

Critical Thinking Skills for Intelligence Analysis

Douglas H. Harris and V. Alan Spiker
Anacapa Sciences, Inc.
USA

1. Introduction

Whether performed by national agencies or local law enforcement, the ultimate objective of intelligence analysis is to develop timely inferences that can be acted upon with confidence. To this end, effective intelligence analysis consists of integrating collected information and then developing and testing hypotheses based on that information through successive iterations of additional data collection, evaluation, collation, integration and inductive reasoning. The desired end products are inferences that specify the who, what, when, where, why and how of the activity of interest and lead to appropriate actions. This process is illustrated in Figure 1.

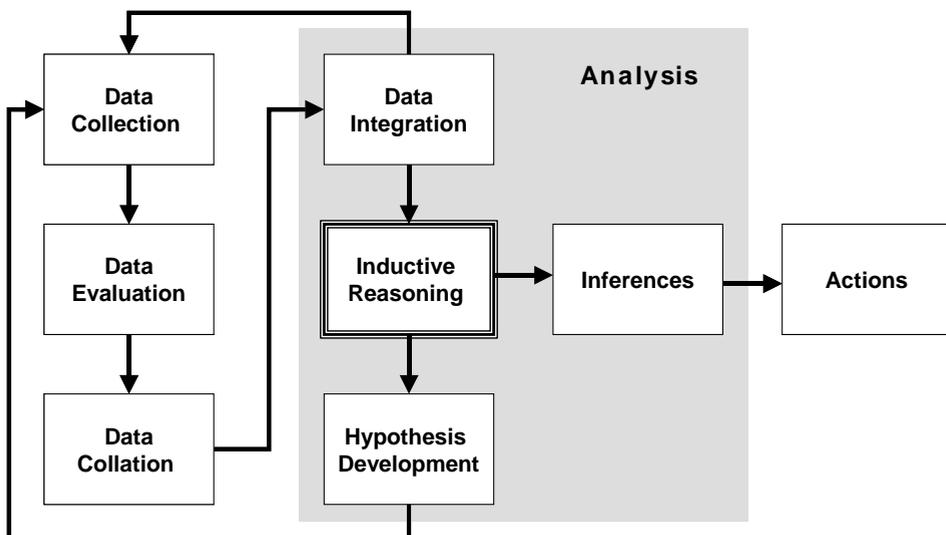


Fig. 1. The intelligence process

While in the last couple of decades a number of useful tools have been developed to aid in data collection, evaluation, collation and integration, analysis remains highly dependent on

the cognitive capabilities, specifically the critical thinking skills, of the human analyst. For this reason, it is important to understand the inherent capabilities and limitations of the analyst and, in particular, the cognitive challenges of intelligence analysis that must be overcome through training in and application of critical thinking (Harris, 2006a, 2006b; Heuer, 1999; Moore, 2007).

Our concern with and study of critical thinking skills for intelligence analysis relates to that aspect of ergonomics research that seeks to understand how people engage in cognitive work and how to develop systems and training that best support that work. These efforts have come to be known as cognitive ergonomics or cognitive engineering. While our focus here is specifically on the domain of intelligence analysis, we recognize the many areas of endeavor that require critical thinking skills. These include the professions, business, military, education, and research and development.

Just what is critical thinking? Critical thinking was first conceived in the early 1940's by two psychologists, Goodwin Watson and Edward Glaser. Watson and Glaser also developed the first test of the skill, the Watson-Glaser Critical Thinking Appraisal (Watson & Glaser, 1980), which is still widely used. Since then, almost all of the theoretical development has been conducted by educators and philosophers, where the focus has been on identifying people with superior critical thinking aptitudes through testing. The notion of critical thinking as a *skill* that can be improved through focused training, as is the view of a psychological construct, has received far less attention. However, see Halpern (1996) and Baron and Sternberg (1986) for notable exceptions.

In desiring to develop a consensus definition, the American Philosophical Association attempted to develop such a definition based on the responses of 46 experts (American Philosophical Association, 1990). The resulting definition was "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual considerations upon which that judgment is based." A review of the literature covering the 10 years subsequent to that exercise (Fischer & Spiker, 2000) revealed many different conceptions of critical thinking with only a modest degree of overlap. It appeared that the concept of critical thinking could not be adequately addressed by a simple verbal definition. A more comprehensive model was required to address important components and interactions, and to serve as a basis for empirical testing.

2. Model of critical thinking

Critical thinking has not endured the kind of empirical inspection typically bestowed upon constructs developed by psychologists. Its relationship to other, well-established psychological constructs such as intelligence, working memory, and reasoning, for example, has rarely been studied. It is the authors' admittedly subjective opinion that the lack of empirical study of critical thinking and its relationship to other individual difference dimensions has produced a fractionated view of the construct. Without the grounding of data, theorists have been free to postulate divergent concepts. An effort in philosophy to reach a consensus definition in 1990 had little effect on unifying the field.

To fill this gap, Fischer and Spiker (2004) developed a model that is sufficiently specific to permit empirical testing. The model identifies the role of critical thinking within the related

fields of reasoning and judgment, which have been empirically studied since the 1950s and are better understood theoretically. It incorporates many ideas offered by leading thinkers (e.g., Paul & Elder, 2001) in philosophy and education. It also embodies many of the variables discussed in the relevant literature (e.g., predisposing attitudes, experience, knowledge, and skills) and specifies the relationships among them.

The model can, and has been, used to make testable predictions about the factors that influence critical thinking and about the associated psychological consequences. It also offers practical guidance to the development of systems and training. An overview of the model's main features is provided here following a brief review of current thinking about reasoning and judgment, on which the model is based.

2.1 Dual system theory of reasoning and judgment

Prior to the early 1970's, the dominant theory of decision making stated that people made judgments by calculating (1) the probability and (2) the utility of competing options. Although this rational-choice model took on a variety of forms, all versions posited a rational actor who made calculations of probability and/or utility, and selected the option that had the highest value. In the 1950's, however, researchers began to notice that the model failed to predict actual behavior (Meehl, 1954; Simon, 1957). Evidence that falsified the rational choice theory accumulated over the following decade.

In the early 1970s, an alternative theory proposed that people use heuristics, as opposed to the rational weighing of relevant factors, to make judgments. The "new" theory was, and continues to be, supported by empirical study (Baron & Sternberg, 1986). The heuristic theory states that many judgments are based on intuition or rules of thumb. It does not propose that all judgments are made intuitively, just that there is a tendency to use such processes to make many judgments. The most recent versions of heuristic theory, in fact, propose that two cognitive systems are used to make judgments (Kahneman, 2003). The first system, intuition, is a quick, automatic, implicit process that been proposed to explain judgment. To accommodate the multiple theories, many researchers now use associational strengths to arrive at solutions. The other system, reasoning, is effortful, conscious, and deliberately controlled. Since the 1970's, multiple and similar two-process theories have referred to the implicit associational type of process as System 1, and the conscious deliberate process, as System 2. The following example shows how these two processes may lead to different judgments.

Suppose a bat and a ball cost \$1.10 in total. The bat costs \$1 more than the ball. How much does the ball cost?

