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VISUAL ANALYTICS FOR SENSE-MAKING IN CRIMINAL INTELLIGENCE ANALYSIS

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Psychological Factors in Criminal Intelligence Analysis: What they are, why they are important, and how to deal with them

E.-C. Hillemann[1], M. A. Bedek[1], A. Nussbaumer[1], M. Pohl[2], J. Haider[2], S. Attfield[3], N. Selvaraj[3], N. Kodagoda[3], C. Groenwald[3], A. Bielska[4], C. Pallaris[4], G. Ellis[5]

[1] Technical University of Graz, Austria
[2] Technical University of Vienna, austria
[3] Middlesex University London, UK
[4] i-Intelligence GMBH, Zurich, Switzerland
[5] University of Konstanz, Germany

Project Coordinator
Middlesex University London
The Burroughs, Hendon
London NW4 4BT
United Kingdom.

Professor B.L. William Wong
Head, Interaction Design Centre
Faculty of Science and Technology
Email: w.wong@mdx.ac.uk

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ABSTRACT

This paper presents a framework that deals with psychological aspects that are relevant in the daily work of criminal analysts. These aspects include structuring and reasoning of criminal information, understanding and sense-making of information, and the mitigation of cognitive biases in the analytics process. Each of these human factors is described in terms of a problem statement, how the problem is addressed, and which results have been achieved so far. The Human Issues Framework bundles them and gives advice on how they can be taken up by system designers and developers. In this way the Human Issues Framework builds a sound basis for the design and specification of visual analytic systems for criminal analysis from a psychological perspective.

Keywords: Criminal analysis, reasoning, evidential structuring, sense-making, cognitive bias, human issues framework.

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INTRODUCTION

Today's analysts are confronted with a veritable explosion in data volume. In other words, they have to deal with a huge amount of different pieces of information – internal and external, structured and unstructured data – in order to find new insights and consequently to make valuable and sound decisions. With this in mind, the main purpose of VALCRI is to create a visual analytic-based reasoning and sense-making capability for criminal intelligence analysis by developing and integrating a number of advanced user interface technologies with powerful analysis software. A key focus of this project is on appreciating the importance of the human issues on the design of the VALCRI information exploitation system for law enforcement analysis.

Therefore, a major aim in this project is to develop of a Human Issues Framework that builds a sound basis for the design and specification of visual analytic systems from a psychological perspective. The Human Issues Framework brings together these diverse human issues into a single framework that can be used in a practical way for designing systems. In particular, this framework integrates structuring and reasoning of criminal information, understanding and sense-making of information, and the mitigation of cognitive biases in the human analytics process. These psychological aspects are relevant and important for the daily work of criminal analysts and mostly not properly or not at all supported by existing computer systems.

To elaborate a sound Human Issues Framework, it is of great importance to get a holistic understanding of the psychological factors mentioned above that influence the analysis, the cognition and the whole analytic process of criminal analysts. Consequently, this document aims to outline the main findings and relevance of these factors for the VALCRI project. For each of these factors individual sections describe the problem statement, how the respective problem is addressed, and first results. After these descriptions, a section on the Human Issues Framework integrates these factors.

EVIDENTIAL REASONING AND STRUCTURING

It has been said that making sense of a situation involves fitting its elements into some kind of structure that links them together (Klein, Phillips, Rall, and Peluso, 2007), such as a story, a map, a script or a plan. That when people make sense of stimuli they do so by placing them into some kind of framework which allows them to, "Comprehend, understand, explain, attribute, extrapolate and predict" (Starbuck and Milliken, 1988). Most accounts of sensemaking make similar reference to the role of structuring information, whether this be 'in the head' or 'in the world' (e.g. on paper or computer screens) (see also, Russell, Stefik, Pirolli and Card 1993; Pirolli and Card, 2005).

Reasoning with evidence is a type of sense-making, in which structuring plays an important role. From our observations of crime analysts a good deal of their time is spent creating schematic structures with selected information to support their understanding. However, many analysts do not have access to computer-based tools that provide a visual environment for reasoning with evidence, with which information can be organised quickly and easily. These can help the analysts do things such as reflect their evolving understanding of a case, see where there are gaps, focus attention on particular areas, and report and discuss interpretations with colleagues.

But there is an abundance of ways of structuring information, differentiated by the entities that are depicted and how these are related (Blandford, Faisal, and Attfield 2014), and there is a question of the kinds of structuring crime analysts might find benefit from (as well as how this might integrate with analytical tools). For crime analysis, literature points to the potential significance of organising information by theme, in the form of argument and as narrative.

