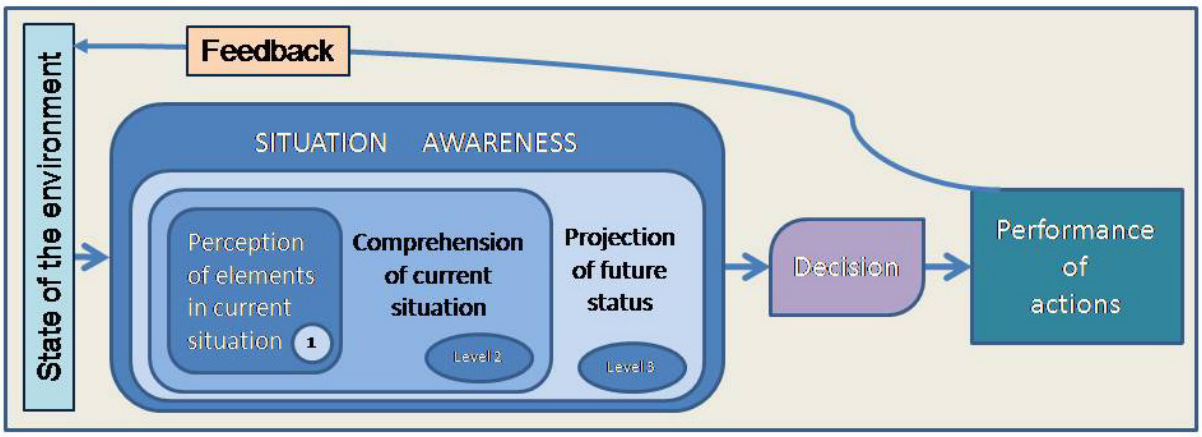
This contribution reads as follows:
The first section investigates the concept of situation awareness and explores its relationship with decision-making processes, on the basis of the difference between information and

knowledge. Section 2 deals with tactical coordination and self-synchronization as an outcome of SA, in some specific aspect of its content. The difference between technical knowledge assets, relational knowledge assets and adaptative knowledge assets is used in order to elaborate on pragmatic and epistemic action processes. The third and last section deals with the dynamics of the interaction between the agents' knowledge filters and pragmatic action. It is here all about embodied knowledge mechanisms and their impact the "shared-ness" of awareness in teams.

1. Decision-making, information and knowledge

Situation awareness was coined by Endsley (2000) as the combination of a perception of elements in the current situation, of the comprehension (in the Weberian sense) of the situation environment and of a perception of the future status of the situation. Altogether they allow decision making, resulting in actions and a potential efficiency. In this perspective, situation "awereness" is allegedly an equivalent to situation "assessment". This concept is therefore merely focusing on the technical knowledge-base at the individual level (incl. the corresponding adaptative knowledge assets) and on the skills and know-how associated to relational knowledge. As already noted (Bryant et al, in Banburry & Tramblay 2004: 107), "Endsley model is not of a form that allows detailed specification of the cognitive operations underlying SA" even though it has contributed to the development of intuitive and 'naturalistic' theories of decision-making. Fiore and Salas (2004: 244) explain also that situation "assessment" is the term used to describe the processes (e.g. attention, pattern recognition, communication) that are engaged to produce the end product of situation "awareness".

Figure 1: The Endsley model (1995)



As Hone et al. (2006) explain, the Endsley model and its related methodology SAGAT (Situation awareness global assessment technique) have been most questioned and most commentators have reduced the SA definition to the three words "Perception, Comprehension, Projection". In her model, Endsley proposes three levels of awareness, corresponding to each phase of her definition: level 1 refers to the amount of unprocessed total or perceptual inputs; level 2 incorporates the cognitive understanding and appraisal of the data conveyed by level 1; level 3 describes the outcome of the perceptual-cognitive process. It is really not sure whether the steps are to be separated in this way, which echoes the traditional debate about the separation between perception and cognition. Endsley's model has been already criticized because it relates clearly to a stimulus-response theorization of individual behaviors which roots in a sequential approach and removes the immediacy.

A major issue for our purpose relates to the conflation of the ambiguous SA acronym options: "situation" awareness and "situational" awareness show a tiny yet critical difference which alters in the end the very content of "awareness". Appraisal of the situation remains a basic part of the process and relates to an individual viewpoint over the situation. In this perspective, Hone et al. propose to reduce the Endsley model in referring to 3 questions worth of attention in virtually any kind of tactical situation: *Who is where?*, *What are they doing?*, *What will they do?*. The authors relevantly insist on the fact that these questions demand at the same time to consider issues in Endsley's levels 1 and 2 together, if not sometimes also some insight belonging to level 3. The analysis of a situation refers here to an appraisal of the current state of the situation, and looks (backwards) over the behaviors of friends and enemies on a battlefield. Situational perspectives render a broader analysis and cannot be separated from a deep understanding of the dynamics associated to the interaction. Situational awareness gives also to the word awareness its full content: understanding of the interactions between all actors (for instance at the tactical level) integrating at the same time all three Endsley's levels.