Most people's immediate judgment is that the ball costs 10 cents. This is a response derived from intuition or System 1, which again, is quick, automatic, and relies on associations. The strong mathematical association between \$1.10, \$1, and 10 cents leads to this quick, but wrong, judgment. The ball can't cost 10 cents because then the bat would have to be \$1, which would make it only 90 cents more than the ball. The more effortful deliberately controlled reasoning, or System 2, process usually produces a different, and correct, answer. When people spend the time and effort to think about the problem, they usually realize the ball must cost 5 cents and the bat must cost \$1.05. Hence, in this example, the two systems

produce different judgments. It would be a mistake to conclude that System 1 always produces different judgments than System 2, however. Nor does System 1 always produce an incorrect answer, nor one that is poorer than one produced by System 2.

In fact, researchers have shown that expert performance in any field, which is commonly the gold standard, is often driven by intuition derived from extensive experience (e.g., Klein, 1999). That said, expert performance is not without fault, and studies have shown that even experts make errors in judgment when well-learned associations lead them astray (Thaler & Sunstein, 2008). The associational processes used in System 1 that make expert performance so quick and powerful are the same processes that are responsible for systematic errors that experts sometimes make. Additional weaknesses of System 1 are that it depends on the quality and amount of experience an individual possesses, and it can't be used effectively in novel situations. System 2 reasoning also has its strengths and weaknesses. While it is highly useful in novel situations and problems, it is also slow and effortful. It usually cannot be utilized concurrently with other tasks and, like System 1, it can also produce wrong judgments.

Most recent theories, however, believe that Systems 1 and 2 *run in parallel* and *work together*, capitalizing on each other's strengths and compensating for their weaknesses. For example, many researchers believe that one function of the controlled deliberate process is to monitor the products of the automatic process. System 2 is thought to endorse, make adjustments to, correct, or block the judgment of System 1. However, if no intuitive response is accessible, System 2 may be the primary processing system used to arrive at a judgment. The similarities between descriptions of critical thinking and System 2 are striking. The words "effortful, controlled, deliberate, purposeful, and conscious" are frequently used to describe both.

2.2 Overview of the model

As shown in Figure 2, the model assumes that critical thinking skills are executed by System 2, and that these skills also serve to monitor, evaluate, and control the judgments produced by the System 1 associational process. Hence, Figure 2 shows that System 1 judgments provide input to critical thinking skills. The two processes are thought to run in parallel and interact to produce judgments. Because System 1 is truly an automatic and uncontrolled process, it cannot be consciously initiated or stopped. For this reason, only the products, and not the process, of System 1 is monitored. Because System 1 is quick, it often comes to judgment before System 2, but System 2 may override, or confirm, that judgment. Therefore, System 2 has the potential for controlling judgment, although it may not always utilize that potential.

Critical thinking can provide a thorough examination of the problem at hand. Although System 1 might derive just one solution (Klein, 1999), System 2 can provide multiple potential solutions. System 1 works to narrow possible action paths, which is often highly effective when the task must be accomplished quickly and when the problem space is limited. However, when the problem space is novel or complex or when solutions must be innovative, critical thinking skills are more powerful. They also have the meta-cognitive capability to monitor the progress of their own processing, as represented by the self-monitoring arrows leading out and back into the System 2 processor in Figure 2.

Figure 2 also shows how the processing engines interact with environmental and individual factors. Both systems receive initial input from the environment in the form of information about a situation or problem that requires judgment. Part of that input is a meta-task that defines the general purpose of judgment. The other part of the input is information about the situation. System 1 immediately and automatically begins processing of the input by searching through its associational network for potential solutions that will satisfy the purpose. Critical thinking, motored by the System 2 processing engine, receives the same input, filtered through predisposing individual difference factors, which are discussed in greater detail below. If critical thinking skills are engaged, they will begin to evaluate solutions offered by System 1 or they will apply deliberate reasoning to the problem.

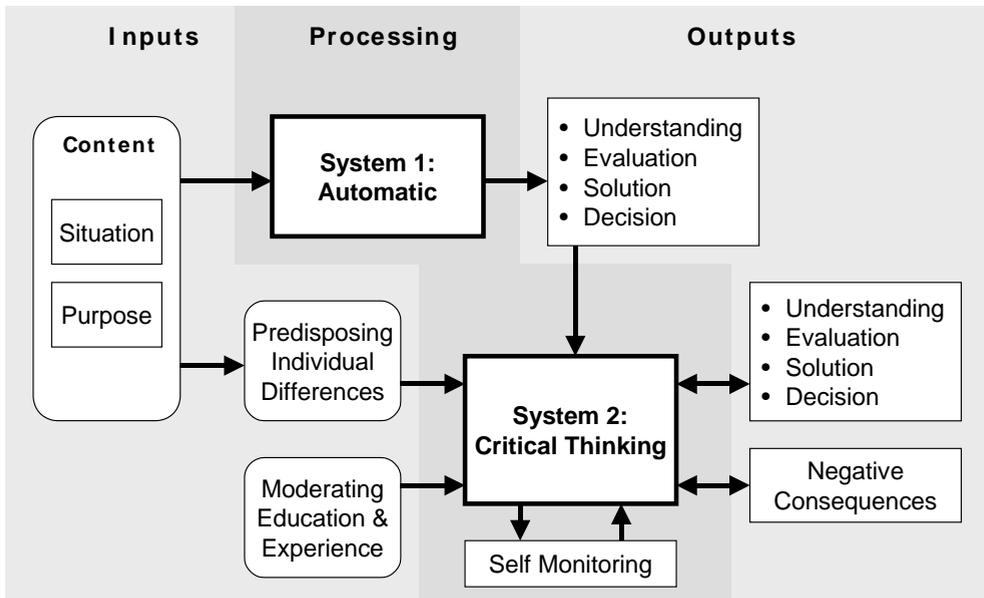


Fig. 2. Model of critical thinking (from Fischer & Spiker, 2004)

Whether or not critical thinking is utilized depends on a variety of factors, including individual predisposition and situational variables. The sum value of these factors provides the impetus to engage in effortful critical thinking, but that motivation must exceed some threshold value. In the paragraphs below, each component of the model is examined in more detail.

2.3 Components of the model

2.3.1 Inputs

As noted above, the opportunities for judgment are set in motion by the contextual factors--the situation and the purpose. While the automatic System 1 will engage in all conditions, two characteristics of the situation must be present to elicit critical thinking: the stimulus material must contain substantive information and there must be sufficient time available to

engage System 2. Other characteristics of the situation that make it more likely that System 2 will be engaged include the presence of conflicting information, disordered or unorganized material, uncertain information, and complex material .

Critical thinking is not an end in itself, but serves objectives specified by purpose (meta-tasks). The purpose also dictates the specific response that will be required to successfully end the process. For example, the situation may include a meta-task to understand, make an evaluation, make a decision, or solve a complex problem. Even if the final result is based on System 1 processing, System 2 determines when the requirements of the purpose have been met. Hence, successful completion of the meta-tasks as determined by System 2 can also provide input that terminates an episode.

Predisposing factors influence the likelihood of a person using, or persisting in using, a critical thinking skill. Like features of the situation, they serve as input conditions, and as a filter through which the situation and purpose are evaluated. Some may be key factors that strongly affect an individual's use of a critical thinking skill. Other factors may have a weaker relationship to critical thinking, perhaps increasing the likelihood of engaging in a skill by a marginal amount. In summary, predispositions are measurable ways in which people differ, whether fixed or modifiable, that influence the use or persistence of use of critical thinking.