Sorting by theme involves classifying information by topic area. Defined by the analyst, emerging themes can provide an early organising principle that can become more detailed and differentiated during the course of an investigation. It offers an initial scaffolding under which other structures can be created. Sorting may involve a binary relevant/irrelevant judgement or there could be multiple themes. In e-discovery investigations lawyers 'code' or tag documents against a series of investigation themes or 'issues' (Attfield & Blandford, 2011).

Argumentation is a form of structuring that relates ideas through links of inferential justification. For example, a link between pieces of evidence and a conclusion about who the culprit may be is an argumentation link. Visual representations of argument have a long history, including Wimore's visual language for arguments in legal cases (Wigmore, 1931) and Toulmin's scheme for representing everyday arguments (Toulmin, 1958).

A narrative on the other hand, is a spoken or written account of events as they unfolded over time. It has the form of a story or chronicle. From a psychological perspective, narrative seems to be an important form through which people make sense of criminal evidence (c.f. Pennington and Hasties' Story Model (1992) and Wagenaar and Crombags' Anchored Narrative Theory (Wagenaar, van Koppen & Crombag, 1993).

Based on a review of the literature we have developed a series of guidelines for the design of information structuring tools to help police crime analysts. For example, a systems can allow users to easily sort into and represent emerging themes, and it can also learn from such choices to help with decisions further down the line. It can also help analysts to structure events into 'anchored narratives'— narratives tied to evidential justifications.

Informal causal reasoning is central to the way we reason about narratives and we can think of developing ways to analyse data such that explanations and narratives can be developed and used quickly to drive further sense-making. By analysing inter-views with analysts we have been able to further understand the way they think about narrative and develop further guidelines specific to this, such as supporting the idea of 'proto-narratives'—small numbers of events linked through coincidence suggesting possible causation.

By conducting further analyst interviews we have also developed a model of crime investigation and in relation to that, described the role of what are known to analysts as think-steps (Selvaraj, Attfield, Passmore and Wong, 2016). For some analysts these act as a central structuring concept. Think-steps are adaptable conceptual templates based around generic crime types or phenomena. Analysts use them to thematically decompose information about a case, identify missing information, and tell the story of the case. They offer a crossover between thematic analysis and narrative.

In ongoing work we are developing a design framework for how analysts performing crime analysis might annotate the visualisations that they develop using VALCRI. This framework includes meta-investigation elements such hunches, questions, plans and conclusions and ultimately structure these into arguments that can support decision making about issues such as resource allocation in crime areas.

ADVANCES IN SENSE-MAKING AND INSIGHT

Problem: The goal of the VALCRI project is to support intelligence analysts in their work. This is not always a straightforward process. Analysts have access to large amounts of information from different sources, therefore, it is often difficult to detect important patterns in this information. It is very time-consuming to get an overview of the events in a criminal investigation. Information systems can be designed in a way to support such sense-making activities. Currently analysts lack tools that provide appropriate views and interaction techniques to improve sense-making and insight.

How do you address it: To solve this problem we first collected guidelines from Human-Computer Interaction for the appropriate design of such information systems. Such guidelines give advice to interface designers how to design their systems. Empirical research is necessary to answer specific questions that arise from the work of intelligence analysts and the requirements for an integrated system that can optimally support their sense-making processes. Therefore, we conducted experiments to clarify open questions. One of these experiments addressed the problem of how to visualise movements and meetings of two or more people in time. The traditional way to visualise such information is with maps. With such maps there is often visual clutter, which makes it is difficult to follow the movements of single individuals. We have therefore developed visualizations that show the movements and the meetings of persons more clearly. Another experiment addressed the problem of how to visualise the connections in social networks, e.g., the connections between people committing crimes together. Again, the question was how to visualise the temporal development of such networks. The question was whether a traditional node-link diagram or a matrix was more appropriate for this task. We found out that for some tasks of the analysts the network is better suited and for other tasks the matrix, hence, it is crucial to provide both and therefore enable the analyst to get different views on the data.

Results: We think that it is essential for the design of information systems for criminal intelligence analysts to understand how human sense-making and insight generations work. It is often not clear how these sense-making processes work. Empirical research is necessary to develop knowledge about these processes. Based on this research, guidelines can be formulated.

COGNITIVE BIAS MITIGATION

Problem: We make thousands of decisions every day. Most are part of general living, such as where to place the foot on the next step, others need more thought such as what flavour yoghurt to buy, but are generally not critical. However some decisions are important - from deciding where and when to cross the road, up to a doctor assessing the injuries of a patient at an accident and emergency hospital.

Humans have evolved to make most decisions rapidly with little conscious effort, due to necessity (e.g. approaching danger) and limited brain processing power and employ 'rules of thumb' or heuristics. Most of the time, such decisions are appropriate or at least adequate but occasionally, often when there is a degree of uncertainty, poor or surprising decisions are made which appear to be irrational. These are commonly referred to as cognitive biases.