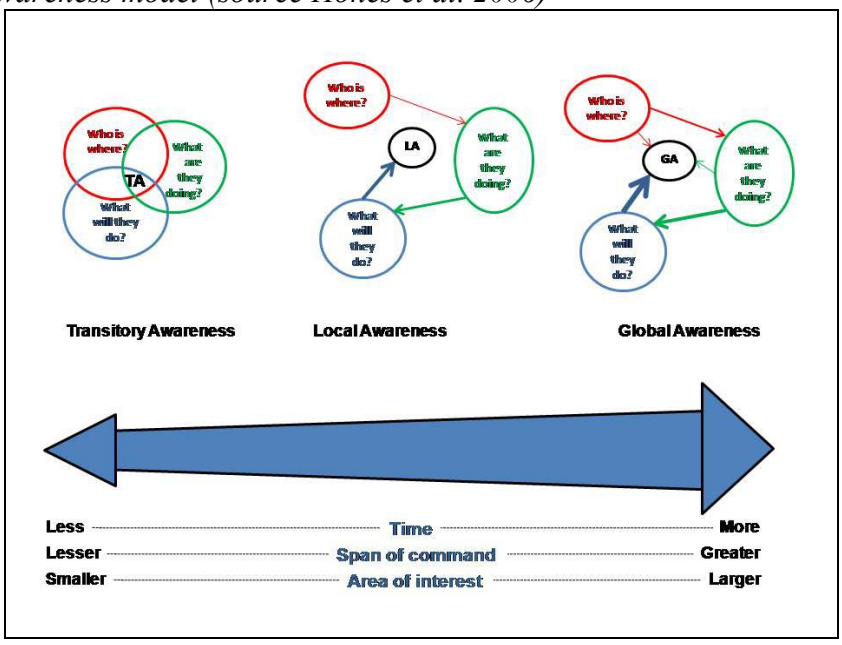
Decision-making in a dynamic context remains inherently associated to the process of learning and adapting in real (irreversible) time. Making decisions depends on individual views on the future and involves the recognition of possibly wrong expectations. The Popperian opposition between the "bucket theory of knowledge" and the "searchlight paradigm" (Popper 1979; Boland, 2003, p 177) coins an endogenous theory of individual knowledge: Learning represents a process without end, where the current state of knowledge[1] represents an assumption over the real word and therefore a "potential step forward" if it will be ever corroborated by the real world. Filling the bucket with data and information does not foster decision-making as the elements recollected might well not be worth for the decision to be made. Collecting information contributes to the processes of knowledge elaboration and of decision-making. How do decision-makers know that they have enough knowledge to be efficient in making the decisions? This is nothing but a logical point: Nobody knows a priori. Anyone will test his knowledge with the decision he made and thereby decision-making remains a process and not a single isolated event. This is a point associated to the relevance of the various aspects used in decision-making rather to the volume of information used for it. Obviously all aspects remain situated and constrained, as the environment conveys its own characteristics of time (speed, urge) and space (distance, milieu specificity). Basically this is a matter of relevance: Decision-making remains always goal-oriented. The process of testing one's knowledge remains as such a form of situational logic, where unintended consequences of one's decision also impact the next decision. As situational analysis explains (eg Boland 2003; 256), once such knowledge is acquired it cannot be unlearned. Once a decision has been made and its consequences have been appraised, the initial decision cannot be erased from anyone's mind.

When an individual is able to "predict" futures status and states of the situation, he grasps the situation in such a way as to give sense to all behaviors in the course of the interaction. These remarks are obviously consistent with Hones et al. (2006) points about *transitory* awareness, *local* awareness and *global* awareness (*cf* figure 2 below). Instances may be given easily. A

[1] It has now become commonplace to distinguish information from knowledge. Knowledge differs from information because an (individual) computational process transforms the data conveyed by reality and selects among all available sources. If Popper is right, the problem of induction is twofold: knowledge does not have to be proven true (and therefore become Knowledge) in order to be used by an individual; knowledge does not have to relate necessarily to an empirical proof and may rely on mere logical deduction (rejection of inductivism).

pilot participating to aerial defense missions may have good TA, low LA and minimal GA, while his mission commander in the same patrol may locate only some feet away with TA, LA rated at 'good' and GA at 'very good'. Each of them is concerned by levels 1 and 2 inquiries, but the aspects associated to the level 3 change drastically according to the role of each contributor to the mission and explain also how the treatment of information and data is reshaped by the attention to dynamic and global aspects. As most authors now consider (*cf* the sources quoted in Hones and al 2006, section 2), there is no single point as TA, LA or GA but a sort of continuum (including to some extent forms of overlapping between them) depicting different apprehension of time, command span and areas of interest.