Moderating variables influence how, and how well, critical thinking skills are performed. For example, domain expertise, recent experience, and education influence the quality of the reasoning produced by the process. They do not, however, influence whether one executes a particular skill, as do predisposing factors.

2.3.2 Processing

The task posed by a particular situation should not be confused with the system that is used to solve it. For example, one may have the task of understanding an intent statement that could be achieved using associational processes of System 1 or controlled skills powered by System 2. Therefore, an individual who is trying to understand an intent statement may or may not be using critical thinking to do so. Even more important, the application of critical thinking skills driven by System 2 does not always produce the best solution to a task. It would be a mistake to encourage the exclusive use of critical thinking because that strategy would deny the power and effectiveness of System 1. Similarly, it is not advisable to only develop associational processes because controlled deliberate reasoning can both produce superior solutions and provide necessary checks on the products of System 1. Moreover, the issue of which system is most effective is practically irrelevant because most theorists believe that both are almost always used in conjunction to produce a solution. Hence, the real issue that determines the quality of a solution is how well the two systems interact.

There is a general consensus in the literature that individuals are reluctant to engage in critical thinking (Moore, 2007). This is based on widespread observation of incoherent reasoning, nonsensical beliefs, lack of respect for evidence, poor reasoning test scores, and unsupported decision-making in various populations. Indeed, much of the literature is devoted to a movement to increase the application of critical thinking in various populations. One of the central topics has been the question of why the public seems

disinclined to use it. Some theorists posit that individual characteristics, such as intellectual laziness, arrogance and cowardice (which are represented in the model as predisposing individual differences), are the reasons why it is avoided. The model of critical thinking discussed here, however, posits that negative affective consequences associated with the application of critical thinking are the primary inhibitory sources.

The model posits that individuals who engage in critical thinking for any substantive length of time are likely to experience negative affective reactions. For example, the process can produce mental fatigue, increased effort, increased anxiety, cognitive dissonance, and decreased self-esteem. Negative affect experienced during an episode might be countered by positive affect that is the result of a positive outcome (e.g., solving a difficult problem) that, in turn, is a direct result of critical thinking. Therefore, its application can be positively rewarded and hence, increased use may be realized. Some individuals, then, may not experience associated negative affect; but at the very least, by definition, critical thinking requires more effort than System 1 processing, and is therefore a less desirable means to achieve judgment in that limited sense.

2.3.3 Outputs

The quality of a solution produced by the application of a critical thinking skill is likely to be affected by how well the skill is executed. Decrements in performance may be produced by failing to apply an essential component (e.g., failing to clarify ambiguous information in a message or failing to consider alternative explanations for a pattern of data), failing to perform accurately a component of the skill, or by lacking sufficient knowledge to be processed. Therefore, one could apply critical thinking and still produce inferior solutions to a task. Moreover, it is not possible to determine whether System 1 or System 2 was applied to derive a solution based on the solution alone. The quality of a solution may also be affected by moderating variables such as educational level and experience. These issues are important to the design of training that seeks to improve critical thinking skills.

Figure 2 shows that negative experiential consequences serve as both a byproduct of critical thinking and as input to the decision to maintain a critical thinking episode, as depicted by the bidirectional arrow. When the affective consequences of applying the critical thinking skill become too negative, the motivation to maintain the episode is decreased. If the negative consequences are sufficiently strong, they may result in a cessation of the episode.

Finally, it should be recognized that effective critical thinking depends on gaining insights as well as reducing mistakes (Klein, 2011). Critical thinking is valuable for reducing mistakes but, in the process, may interfere with the process of gaining insights. It is notable that the concept formulated by the American Philosophical Society (1990) encompassed both reducing mistakes (by analyzing arguments, assessing claims, querying evidence and justifying procedures) and enhancing insights (by decoding significance, examining ideas, and conjecturing alternatives).

2.4 Validation of the model

Some preliminary research has been completed toward validating the model (Fischer et al., 2009). A series of controlled studies was conducted of the effect of web-based critical

thinking training on the information interpretation and analysis performance of Army officers. Subjective responses from the participants indicated that the training was considered highly relevant, beneficial to their military work, offered training that was not available to them elsewhere, and that the self-paced feature of the program was highly desirable.

Objective measures indicated that the training encouraged critical thinking and enhanced the understanding and analysis of information that resulted from a greater depth of processing. This was evidenced by increased officer sensitivity to likely errors, increased awareness of weak elements that might easily be overlooked, and by an enhanced ability to distinguish between information actually present and their own inferences about or interpretations that go beyond the information explicitly provided. Participants who completed the critical thinking training made significantly fewer unjustified inferences than participants assigned to the control conditions; they did make inferences but justified them by pointing out explicit supporting information. Therefore, the training appeared to encourage discrimination of what is “known” or “given” from what might be inferred.

3. Human limitations that affect critical thinking

Our experience to date in training and applying intelligence analysis skills suggests that some of the principal challenges that affect critical thinking are human limitations. Humans are limited in their capabilities to address complexity, by the biases they bring to the process, by their difficulties in handling uncertainty and, often, by the lack of relevant domain expertise (Harris, 2006a, 2006b; Heuer, 1999).

3.1 Complexity

The complexity of information to be analyzed can increase rapidly and easily. For example, from calculations of combinations, there are 6 possible ways that 4 entities can relate to each other but there are 496 possible ways that 32 entities can relate to each other. The potential extent of complexity becomes apparent when one realizes that it is not uncommon for an analyst to address hundreds or thousands of entities. Since it has been well established that humans’ ability to process information is greatly constrained due to working memory limitations (Miller, 1956; Baddeley, 1986, 1996; Engle & Kane, 2004), complexity can be a significant analytical challenge. Of course, there are various other contributors to complexity—types of relationships, variability of conditions, and so on (Auprasert & Limpiyakorn, 2008). Moreover, some of the simplifying strategies that analysts might employ may lead to biased results, such as focusing on vivid, immediate cases rather than on more abstract, pallid statistical data that are often of much greater value.

3.2 Bias

There are also many ways that bias can affect the analysis of information (Heuer, 1999) but, for the intelligence analyst, combating confirmation bias is one of the greatest challenges. Confirmation bias is the selective use of information to support what we already believe, ignoring information that would disconfirm the belief. Examples of tendencies most humans share that contribute to confirmation bias are:

- humans tend to perceive what they expect to perceive and, as a consequence, valuable experience and expertise can sometimes work against an analyst when facing new or unexpected information or situations;
- mind-sets are quick to form but resistant to change, leading analysts to persist with a hypothesis in the face of growing disconfirming evidence; and
- well-established thinking patterns are difficult to change, leading to difficulties in viewing problems from different perspectives or understanding other points of view.

3.3 Uncertainty

The work of the intelligence analyst is conducted within the realm of uncertainty and with the aim of reducing the veil of uncertainty through which judgments, decisions and actions must be taken. Since few inferences in the dynamic, complex world of decision-making lend themselves to the rigor of statistical analysis, most of the objective, mathematical approaches to the assessment of uncertainty are not applicable. Thus, in assessing and communicating the level of confidence that should be associated with a specific inference, the analyst must employ subjective conditional probabilities. That is, not only must critical thinking skills be employed to assemble evidence, generate premises and develop an inference, they must also be employed to arrive at the level of confidence one should have in the inference (Klein et al., 2006).