One example of a heuristic is Availability, where people tend to estimate the likelihood of something to happen "by the ease with which instances of occurrences can be brought to mind" (Tversky & Kahneman, 1974, p. 1127). Consequently, it is often found that people will think that travel by airplane is significantly more dangerous in the aftermath of a plane crash being reported in the media.

An example of a bias is the Confirmation, where people tend to search for confirming rather than for disconfirming evidence with regard to their own previous assumptions. For example, if you think that eating chocolate makes you loose weight then a Google search "loose weight with chocolate" will confirm this. However, if you look for disconfirming evidence, you will soon find that the large number of 'loosing weight' articles is based on a hoax research publication, specifically designed to test the gullibility of news reporters.

The actual cognitive processes involved in decision making are still unclear. Kahneman & Tversky's heuristics and biases program is thought to be too vague and simplistic, Gigerenzer's 'heuristic adaptive toolbox' adopts an algorithmic probabilistic approach but is limited in scope, and the many dual-process theories (fast, unconscious, low effort, heuristics-based verses slow, thoughtful, effortful, controlled) are lacking empirical justification. Despite the uncertainty in the actual decision making processes, it is evident that poor decisions are regularly made in certain situations without the person being aware that their behaviour is being unduly influenced in a detrimental way. Therefore we feel that it is an important area of research to try limit the possible negative effects of cognitive biases on analysts' decision making.

For psychologists, the interesting question for any psychological mechanism or variable is “Can it be measured?”. In the case of the Confirmation bias, one approach is the “Selective Exposure Paradigm” from Fisher and others (2008): In an experiment, participants are confronted with two alternatives (e.g. 2 different supermarkets) and they have to make a decision (e.g. in which supermarket they would buy some food). After a preliminary decision is made, the participants are then exposed to various pieces of information that either confirm or disconfirm the initial decision. A possible tendency for confirmatory search can be identified if a participant doesn´t change his or her initial decision, even when confronted with disconfirming pieces of information.

As we do not have a good understanding as yet of decision making processes, this makes it difficult to mitigate cognitive biases, especially if we take the view that these 'errors' are involuntary and hence are difficult to recognise and control. Various strategies have been proposed but there is very little hard empirical evidence to suggest that any of them work reliably. Some training and raising awareness of cognitive biases with the users would seem to be a good idea, but is generally unsuccessful in the long run. Also strategies such as considering the opposite or multiple alternatives in the case of the confirmation bias have been suggested. This has been applied in formal techniques such as ACH, but for realistic complex problems it has proved unsatisfactory, often due to the time pressures. Checklists (and similar cognitive forcing strategies) have been proposed and in some cases or used, especially in more critical areas such as medical diagnosis and process control systems (e.g. power plant), to avoid biases associated with primarily memory recall. Whilst these can help prevent common mistakes, they are not experimentally validated in real world situations.

One approach is the (dis)similarity focus initially described in another context by Mussweiler and Damisch (2008): participants are asked to compare two pictures and to either find similarities (similarity focus) or differences (dissimilarity focus) between the pictures. Initial results show that participants who were looking for dissimilarities in the pictures showed less confirmatory search tendencies in a selective exposure experiment afterwards. It is yet unclear for how long such effects actually hold and the underlying psychological mechanisms are not yet fully understood, which provides the great challenge for psychologists to carry out more research, additional experiments and studies.

How do you address it: In order to take account of the possible effects of cognitive biases in criminal intelligence, (a) cognitive biases have been identified that are relevant in this field, and (b) computer system design principles have been elaborated that may help mitigate some particular. The identification process is based on the bias categorization of a previous project (RECOBIA), an extensive literature review, and an end user requirements elicitation. The suggested mitigation techniques are based on a literature review and are undergoing empirical studies to evaluate them.

Results: The following eight cognitive biases have been identified as the most relevant ones:

- Confirmation bias: The tendency to search for or interpret information in a way that confirms one's preconceptions or hypotheses.
- Anchoring and Adjustment Effect: The tendency to rely too heavily or 'anchor' on largely unrelated information when making decisions.
- Clustering illusion: The tendency to see patterns where actually no patterns exist.
- Framing Effect: The tendency to draw different conclusions from the same information, depending on how that information is presented.
- Availability heuristic: The tendency to make judgments about the probability of events occurring by how easily these events are brought to mind.
- Base rate fallacy: The tendency to base judgments on specifics, ignoring general statistical information.
- Selective perception: Paying particular attention to some parts of their working environment to the point where it distorts the reality of the situation.
- Group think: A deterioration of mental efficiency, reality testing and moral judgment resulting from group pressure.