Figure 2: The 3 Questions Awareness model (source Hones et al. 2006)



Cognitive science has substantially influenced research about teams and, more specifically cross-disciplinary investigation about team cognition movements. The issue at stake here deals both with the efficiency of teamwork and involves the adaptation of coordination strategies: as explain Salas and Fiore (2004: 4) closed-loop communication and a sense of collective orientation are required so that agents can reach the goals assigned to the team. The issue of decision-making in a team represents therefore something "more" than work accomplished individually within a group of individuals; the result of a collective cognitive, behavioral and attitudinal activity. Team processes and performance are affected by inter-individual and intra-individual factors, where the requisite set of knowledge enabling to perform team tasks concretizes in a <u>process</u> (*how to engage in team-related tasks*) as well as a <u>product</u> (*memory for team-mate capabilities*). The process relates to team-relevant knowledge and, for instance, to its transmission within the group (Salas and Fiore, 2004, chap 11: 235); the product to shared mental references. The result may be appraised by coping with the complexity of the phenomena surrounding team process and affecting consequently the decisions to be made at the individual level. Overcoming the problems in teams in the course of action then represents an issue in team coordination or, more specifically a problem in binding team cognition with team coordination (which parallels the binding problem in theories of consciousness). What is here *shared*? What produces *awareness*? "Sharing" presupposes either a reference to the concept of information or to the concept of knowledge. In case one deals with information sharing, the general framework of the mobilization of technical know-how and skills applies into the process. Outcomes affect mainly team coordination. In case knowledge sharing is investigated, the problem shifts onto the binding

of team cognition and team coordination: the convergence at the level of the team of individual computational mechanisms, expectations and truth-status appraisal.

2. Tactical coordination and (self-)synchronization as the outcome of SA

Team cognition and team coordination may be illustrated in the framework of tactical features. The information set associated to a precise tactical environment combined with previously acquired knowledge assets may explain the outcomes of the decision process and illustrate coordination on a battlefield. The decision to be made mobilizes from his/her experience (competency) and refers to previously acquired competencies. Experience acquired on battlefields and in training programs represents a basis for the appraisal of available information sets in a precise tactical situation. It may also balance the incompleteness of relevant information and help for the elaboration of new assumptions over the environment (e.g. friends' and enemies' behaviors on the battlefield). This combination of raw data and of computed experience builds a knowledge set serving as a kind of filter over the data flows surrounding the individual; during the course of action, individual experience will be backed to teammates' competences and team efficiency will be the outcome of such complementarities inside the team.

Such an analytical framework stems from the examination of individual competencies. At the level of the military, the individual embodies technical, relational and adaptative knowledge assets.

- **Technical knowledge** assets are the specific skills and know-how required for the use of armament systems in a specified environment in order to achieve precise performance levels.
- **Relational knowledge** assets relate to the ability to interact inside tactical military units, and also to a further level with other units at the operational level (incl. the incorporation of the consequences of the introduction of ICTs in the framework of joint operations). Relational knowledge assets mobilize individual competencies about the actors present in the mission, and suppose know-how about the management of the various protocols suited for the interaction between all of them. Obviously, empathetic abilities are important in this framework yet it should be separated into different parts contributing at their own level to coordination. One aspect deals with the expectations about teammates's decision making and refers to previously acquired reference patterns such as doctrine and maneuver rules. Another point deals with the ability to walk in teammates' shoes, to feel and anticipate feelings and reactions against the various features of the tactical environment. Empathy remains important in the course of the action. It remains possible to prepare for efficient coordination through training and working on all subparts of relational knowledge assets. The acquisition of reference patterns in training will also convey empathetic relationships within the tactical group, provided that the team will operate in real operations with the very same soldiers who trained together.
- **Adaptative knowledge** assets relate to the ability of reassessing the interaction with other individuals/units in accordance with the evolution of the tactical and operational situations:
    - Assessment of autonomy range at the individual level (technical knowledge) and in the prerogatives associated to leadership (management, repartition and distribution of activities at the level of tactical units, whatever their size and the complexity level associated to it);
    - Integration of responsibility levels and readiness;
    - Control of the quality and efficiency levels.