Moreover, the analyst is faced with a tradeoff between the level of detail in an inference (the answers to who, what, when, where, why and how questions) and the level of confidence that can be given to the inference. More detail provides a more useful inference but typically at the sacrifice of confidence; less detail provides a greater level of confidence but typically at the sacrifice of usefulness. One of the challenges faced by the analyst is to make an effective tradeoff between detail and confidence.

3.4 Domain expertise

The final potential problem, to be discussed here, for the intelligence analyst is the lack of domain expertise; that is, an analyst cannot be expected to be an expert in all of the information domains required for a typical analysis. Critical thinking skills are required to compensate for lack of domain expertise and, also, to facilitate the development of expertise in domains that are important to current and future analyses. Closely related to this challenge is the availability of information, which might range from large volumes in some domains to very little in others. In the first case, critical thinking is required to sort out the relevant from the non-relevant from the volumes available and, in the second, to develop assumptions to be used in place of non-available facts. Another problem is language, where analysts may have to depend on translations away from original sources or where cultural information is vital to the analysis but they don't have much prior knowledge of the culture.

4. Challenges ahead for intelligence analysis

At the 2006 annual meeting of the International Association of Law Enforcement Intelligence Analysts, the US Deputy Director of National Intelligence for Analysis described his view of the challenges ahead. His main point was that the extension of current trends (for example,

increased globalization, communications flow, opportunities for terrorism) will continue to blur the line between personal security and national security, which in turn, will blur the line between law enforcement and military operations, and between activities involving people and those involving territory (Fingar, 2006).

There is increasing awareness of the importance of intelligence, particularly that from open sources. A senior advisor to the Secretary of Defense recently stated that most information (perhaps as much as 90%) that matters now is available to anyone with an internet connection, that understanding and influencing foreign populations was very important, and that future enemies are unlikely to confront the world's overwhelming military power with conventional warfare, but with a technology-assisted insurgency (Packer, 2006).

Open source intelligence is an intelligence-gathering discipline that involves the collection, analysis, and interpretation of information from publicly available sources to produce "usable" intelligence. It can be distinguished from research since the former's intent is to create tailored or customized knowledge to support a particular decision or satisfy a specified information need by an individual or group. The sources of this information are now quite vast, and include media (newspapers, magazines, radio, TV, Internet), social networks (Facebook, Twitter, YouTube), public data (government reports, speeches), observation and reporting (plane spotters, satellite imagery), professional and academic (conferences, papers), and geospatial dimensions. The latter are often glossed over, but must be considered since not all open source data is text-based. These data come from various sources, including maps, spatial databases, commercial imagery, and the like. As information has become more available by virtue of the Internet and other digital media, the physical collection of information from open sources has become much easier.

5. Application of available technology

Technology is now employed extensively by intelligence analysts to extract meaning from available information, to support the performance of a variety of analyses, and to aid in the communication of analytical results to the users of intelligence. The design of systems to support the intelligence process, and specifically intelligence analysis, can benefit from what we now know about the nature and role of critical thinking in this process. This knowledge of the specific skills required also supports the application of cognitive ergonomics to the development of training systems and methods that best meet analyst performance requirements. To be meaningful and realistic, training content and exercises must be developed and implemented within the context of available technology. Below, we summarize some of the technology that might be employed for extracting and analyzing information, the design of which can benefit from cognitive ergonomics that addresses specific critical thinking skills.

5.1 Extraction of entities, concepts, relationships and events

Software applications are required to analyze, from any source of text data, and automatically extract many different entity types, such as people, dates, location, modes of transportation, facilities, measurements, currency figures, weapons, email addresses, and organizations. The extraction capability is extended to the detection and extraction of

activities, events and relationships among these types of entities. Automatically extracting this information means that analysts do not have to read extensive amounts of text to pull out these types of information manually; they can focus sooner on the relevant information. Automated event and relationship extraction helps analysts more quickly discover associations, transactions, and action sequences that can be employed in the development of link, event and activity analyses. Therefore, assuming that this is done effectively, analysis can begin with information that has been automatically extracted and organized from much more voluminous amounts of information available to the analyst.

Information relevant to global operations might be in various languages other than English, such as Arabic, Chinese, Farsi and many others. Technology is available to support and augment the efforts of the limited number of translators typically available to exploit foreign language documents. Language processing software can help translators analyze documents in their native language and help them select the most relevant documents or sections of documents for translation. Available software might contain a suite of natural-language processing components that enable language and character encoding identification, paragraph and sentence analysis, stemming and decompounding, part-of-speech tagging, and noun phrase extraction. With such a system, analyst training can assume that the capabilities exist to provide the analyst with information that has been extracted and translated relatively effectively, by means of automated and human processing, from numerous different languages.

Software can also provide user-guided text extraction from unstructured data sources, supporting the transformation of user-identified text-based information into structured graphic formats for further analysis. The user can highlight important information contained in text documents—entities and associations among entities, for example—and easily put it in chart form to enhance visualization of the information without having to retype information. This type of conversion can be employed with a variety of text formats and applications.

5.2 Database development and query capabilities

Technology can also help store, organize and query data extracted from multiple sources. Multi-user databases can now be built relatively quickly without the need for advanced, specialized technical expertise through the use of built-in forms and automated importation of information from data extraction tools and systems. Complex database query languages that previously had to be learned by analysts can now be replaced by simple, more intuitive, ways to query data, such as using graphics to “draw” questions. Some of the tasks that can be facilitated by currently available technology include the following:

- Conduct full text searches of the database to find exact matches, synonyms or words that sound similar to those in one’s search criteria.
- Draw the query question by dragging and dropping relevant graphic icons and links from previously constructed charts. One can then save, organize and share queries and information with other analysts.
- Reveal all relationships between a selected chart item and other entities in a database.
- Visually establish the shortest path between two data elements, even if the relationship involves several degrees of separation.

- Maintain the quality of the database by searching a set, a query result or the entire database for duplicate information.
- Create reports that can be printed, posted to a web page, or saved in a word-processing application to facilitate the communication of query results.
- Enable location-based database queries by interfacing with available geographical mapping software.
- Interface with analytical software to provide the means for allowing the manual analysis of data and/or the automatic generation of charts, such as link diagrams, event timelines and financial transaction flow charts.

Geographic information system technology and services are available to augment database development and query capabilities. For example, required geographical information can be obtained through a web-based map interface (e.g., Google Maps, Google Earth, Ushahidi), providing access to geo-referenced infrastructure data. One existing system provides more than 1,300 layers of infrastructure data encompassing the physical, economic, socio-demographic, religious, health, educational, energy, military, transportation, political, governmental, geographical and chemical infrastructures of the United States. For example, some systems can provide the name, address, administrator contact information, number of beds and personnel for each hospital in the United States. Similar information can be provided for schools, fire stations, airports, and related facilities.

For the part-task training exercises and scenarios required to develop critical thinking skills, database development and query capabilities are not likely to be required of the trainee. However, the development of training exercises and scenarios, to be realistic, must be compatible with current and future database configurations, formats and capabilities. For this reason, the training developer must be knowledgeable about these and future systems and how they are likely to be employed in the intelligence process.