As the VALCRI system is very much a visual environment for the user, another strand of our research is studying the possibility that cognitive biases may interfere with the interpretation of graphs or charts. As with traditional cognitive biases, the user has to make rapid judgements on what the set of marks on the screen, usually in an abstract form, actually represents.

In order to support the mitigation of a subset of the relevant cognitive biases, design guidelines have been developed that inform the system design:

- Visualization types: Relevant information can be visualized through the use of different visualization techniques. The user interface should provide multiple options to visualize the available data.
- Levels of uncertainty: The user should be made aware of uncertainties in the underlying data and also the effect of subsequent transformation processes which made add to the uncertainty. This can be realized through the use of visualizations.
- Extent of the data: Supporting information should be kept in front of the user (at least as summaries) to help to reduce the likelihood of information, which may include disconfirming evidence or probabilities of deception, being lost in the large volume of data.
- Statistical data: Make base rate data visible so that the user is aware of what is considered normal. The system can also help in assessing and manipulating statistics.
- Computerized critic questions: This strategy is also called the devil's advocate method. This procedure has the advantage that the analyst has to be prepared to defend his/her reasoning.
- Group decision making: When working or discussing in a group, everybody has to defend their own hypothesis and consider other (possibly contradicting) hypotheses.
- Evidence-based reasoning: Many of the aforementioned guidelines can also be applied to assist the user with structured argument mapping.

HUMAN ISSUES FRAMEWORK

Intelligence work does not take place in a vacuum. The process of collecting and analysing information is influenced by a range of variables or "human issues". These issues impact both the process of intelligence and its outputs.

They include but are not limited to cognitive factors such as sense-making, evidential reasoning and bias mitigation (as described above). They also include non-cognitive variables including: the quality of one's data, the nature and quality of inter-and intra-team collaboration, legal and ethical constraints, operational factors, personal and interpersonal factors, situational and dispositional factors, socio-cultural factors, technology and socio-technological dynamics and so on.

The range of issues affecting intelligence work is reflected in the Five Architectures Framework. This framework posits that intelligence work spans five separate but interconnected domains:

- The organisational domain, which includes the activities pertaining to an organisation's mission, objectives, etc.
- The operational domain, which includes the activities pertaining to the execution of orders, projects, etc.
- The informational domain, which includes the activities pertaining to the use and management of information.
- The technological domain, which includes the activities pertaining to the use and management of IT.
- The cognitive domain, which includes the activities pertaining to analysis, synthesis, etc.

The Five Architectures Framework is the backbone of the Human Issues Framework (HIF) which is a research aid developed as part of the VALCRI project to help us understand a) how the analysts work and b) the many factors that influence the outcomes of the intelligence work. Put differently, the HIF looks to identify what impact these issues have on process and product.

In its current guise, the HIF encompasses four levels of analysis:

- The Sense-making and Evidential Reasoning level
- The Bias Mitigation level
- The Five Architectures Framework itself
- The Legal, Ethical, and Privacy Issues level

These levels provide a rich window into analytic work, its enablers and inhibitors, and how to improve it. Taken as a whole, the HIF also acknowledge that even the best tools do not always produce the desired outcome when other factors constrain the analyst's effectiveness (e.g. organisational factors such as the lack of training; operational factors such as poorly planned or badly executed processes; informational factors such as poor data quality, etc.).

The HIF also underscores the variability of intelligence work. This variability appears on at least five different levels:

- The National Level - There are national specifics that affect how criminal intelligence units operate
- The Organisational Level - Differences are also apparent at the organisational level. For example, local police units are subject to different regulations than their federal equivalents
- The Unit Level - Units within an organisation are also subject to variation. Thus, they may differ as a result of the training provided, the scope of their work, the types of analysis they perform, the technical tools available, etc.

- The Individual Level - Inevitably, there are also significant differences in the way individual analysts work.
- The Requirements Level - One of the biggest errors an analyst can commit is to consider all requirements alike and manage them using a common set of tools, technologies and processes.

The HIF has crucial implications for developers. First and foremost, it suggests that any decision support or analytical tools should be flexible enough to support a range of intelligence workflows. Second, they should be sensitive to both the cognitive and operational dimensions of sense-making, evidential reasoning and bias mitigation, as well as the legal, ethical and privacy-related constraints that inform criminal intelligence analysis.

Finally, these tools should be evaluated using the Five Architectures framework. Doing so would help us identify the technical factors that positively or negatively influence intelligence work. Factoring these variables into the development process should increase the tool's utility and adaptability to changing circumstances.

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	VALCRI Partners	**Country**
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