Individual competencies relate directly to the interaction of technical, relational and adaptative knowledge assets at the level of one single individual. This perspective makes it possible to articulate the collective and individual aspects associated to competences and makes it possible to goes much further than the traditional view of individual competencies as "knowledge in action". Technical and relational competencies affect a wide range of resources, including empathic behaviors and the ability to cope (at the individual and collective levels) with emotional aspects such as stress. Adaptative knowledge assets relate much more to the ability of individuals to cope efficiently with the changing environment of missions and within the so-called "fog of war". It is important to stress the difficulty associated to the bridge between individual-based and crew-based analysis: in interconnected networks, the distribution of diverse forces and the distances between units/individuals challenge decision-making processes. The traditional development of individual-based contribution to a mission is depicted by the OODA (observe-orient-decide-act) loop, yet the confrontation of this presentation to reality reduces the realm of intervention to improvements associated to reduction/expansion of the loop. The loop may be conceived of as occurring at many levels of the organization. The delegation of authority depends on the transfer of and on the access to information inside the structure of organization. The forms of command and control are related to quality and speed in the distribution/access to information, which may be inserted into the OODA loop description. The objective of information dominance is to reduce the time required to complete the OODA loop (at all levels) on the friendly side, while increasing it for the enemy: from a crew in a battle acting on information directly, to a local command organization acting at the operative level (including the cooperation of a large number of units), to staffs operating at a global information level in order to plan and manage actions to be executed among a large range of forces. In fact, decision making may be described as a sequence of interaction between memory and classified situations, where Situation awareness relies on the assessment of shared references enacting consistent actions. Obviously this process would not be difficult enough to deal with if it would not take place in the normal tempo of operations, occurring sometimes at Mach 2.

These aspects obviously depend from the individual ability to interact with the stimuli of the external world, and to process, filter and transform these stimuli into data and information manageable by his knowledge reference patterns. These patterns relate directly to stored mental models and to values.

- Mental models provide the individual with the various decision possibilities; they result directly result from the accumulation of training and experience.
- Values and preferences are directly related to the ethical rationales ruling any soldier's behavior: ethics might be considered as the set of references used by the soldier to decide about his action/reaction when the orders do not provide enough elements to cope with the current situation and decide about the relevant action.

Collective competences relate to the ability to benefit from complementarities of individual competencies and to the specific emergence of efficient organization modes, arm systems and operational doctrines. They grow with the possibilities to develop a consistent collective representation of the current state of the battlespace (how it currently is). Situation awareness deals therefore both with the interpretation of the situation and with the awareness of the same stimuli. Both points need to be questioned: what about the selection of other real-world data? What about another interpretation of the stimuli? Both steps depend directly from the computational assets 'implemented' in the soldiers' brains during the long process of training and of experience accumulation. It is here important to bear in mind that mental models and values/preference sets are dynamically related to the perception of real-world features and co-evolve. In the battlespace, these elements are rather named target detection and identification,

navigation and localization of friends and enemies, engagement, maneuvering, firing, mission planning and re-planning, tactics development. In fact, SA aspects are omnipresent in the Observe-Orient aspects of the OODA loop, and condition directly the content of the Decision (*cf* figure 1 supra).

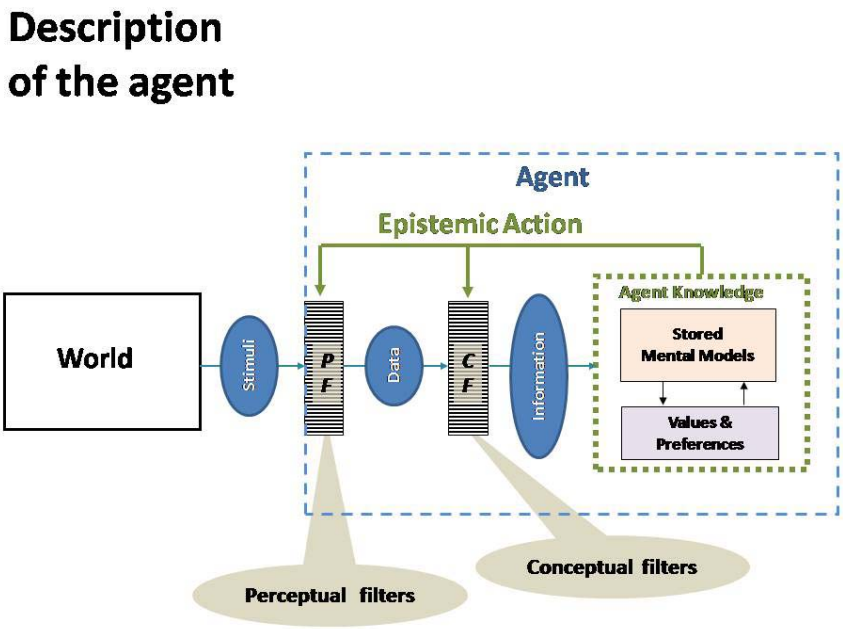
The first consequence of the impact of ICTs between soldiers and platforms (airplanes, main battle tanks, etc) is related to information management. Command and control, tactical actions are not a single individual task but an intricate set of organizational procedures and decision-making authorities. ICTs modify the management of information and reduce the asymmetry between the different levels of the hierarchy as regard their access to information, which also affects the repartition of prerogatives and subsidiarity (Mérindol & Versailles, 2007). The NCW doctrine focuses on new possibilities of information transmission and introduces the new concept of self-synchronization as a new principle in military intervention (Davis, 2004, 95-9). In reality, self-synchronization does not only deal with information, but rather with the soldiers' computation of (relevant) information selected from the current "environment". It is therefore necessary to bring situational representations of the battlespace at this level of complexity. Individual soldiers' computational mechanisms have to provide the nuances required for this modelization.