5.3 Data integration support

Analytical software applications now serve to support the analysis function by providing tools that permit the analyst to convert information into a variety of formats, from multiple sources, into graphic products that lead to greater understanding of the information by both the analyst and the ultimate user of analytical products. This is the part of the intelligence process that is typically referred to as data integration. Significant advances have been made in the development and improvement of these systems; further enhancements can be made through the application of cognitive ergonomics, specifically through the application of our knowledge about the critical thinking skills that must be supported.

Analysts can uncover and interpret relationships and patterns hidden in data through the generation of intuitive charts. Moreover, information about each entity and link portrayed on a chart can be accessed through embedded data cards connected to the displayed icons or through links from icons back to the database. A sample chart is shown below in Figure 3. The mechanics for obtaining the additional information is typically just a matter of clicking on the icon of interest.

One valuable capability that can be provided by analytical software applications is data filtering. An important critical thinking strategy to counter the effects of complexity is that of determining specific analytic objectives and filtering out information in the database that is not relevant to meeting that objective. Examples of specific analytical objectives include the following: defining the flow of money into a specific organization; clarifying the span of control of a specific individual; including only information above a specified level of validity; tracking events that occurred only during a specified time period; and examining financial transactions above a specified amount during a specified time period.

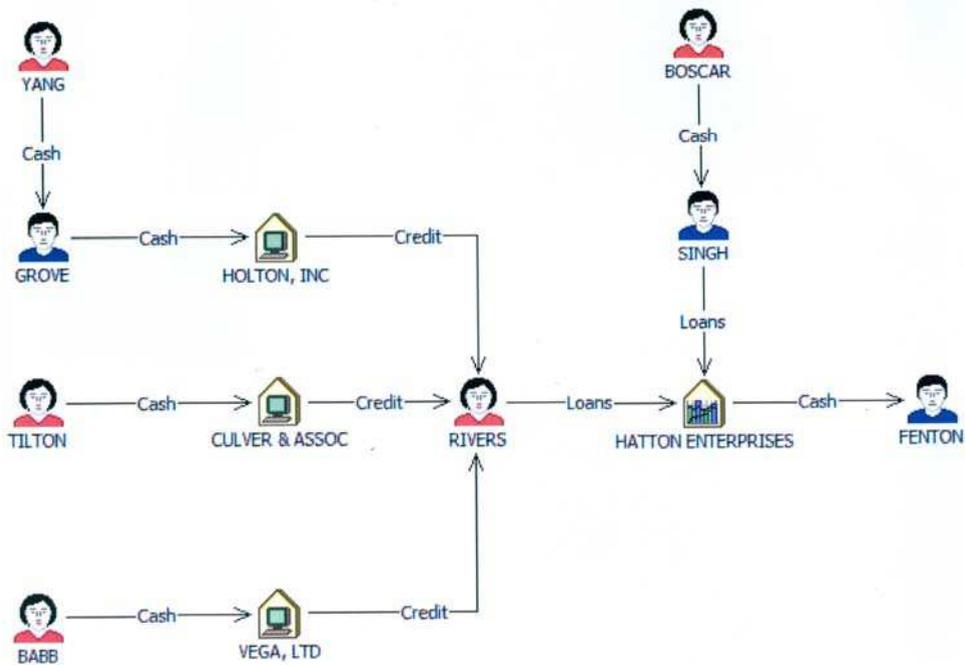


Fig. 3. Sample data integration diagram

The results from pursuing these specific objectives might provide support to a set of premises that lead to the development of an inference about the who, what, when, where, why and how of the activity of interest. Other capabilities provided by analytical software include the following:

- Switch between network and timeline views to identify patterns in both time and space.
- Automatically compare labels, types, attributes, names and aliases when combining data from different sources.
- Augment charts by including visuals such as maps and photographs.

6. Key critical thinking skills for intelligence analysis

Harris (2011) reviewed the literature and identified 120 elements considered by researchers and educators as important for critical thinking. Like elements were grouped together. Two survey instruments were then developed based on the listing of 18 critical thinking skills and designed to identify those skills that would provide the highest training payoff. The first instrument was designed to collect data from a sample of 73 intelligence analysts at a software user's national conference in Washington DC following a 60-minute presentation on critical thinking. The second instrument employed a similar, expanded approach to collect data from six instructors who conduct intelligence analysis training and 14 students who had just completed a two-week course on intelligence analysis. Analyses of these data identified 11 critical thinking skills that appeared to have the highest payoff for intelligence analysis and mapped these skills to four specific intelligence analysis functions:

- assess and integrate information,
- organize information into premises,
- develop hypotheses, and
- test hypotheses.

He then developed specifications for the development of web-based training on these skills, and developed and installed on-line prototype demonstrations of a critical thinking strategies overview module and a module for one of the 11 specific skills—consider value-cost-risk tradeoffs in seeking additional information. The 11 critical thinking skills are listed and mapped to intelligence analysis functions in Figure 4. A description of each skill is provided below, related to the intelligence analysis function it serves.

6.1 Assess and integrate information

The three skills associated with this first function are: envision the goal (end state) of the analysis, assess and filter for relevance and validity, and extract the essential message. These skills are described in the paragraphs that follow.

6.1.1 Envision the goal (end state) of the analysis

This skill is the ability to envision the desired goal (the desired end state of the analysis in terms of providing a useful inference that can be acted on with confidence in a timely manner) and to use that vision to guide and limit the analysis to tasks that will achieve the desired goal. This critical thinking skill constitutes an overall check on the process and products of thinking to ensure that it is moving the analysis forward along the right path.

There are many circumstances and reasons why an analyst might head down the wrong path, particularly early in an analysis. The directions given at the outset for conducting the analysis might be vague and confusing; the volume of information might be so great as to provide many opportunities to head in the wrong direction; and some types of information might be more compelling than others, even if not as helpful in meeting the analytical objectives. Consequently, particularly early in the data collection and integration efforts, the

analyst must expend effort to envision the goal of the analysis and maintain that vision during the analytical process.

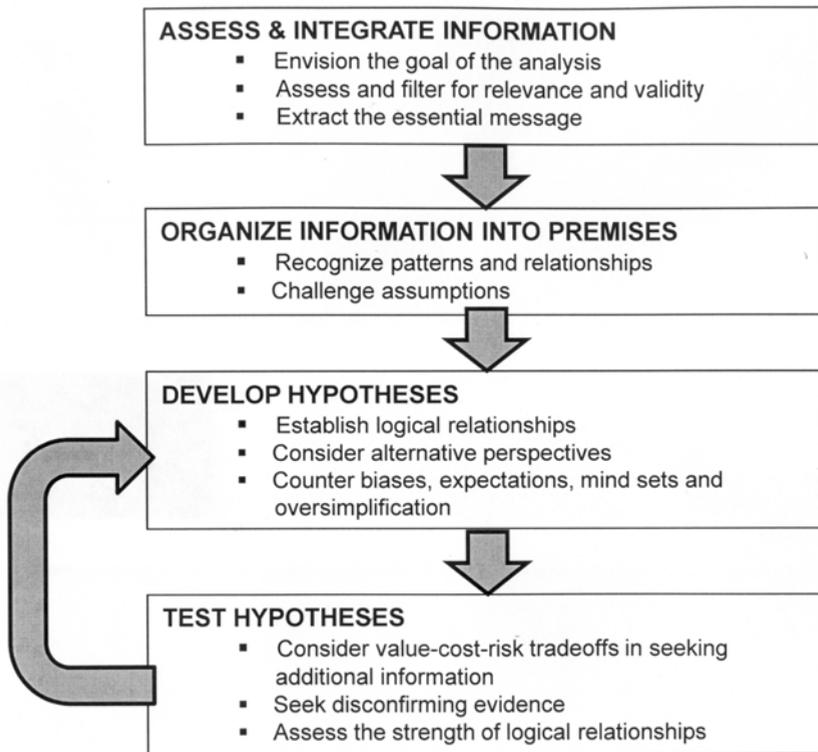


Fig. 4. Critical thinking skills grouped into the intelligence analysis functions they support

6.1.2 Assess and filter for relevance and validity

Critical thinking is required to distinguish between relevant and irrelevant information, and valid and invalid information, relative to the desired end state, purpose or goal of the analysis. This skill is obviously related to envisioning the goal, because the analyst needs a well-defined goal before being able to determine what information is likely to be relevant in meeting that goal. The principal skill involved here is the assessment of information for its

potential relevancy to the objectives of the analysis; once relevancy has been determined one must then assess validity to provide assurance that it will contribute positively to the analysis.

Assessing and filtering information contributes to intelligence analysis during the assessment and integration stage. If one of the objectives of the analysis is to determine the relationships among entities of various types (for example: individuals, organizations, places, and vehicles) the information most relevant to the analysis would be linkages among entities. For this objective, information that does not provide linkages would be considered not relevant. Thus, in addition to critical thinking skills, the analyst needs to understand and be proficient in the application of specific analytical techniques such as link analysis or financial profiling.

6.1.3 Extract the essential message

Extracting the essential message is the ability to sort through the details of information and distinguish the essential from the non-essential. It also encompasses the ability to generate clear, concise statements that summarize the main point (the gist) of the information. The process is often automatic, because most people have extensive experience in attempting to get the main idea from what they read, see and hear. The automatic process usually works well if the amount of information is limited and the main points are stated clearly and unambiguously. However, critical thinking is needed when the information is extensive, is created in different formats and styles for different audiences, and the content has a high degree of complexity. The problem is further intensified when information is poorly presented with the main points not clearly discernable from the details.

The intelligence analyst typically deals with extensive amounts of information that is likely to be complex, is often ambiguous, may be prepared by someone from a different culture, and is not always presented clearly and simply. As a consequence, skill is required to extract the essential message from information and to summarize this message for future use in the analytical process. It is extremely useful to summarize a large amount of complex information with a simple statement so that the entire body of information need only be consulted subsequently to seek or verify specific details. Also, the gist serves as convenient shorthand to help communicate, is more easily remembered, and helps the analyst focus on the most important issues.

6.2 Organize information into premises

The skills associated with this function are: recognize patterns and relationships, and challenge assumptions. These skills are described in the paragraphs that follow.

6.2.1 Recognize patterns and relationships

An important function of intelligence analysis has been referred to in recent years as “connecting the dots” (Lahneman, 2006). While this expression is not very definitive, it does provide a general feeling for a skill that is important to the work of the analyst—recognizing and confirming patterns and relationships. A special aspect of this skill is establishing

causes and effects that may be vital to understanding a situation, threat, process or set of events—who is sending suicide bombers into the crowded market places of the city, for example. This particular skill is one of recognizing patterns and relationships in the process of building premises that will lead, ultimately, to the development of hypotheses.

A critical task in the intelligence analysis process is the organization of information into premises—summarizing related items of information, results of data integration efforts, and/or information that answers a question into a summary statement that encompasses the central idea (premise) contained in the information. To complete this task successfully, the analyst must be able to recognize the patterns and relationships that serve as a logical basis for premise development.

6.2.2 Challenge assumptions

Information obtained for analysis may contain or be based on assumptions (ideas treated as facts but that are not yet supported by available evidence) that are not immediately obvious. On the other hand, the analyst might introduce, in the process of the analysis, assumptions that are mistakenly treated as evidence. Consequently, the analyst must have the capability to identify and challenge any and all assumptions, because they are very likely to be invalid or misleading.

The tendency to overlook or accept assumptions in an analysis might be related to biases introduced into the process, such as certain mind sets and expectations, but they can also be a function of simply not being attentive to their possible existence. The need to challenge assumptions arises mainly while organizing information into premises. Premises should be based on the evidence at hand, an effort that can be defeated by the inclusion of ideas and beliefs based on conjecture. Therefore, as a part of the premise formulation process, there should be a conscious effort to identify, challenge, and remove information that cannot be supported by the evidence at hand. This is an important analytical effort because the premises, once developed, provide the primary basis for hypothesis development.

6.3 Develop hypotheses

The skills associated with this function are: establish logical relationships; consider alternative perspectives; and counter biases, expectations, mind sets and oversimplification. These skills are described in the paragraphs that follow.

6.3.1 Establish logical relationships

The application of inductive logic to a set of premises to develop one or more hypotheses is at the heart of the intelligence analysis process. The hypothesis is a tentative explanation, subject to further testing, of a situation, process, threat, or activity of interest. Developing useful hypotheses requires skill in applying logical reasoning to a set of premises that have been developed from data organized and integrated for this purpose.

The critical aspect of this skill is that of organizing a set of premises into an argument that leads to an explanation that is based on the facts summarized in the premises, but that projects the explanation beyond these facts alone. That is, the analyst develops a

hypothesis that fills in missing gaps to provide a more complete and more useful explanation. The set of hypotheses thus developed serve as the basis for guiding the collection of additional information to fill in the gaps with facts rather than conjecture. The establishment of logical relationships enables the intelligence analyst to link information to premises, premises to hypotheses, and hypotheses to inferences that can be acted on with confidence. The logical relationships are necessarily inductive in nature—going from the specifics to the general, permitting discovery of what was previously unknown. It is the tightness of this logic that provides the necessary discipline for the ultimate development of useful, valid inferences.

6.3.2 Consider alternative perspectives

This is the ability to develop explanations from different perspectives for the same information. An important component of this ability is to set aside one's own inclinations, values, beliefs, expectations, and preferences so as to develop explanations that cover the full range of possibilities. Some aspects of this skill have been called divergent thinking—generating different ideas about a topic from available information or knowledge. But while divergent thinking is characterized by spontaneous, free-flowing, unorganized idea generation, this skill requires the development of explanations from the deliberate consideration of a set of premises that have been systematically derived from available information.

Intelligence analysis relies on the development of alternative competing hypotheses. After a set of premises has been derived from information determined to be relevant and valid, alternative hypotheses are developed that define the full range of possible explanations for the information. This process requires the critical thinking skill of considering alternative perspectives. The resulting alternative hypotheses, then, serve to guide collection of the additional information needed to formulate a useful inference.

6.3.3 Counter biases, expectations, mind sets and oversimplification

Analysts are subject to the same biases, expectations, mindsets and oversimplifications that affect the thinking of all humans. While these negative influences might have limited impact on the lives that most of us live, they can be devastating to the work of the intelligence analyst. Consequently, analysts must develop the ability to understand and recognize the possible effects of these influences and to develop skills to keep them from distorting the products of analysis.