Boisot's presentation describes the agents with the following steps (*cf*. figure 3 below):

- The external (real-life) world is associated to the emission of stimuli;
- Stimuli are available to the individual but he/she can only notice the external elements in accordance with his/her perceptual filters;
- Perceptual filters altere the external reality and profide the individual computational apparatus with data;
- Data a computed by the conceptual filters and provide agent's computational apparatus with an information set;
- The information set enters the computational mechanism which aims at relevant decision outputs.

Situation remains part of the real-world. In fact, when soldiers or crew members operate on the battlefield, they hardly may refer to complete developments of the cognitive process and mostly pass through "ready-to-use" links. If the process were to be performed along a fill development, action would only occur pragmatically after the validation of stored mental models by the perceptual and cognitive filters. This process is hugely time-costly. Epistemic action always occurs in the process, but soldiers try to cope with reality in focusing directly on stimuli: this means that the response to stimuli is enacted by the recognition of specific patterns at the moment stimuli are met by perceptual filters. The process then relies on direct relationships between a whole set of cognitive features and ready-to-use sequences. These are truly conditioned as a common base of reflexes, and will be coined here as embodied knowledge (*cf* Max Boisot's schemas in the annexe below).

Figure 3: Max Boisot's description of the individual knowledge process



"Situation awareness" is cognitively dependant from all steps described here. The agent's behavior remains a consequence of the whole perception system (yet referring to the systemic character of the interpretative apparatus does not mean that a wholist interpretation of the situation be required).

In reality Endsley's model does not provide enough conceptual space to the dynamics of mental modeling and situational representations. This goes much further than Breton and Rousseau (2001)'s classification of SA 26 definitions, raising a division in classes associated to 'state' or 'process'. Mental models are dynamic. Values and preference sets may well not adapt to reality as fast as the mental models themselves, but both remain the outcome of the assessment of consistence and relevance tests (correspondence) with reality. The agent remains sticked in a trial-and-errors process where the confrontation between knowledge and reality alters his interpretative apparatus. Boisot clearly separates epistemic action from pragmatic action:

- Epistemic action develops the retroaction of the agent's knowledge assets onto the perceptual and conceptual filters; it then alters the condition of implementation of Situation awareness from an individualistic perspective;
- Pragmatic action deals with the agent's action onto the real world; it describes here the tactical action and remains the only visible part of the computational iceberg.

In the development about situation awareness, epistemic action relates to perception, conceptualization and interpretation of the real-life stimuli by an individual. Tactical action supposes that organizational procedures be together consistent and that individuals all develop the same interpretative logic (dynamically). In the course of military operations, workload constraints and the tempo of operations induce that pragmatic action only is to be operated. Epistemic action is reserved for individuals who are not directly in charge and have the very specificity to prepare the forthcoming parts of the mission and adapt it to the current situation: these people specialize in overcoming the fog of war. Such a repartition of prerogatives is typical of the pilot / navigator crew organization on combat aircrafts, where the pilot is in charge of short run aspects while the navigator prepares the team for mid- and long-term constraints.

In the development, pragmatic action relates to the implementation of tactical decisions and individual action does not convey any specific difficulty in this framework provided that they master the relevant level of technical and relational knowledge assets. Collective action requires that individual knowledge sets and decision-making processes lead to together consistent outcomes. They may result from individual knowledge assets which do not evolve at all, or which evolve together consistently. The problem arising here relates to the identification of the step where the collective computation occurs: analytical issues will not deal with the same difficulties if coordination relates to pragmatic action, to epistemic action, to the elaboration of stored mental models, of preferences, of perceptual / conceptual filters. Broadly stated, it remains important to distinguish at least the processes associated to pragmatic action from the ones linked to epistemic action.

These elements provide another insight for distinguishing several concepts:

- "shared awareness of a shared situation" refers to the fact soldiers on the battlefield share the complete set of links between stimuli / data / knowledge / information / filters / decision-making and pragmatic action;
- "<u>shared</u> awareness of a situation" only focus on the perceptual and conceptual filters, on data and information;
- "awareness of a shared situation" refers to the individuals' computational black boxes result in the same decision (with or without reference to a deterministic common cognitive process);
- etc.

This contribution therefore tries to reconciliate Sarter and Woods (1995: 16) and Endsley (1995, 1998) definitions of situation awareness in pointing out their complementarities: SA covers a variety of cognitive processing activities [so Sarter and Woods] and, at the same time, reflects the perception of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" [Endsley]. It comes then to Bryant and al.' conclusion, even though the conceptual reference to Boisot and Popper does not use the same concepts at the level of the individual cognitive description: "*the key element of organizational C2 is not time per se but the validity of the conceptual model as it unfolds over time*" (op cit: 113). The main important demarcation between our development and the Endsley family of SA models deals with her description of hierarchical linear processing systems. The current reference to SA as a process depends on the joint properties and combination of the situation and of the soldier's expertise.

Tactical action efficiency remains related to the organizational features allowing for a consistent evolution of the epistemic action. In fact, the best [organizational] answer to the complexity of the battlefield is performed when the dynamic evolution of the epistemic processes occurs on consistent lines at the level of military <u>*operational*</u> decision processes [not tactical]. The best [organizational] answer to the complexity of the battlefield occurs when the dynamic evolution of pragmatic action occurs on consistent lines with the evolution of the tactical situation.

3. Tactical action as the application of the agents' embodied knowledge

The tempo of operations is too fast and requires that soldiers on the battlefield operate along modes full of fast computations and automatisms in order to perform armament systems in an efficient and coordinated way. Full computations run the complete process described in the previous section and in figure 3 supra. The very notion of automatism supposes that training

and experience have led to the elaboration of actions directly answering the perception of specific stimuli and of runs embodied knowledge assets. In this later situation, the process does not run the process leading to the elaboration of "constructed" knowledge; consistently with Popper's trial and error process and with the theory of evolutionary epistemology, it is used as a test potentially invalidating the epistemic apparatus as a whole. The difficulty relates to the global invalidation of the whole action process if the trial and error process invalidates the test. Pragmatic action represents a consequence of a provisory consistent link between stored mental models, values and preferences and filters sets (both perceptual and conceptual sets). The possibility of sooner reactions results directly (consistency and relevance tests) from the individual commitment to previously tested links between decision options and real-life situations.

What about situation awareness in this framework?
Tactical action represents here the direct consequence of the coordination of soldiers recognizing the same reference patterns and reacting with their corresponding contributions. This is truly an issue in the convergence of situation assessments. Here it is important to recognize that such a situation is only worth the preparation if the series of potential answers turns out to be predictable: The prerequisite to such a tactical preparation relates to the deterministic character of the answers in a predictable environment. The situation might be depicted as the set of tactics associated to the deterministic moves on a chess board. The framework of action seems both operator- and situation-focused. SA is viewed as the automatic relationship between the static recognition of reference patterns and the automatic commission of pre-conditioned behaviors and collective scenarios; individuals are nothing but complex automats playing the perfect anticipations developed at the strategic/operational levels. When pre-organized coordination sets cannot apply anymore, the tactical organization cannot apply anymore and fails as a whole. One concern depends clearly from the location of the dynamic engine: traditional literature on SA depicts the possibility of direct perception and alleges information be contained in the environment. This contribution explains that direct links do only need stimuli and no such thing as information motivate the exercise of direct answers through pragmatic action; the recognition of forms is performed directly at the level of the perceptual filters.

This analytical explanation leads to specific appreciations of training and the capitalization of direct experience on the battlefield. Thinking about knowledge assets on the basis of the difference between constructed and embodied knowledge makes it possible to appraise SA as a network of concomitant processes serving the twofold purpose of the improvement of the efficiency of the epistemic apparatus (perceptual and conceptual filters, stored mental models) and the answers to real-life situations through pragmatic action. In fact, we draw back to McGuiness and Foy (2000) contributions, where they explicitly argue that Endsley's model "should not [be] interpret[ed] […] as a linear or hierarchical sequence but more as a network of parallel functions serving a common purpose". It is not sure whether the model of *parallel functions* reflects a relevant situation and represents a domain worth of inquiry because the system of composition rules supporting decision making processes might not be graspable outside the realm of physiology and cognitive experimental psychology. The double question of identifying processes and architectures remains a usual question in cognitive psychology. In reality, it remains much more important for our purpose to check that the logical order between the system and the architecture remains a closed network where any analytical aspect may become the starting point of the description of the process. [*to be developed*].