This skill involves the ability to continuously reevaluate one's view of the situation for these types of negative influences and to take the appropriate steps to eliminate them from the analysis. Although the types of influences addressed in this skill can enter the intelligence analysis process anywhere along the line, the primary concern is their role in hypothesis development and testing. Prior to this point, the tests for relevancy and validity should help assure the analyst that cognitive biases have had only a limited opportunity to enter the process. Now, as the analyst moves from strictly factual information to using conjecture in developing the most encompassing and useful hypotheses possible, these opportunities for distortion can operate most freely.

6.4 Test hypotheses

Testing hypotheses requires: considering value-cost-risk tradeoffs in seeking additional information, seeking disconfirming evidence, and assessing the strength of logical relationships. These skills are described in the paragraphs that follow.

6.4.1 Consider value-cost-risk tradeoffs in seeking additional information

A dilemma faced by intelligence analysts is whether to stop and report an inference based on available information, or to collect additional information. More information might produce an inference with greater usefulness at a higher level of confidence, but seeking additional information adds to intelligence costs and also risks a result that is not timely enough to be of value. This dilemma might be encountered early in the intelligence process or, more critically, later during the testing of hypotheses. This skill, then, is the ability to evaluate the need for new information by considering the value, cost and risk tradeoffs that are involved.

The analyst faces value-cost-risk tradeoffs principally during the stage of analysis in which hypotheses are being tested; this is a critical part of the process of developing a useful inference. Typically, one or more hypotheses would have been developed at this stage of the analysis and additional information might be required to help confirm or refute them. With limited time and resources available for collecting additional information, the analyst must employ these resources in the manner that will produce the greatest value for the resources expended. The analyst must also be sensitive to producing an inference in sufficient time and at a high enough level of confidence for it to be of use.

6.4.2 Seek disconfirming evidence

This skill is closely related to two skills addressed earlier – consider alternative perspectives and counter biases, expectations, mind sets, and oversimplification. Seeking disconfirming evidence is an important component of efforts taken to develop and test alternative competing hypotheses and is done in the face of biases that work to impede such efforts. A particularly important influence, confirmation bias, affects the development of alternative hypotheses by tending to prevent the analyst from seeking information other than what is likely to confirm a favored explanation.

The skill, then, is the ability to seek disconfirming evidence, particularly in the testing of hypotheses, when the more natural inclination is to seek confirming evidence. This skill is applied to intelligence analysis mainly during the testing of hypotheses. Assuming that the analysis has been performed effectively to this point, the analyst has two or more alternative explanations for the information at hand; testing these alternatives requires the collection of additional information that will ultimately result in selecting the most valid or producing some composite that is the most valid. To overcome our built-in human tendency to seek confirming evidence, the analyst needs to learn the techniques and discipline of seeking disconfirming evidence during the hypothesis testing process.

6.4.3 Assess the strength of logical relationships

The development of a hypothesis from a set of premises is based on the logical relationship that exists between premises and hypothesis. The relationship is necessarily

one of inductive logic, in which the argument proceeds from the specifics (the premises) to the general (the hypothesis). The strength of the relationship depends on the extent of conjecture involved in making the jump from the facts as summarized in the premises and the hypothesis that goes beyond the premises to provide a more useful explanation. More conjecture leads to weaker relationships; less conjecture leads to stronger relationships. The most meaningful way to assess and convey the strength of this logical relationship is to provide a numerical probability estimate of the confidence one can have that the hypothesis or inference is true.

The critical thinking skill is that of assessing the strength of these relationships in a manner that provides a numerical probability of the validity of hypotheses and inferences. Critical thinking is required because the process is a subjective one—subjective conditional probability—calling for a careful and deliberate assessment. The process is necessarily subjective (and consequently requires critical thinking) because the analyst will hardly ever have the type of statistical evidence needed to provide a simple objective calculation of probability (one that does not require critical thinking). In applying subjective conditional probability, the analyst must answer the following question: Given this specific set of premises (the conditions), what is the probability that the hypothesis (or inference) is true?

As stated earlier in this paper, the objective of intelligence analysis is to develop inferences that can be acted on with confidence. For the product of intelligence analysis to be complete, therefore, it must produce an inference that provides the needed explanation and, also, an estimate of the level of confidence that the user can have in that inference. The goal is to provide the greatest level of detail at the highest level of confidence. However, this usually results in a tradeoff—greater detail typically comes at a lower level of confidence. Conversely, the analyst can provide a higher level of confidence but with less detail. Providing confidence assessments enables the analyst to best meet the needs of the user—more detail at lower confidence or less detail at higher confidence. To provide such estimates, the analyst must be capable of generating and communicating subjective conditional probability estimates.

7. Conclusions

In the last couple of decades a number of useful tools have been developed to support the intelligence process, encompassing the functions of data collection, evaluation, collation and integration. However, intelligence analysis remains highly dependent on the cognitive capabilities, specifically the critical thinking skills, of the human analyst. For this reason, it is important for the success of the process to understand the inherent capabilities and limitations of the analyst and, in particular, the challenges that must be overcome through the application of cognitive ergonomics to the design of analysis systems and in the training of critical thinking skills.

To better understand critical thinking and the efforts required to maximize its effectiveness, a model was developed that is sufficiently specific to enhance understanding and to permit empirical testing. The model identifies the role of critical thinking within the related fields of reasoning and judgment, which have been empiri-

cally studied since the 1950s and are better understood. It incorporates many ideas offered by leading thinkers in philosophy and education. It also embodies many of the variables discussed in the relevant literature (e.g., predisposing attitudes, experience, knowledge, and skills) and specifies the relationships among them. The model can, and has been, used to make testable predictions about the factors that influence critical thinking and about the associated psychological consequences. It also offers practical guidance to the development of training for critical thinking skills.

The model is based on the most recent versions of heuristic theory, the foundation of which is that two cognitive systems are used to make judgments. System 1, based on intuition, is a quick, automatic, implicit process that employs associational strengths to arrive at solutions automatically. System 2 is effortful, conscious, and deliberately controlled. The two systems run in parallel and work together, capitalizing on each other's strengths and compensating for their weaknesses. For example, one function of System 2, the controlled deliberate process, is to monitor the products of the automatic process, making adjustments to correct or block the judgment of System 1. If no intuitive response is accessible, System 2 will be the primary processing system used to arrive at a judgment.

Technology can now be employed extensively by intelligence analysts to extract meaning from available information, to support the performance of a variety of analyses, and to aid in the communication of analytical results to the users of intelligence. The design of future systems to support the intelligence process can benefit from cognitive ergonomics, specifically from what we now know about the nature and role of critical thinking. Moreover, findings about specific critical thinking skills can support the development of training systems and methods that best meet analyst performance requirements.

Research and experience to date in training and applying intelligence analysis skills suggest that the principal challenges that affect critical thinking are human limitations. Humans are limited in their capabilities to address complexity, by the biases they bring to the process, by their difficulties in handling uncertainty and, often, by the lack of relevant domain expertise. These limitations must be overcome by appropriately designed training systems and methods.

Recent research has identified the 11 critical thinking skills that are most important for successful intelligence analysis. They are presented below as they relate to the principal intelligence function they serve.