As do explain the process aspects of descriptive situation awareness, processing paths depend on the joint properties of the situation and of the expertise of the operator. The flexibility and

plasticity of the model clearly depend on the interaction between the agents' knowledge filters and their pragmatic action, in a kind of co-evolution. Perception is controlled by the action process, because action represents as such the clue for the validation / invalidation of the (provisory) efficiency of the combination of stored mental models, values and preferences and (perceptual and conceptual filters). Here we come to Popper's famous statement about the amoeba and Einstein in *Objective knowledge* (1972: 247-8): "if the hypothesis does not stand up to […] criticism and to [experimental] tests as well as its competitors, il will be eliminated. […] the critical or rational method consists in letting our hypothesis die in our stead: it is a case of exosomatic evolution". As Popper explains, there is only "just one step" from the amoeba and Einstein because Einstein is a scientist not directly confronted to real-life stuations. When reality kicks back the soldier, he/she may die on the battlefield.

When remaining at the level of descriptive SA, numerous options exist to limit the definition and scope of the mental models. In fact the model proposed by Max Boisot and adapted here to the issues of SA allows for an explanation of the dynamics associated to the various subparts of the individual cognitive and computational model. All subparts do not evolve at the same speeds and constraints addressing them do even sometimes introduce inertias on the very short run (which means inside the tempo of operations). Descriptive SA remains clearly associated to the inquiry of the contribution of prior knowledge to SA. The plasticity of the cognitive apparatus of the individual levels and the following consequences at the level of organization depend directly from it. Models must take into account information that is not present in the environment but that is expected to be present in the situation. Operator's expectations are part of SA. Yet they need to be handled with care as their status in decision making is clearly ambiguous: the limit associated to mere individualistic SA analysis has just been reached. Situation awareness must then turn to shared awareness and inquire the very notion of 'shared-ness'.

At the level of individual, prescriptive models remain closely related to military training and experience building. At the organizational level, prescriptive models of SA open the path to team situation awareness: the interaction between individuals and groups relates to variables such as communication, shared information (at the level of the definitions detailed in section 1 supra) and coordination. Using these concepts will perhaps make situation awareness and team situation awareness together consistent. In reality the main important point relates to the fact that TSA is more than the sum of teams' members individual SA (*cf.* Banburry and al: 2004: 14). Dealing with the determinants and characteristics of the individualistic model presented in section 1, it is possible to claim that individual SA and TSA do emerge in the very same training and expertise building processes. SA does not have to be built up before TSA to be trained. The only prerequisite remains at the level of technical knowledge assets and some relational knowledge assets.

4. Conclusion

This contribution has elaborated on the concept of shared awareness and was intended to contribute to the more complex concept of shared situation awareness. One of the key points focuses on the distinction between the "shared awareness of a situation" and the "awareness of a shared situation".

This contribution has proposed to inquire this concepts proposed by Max Boisot and the distinction between epistemic and pragmatic action in order to grasp the issue of computing the "shared-ness" at the level of teams. The mechanisms associated to tactical activities are related to embodied knowledge processes, involving prepared sets of stored mental models and of perceptive / conceptual filters. The main important problem to be inquired in this

framework relates to the invalidation of embodied knowledge assets by the trial and error process confronting to the situation and to the fog of war. What about replacing embodied knowledge assets for soldiers during the course of action on a battlefield? The process would be painful and costly, if not inconsistent with the constraints of tactical action. What about the adaptation of embodied knowledge to new tactical situations? How to perform it? Such a process will be for sure difficult to organize and implement in soldiers preparation.

5. Bibliography

Banburry Simon, and Sébastien Tremblay, eds; 2004, *A cognitive approach to situation awareness: theory and application*, Alsdershot, UK: Ashgate

Boisot, Max, 1995, *Information space, A framework for learning in organizations, institutions and culture*, London: Routledge

Boisot, Max, 1998, *Knowledge assets, Securing competitive advantage in the information economy*, Oxford UK: Oxford Univ Press

Endsley, Mica R., 1995 : « Toward a theory of situation awareness in dynamic systems », *Human factors*, 37(1), pp 32-64

Endsley, Mica R. and Daniel J Garland, eds; *Situation awareness analysis and measurement*, London: Erlbaum associates

Hone, Geoff N, Lynne Martin, and Robert Ayres, 2006, "Awareness – Does the acronym SA still have any value?", paper I-071, communication to the 11th ICCRTS conference, (Cambridge, UK).