Assess and Integrate Information

- *Envision the end state of the analysis* and use that vision to guide and limit the analysis to those tasks most likely to attain the desired goal, checking on the process and products to ensure movement along the right path.
- *Assess and filter for relevance and validity*, examining information for its potential contribution to the objectives of the analysis.
- *Extract the essential message* by sorting through the details of information to distinguish the essential from the non-essential, and by generating clear, concise statements summarizing the main points.

Organize Information into Premises

- *Recognize patterns and relationships*, establishing causes and effects vital to understanding situations, threats, processes and events during the development of premises in an argument.
- *Challenge assumptions* so as to avoid ideas that might be treated as facts but that are not supported by available evidence or might be related to biases that have been introduced by mind sets or expectations.

Develop Hypotheses

- *Establish logical relationships* by applying inductive logic to derive one or more hypotheses from the set of premises summarizing facts derived from available information.
- *Consider alternative perspectives* by setting aside personal inclinations, values and expectations so as to develop explanations (hypotheses) that cover the full range of possibilities.
- *Counter biases, expectations, mind sets and oversimplification* by developing the ability to recognize the possible effects of these influences and developing techniques to keep them from distorting the products of analysis.

Test Hypotheses

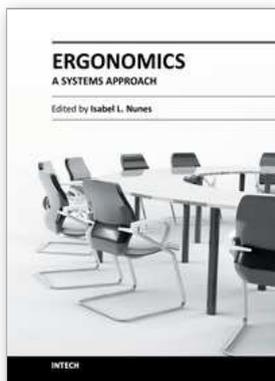
- *Consider value-cost-risk tradeoffs in seeking additional information* to employ available resources in a manner that will produce the greatest value for the resources expended and the time available.
- *Seek disconfirming evidence* during the testing of hypotheses when the more natural inclination is to seek confirming evidence.
- *Assess the strength of logical relationships* in a manner that provides a numerical probability estimate of the confidence one can have in the validity of hypotheses and inferences.

8. References

- American Philosophical Association (1990). *The Delphi report: Committee on pre-college philosophy* (ERIC Doc. No. ED 315 423.)
- Auprasert, B. & Limpiyakorn, Y. (2008). Underlying cognitive complexity measure computation with combinatorial rules. *World Academy of Science, Engineering and Technology*, 45, 431-436.
- Baddley A.D. (1986). *Working memory*. London/New York: Oxford University Press.
- Baddley, A.D. (1996). Exploring the central executive. *Quarterly Journal of Experimental psychology*, 49A, 5-28.
- Baron, J. B. & Sternberg, R. J. (1986). *Teaching thinking skills*. New York: W. H. Freeman and Company.
- Engle, R.W. & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.). *The psychology of learning and motivation*, 44, 145-199. NY: Elsevier.

- Fingar, T. (2006). US Intelligence reform and the analytic community: challenges and opportunities. Proceedings of the IALEIA World Intelligence Training Conference, Mexico City, Mexico, April 24-28.
- Fischer, S.C. & Spiker, V.A. (2000). *Application of a theory of critical thinking to Army command and control*. Alexandria, VA: US Army Research for the Behavioral and Social Sciences.
- Fischer, S.C. & Spiker, V.A. (2004). *Critical thinking training for Army officers. Vol II: A model of critical thinking* (Phase II Final Report). Alexandria, VA: US Army Research for the Behavioral and Social Sciences.
- Fischer, S.C., Spiker, V.A. and Riedel, S.L. (2009). *Critical thinking training for Army officers. Vol III: Development and assessment of a web-based training program*. (Research Report 1883). Alexandria, VA: US Army Research for the Behavioral and Social Sciences.
- Halpern, D. F. (1996). *Thought and knowledge: An introduction to critical thinking*. Mahwah, New Jersey: Lawrence Erlbaum.
- Harris, D.H. (2006a). Overcoming the cognitive challenges of intelligence analysis. *Proceedings of the IALEIA World Intelligence Training Conference*, International Association of Law Enforcement Intelligence Analysts, Mexico City, April 24-28.
- Harris, D.H. (2006b). Critical thinking strategies for intelligence analysis. Invited Workshop Presentation to the United Nations Regional Criminal Intelligence Conference, Belgrade, Serbia, December 12-13.
- Harris, D.H. (2011). Critical thinking training for intelligence analysis. *Journal of the International Association of Law Enforcement Intelligence Analysts*, 20 (1), 76-90.
- Heuer, R. (1999). *Psychology of intelligence analysis*. Washington, DC: Center for the Study of Intelligence, available online at <http://www.cia.gov/csi/books/19104/art1.html>.
- Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, 58, 697-720.
- Klein, G. (1999). *Sources of power*. Cambridge, MA: MIT Press.
- Klein, G. (2011). Critical thoughts about critical thinking. *Theoretical Issues in Ergonomics Science*, vol. 12 (3), 210-224.
- Klein, G.A., Moon, B., & Hoffman, R.R. (2006). Making sense of sensemaking 2: A macrocognitive model. *IEEE Intelligent Systems*, 21 (5), 88-92.
- Lahneman, W.J. (2006). *The future of intelligence analysis: Volume I final report*. School of Public Policy, University of Maryland.
- Meehl, P. E. (1954). *Clinical versus statistical prediction: A theoretical analysis and a review of the evidence*. Minneapolis: University of Minneapolis Press.
- Miller, G. A. (1956). The magical number seven plus or minus two. *The Psychological Review*, vol. 63, pp. 81-97
- Moore, D. T. (2007). Critical thinking and intelligence analysis. Center for Strategic Intelligence Research, National Defense Intelligence College: Washington, DC.
- Packer, G. (2006). Knowing the enemy. *The New Yorker*, 60-69, December 18.
- Paul, R. & Elder, L. (2001). *Critical thinking – Tools for taking charge of your learning and your life*. New Jersey: Prentice Hall.
- Simon, H. (1957). *Models of man: Social and rational*. New York: Wiley.

- Thaler, R.H. & Sunstein, C.R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. New York: Penguin Press.
- Watson, G. & Glaser, E. M. (1980). *Critical thinking appraisal*. New York: Psychological Corporation.



Ergonomics - A Systems Approach

Edited by Dr. Isabel L. Nunes

ISBN 978-953-51-0601-2

Hard cover, 232 pages

Publisher InTech

Published online 25, April, 2012

Published in print edition April, 2012

This book covers multiple topics of Ergonomics following a systems approach, analysing the relationships between workers and their work environment from different but complementary standpoints. The chapters focused on Physical Ergonomics address the topics upper and lower limbs as well as low back musculoskeletal disorders and some methodologies and tools that can be used to tackle them. The organizational aspects of work are the subject of a chapter that discusses how dynamic, flexible and reconfigurable assembly systems can adequately respond to changes in the market. The chapters focused on Human-Computer Interaction discuss the topics of Usability, User-Centred Design and User Experience Design presenting framework concepts for the usability engineering life cycle aiming to improve the user-system interaction, for instance of automated control systems. Cognitive Ergonomics is addressed in the book discussing the critical thinking skills and how people engage in cognitive work.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Douglas H. Harris and V. Alan Spiker (2012). Critical Thinking Skills for Intelligence Analysis, Ergonomics - A Systems Approach, Dr. Isabel L. Nunes (Ed.), ISBN: 978-953-51-0601-2, InTech, Available from: <http://www.intechopen.com/books/ergonomics-a-systems-approach/critical-thinking-skills-for-intelligence-analysis>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.