Huber, Rainer, Petra M. Eggenhofer, Jens Römer, Sebastian Schäfer, Klaus Titze, 2007, "Team composition: Linking individual and team characteristics to team decision-making and performance", paper I-042, communication presented to the 12th CCRP conference (Naval War college, Newport, RI).

Mérindol, Valérie, and David W Versailles, 2007, "Towards and reinterpretation of information communication technologies' impact on command and control", *Defence studies*, volume 7, number 2 (June), pp. 239-258).

Popper, Karl R., 1979, *Objective knowledge, an evolutionary approach*, London: Routledge (2dn revised edition).

Shattuck, Lawrence G, Nita Lewis Miller, Gregory A. Miller, 2007, "Using the dynamic model of situated cognition to assess network centric warfare in field setting", paper I-166, communication presented to the 12th CCRP conference (Naval War college, Newport, RI)

6. Annexes

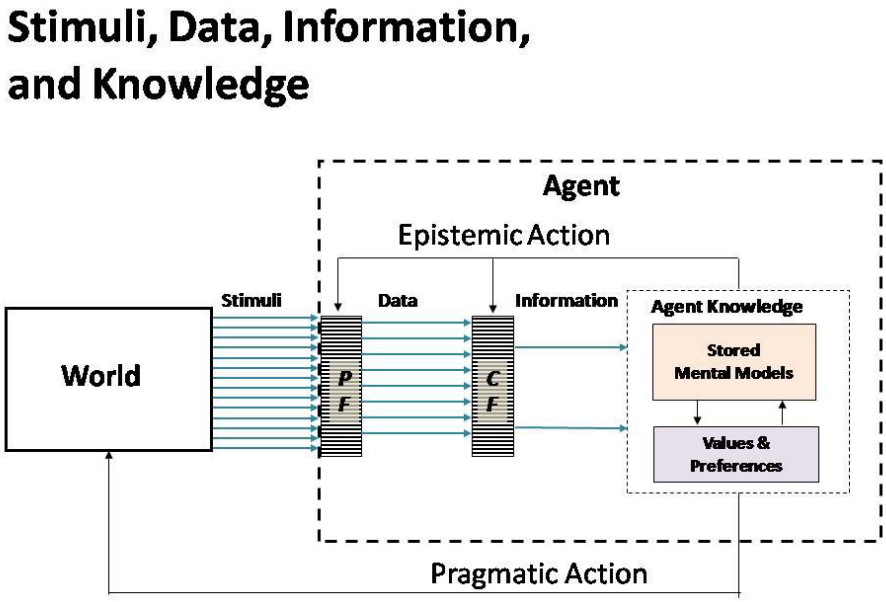


Figure 2
(source: Boisot)

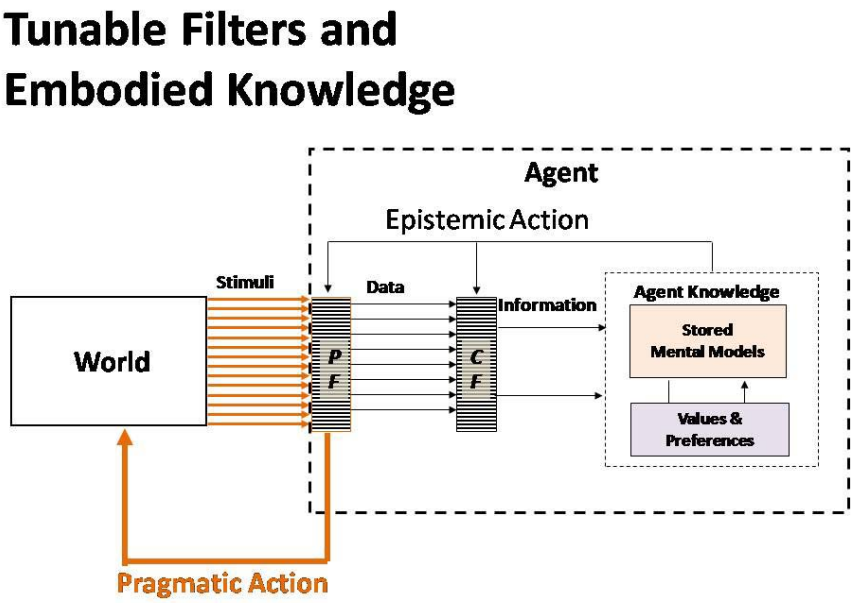


Figure 3
(source: Boisot)