VISUAL ANALYTICS FOR SENSE-MAKING IN CRIMINAL INTELLIGENCE ANALYSIS

***VALCRI* WHITE PAPER SERIES**
VALCRI-WP-2017-001
1 January 2017
Edited by B.L. William Wong

Analyst User Interface: Thinking Landscape as Design Concept

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INTRODUCTION

In this White Paper we introduce the concept of the Thinking Landscape as the basis for the design of the user interface for the prototype criminal intelligence analysis system being developed in project VALCRI. The Thinking Landscape is a UI design concept that embodies the idea of externalizing the thinking and reasoning processes of the analyst in ways that gives abstract concepts a tangible expression within the computer user interface.

These externalized logical concepts and results that may arise from various data analyses may manipulated and organised in support of the analytic reasoning process. These externalized concepts represented as virtual cards in the user interface can be assembled in various ways to create tentative explanations that lead to more formal hypotheses. These hypotheses could eventually be developed into rigorous arguments that will withstand interrogation.

The design rationale of the Thinking Landscape is grounded in what we have learned about how analysts think and reason about the analytic problems they face (Gerber, Wong, & Kodagoda, 2016a, 2016b; Wong & Kodagoda, 2015, 2016). The studies include a set of focus group studies with 20 intelligence analysts (Wong & Varga, 2012), think-aloud studies with 6 analysts performing a simulated intelligence task (Rooney, Attfield, Wong, & Choudhury, 2014), think-aloud studies with 6 librarians carrying out a surrogate task of creating explanations from a literature review task (Kodagoda, Attfield, Wong, Rooney, & Choudhury, 2013). In addition, over a four-month period during the project, we met with 15 analysts from three different European police forces, for a total of 14 days of discussions, CTA interviews, and requirements analysis meetings using sketching and lo-fidelity prototyping techniques to elicit workflows and task demands.

In this White Paper we also introduce the concept of Visual Analytics and how it will be used as the technology approach to the design of the 'Thinking Landscape' as a user interface. Visual analytics is the "… science of analytical reasoning facilitated by visual interactive interfaces" (Thomas & Cook, 2004). As an approach it seeks to support the reasoning process by coupling powerful computational processes to address data analytics problems e.g. big data, semantic similarity in text and document mining, with an interactive visual interface that can dynamically steer computations, and present information as data visualisations in which the visual representations can be directly manipulated and access the data itself.

In addition the UI concept is to be grounded in the principles of cognitive systems engineering, where the objective is the design of a joint cognitive system (Hollnagel and Woods, 1982; 2005) for intelligence analysis. The focus is on amplifying human capability to perform cognitive work by coupling technical functions with the human cognitive processes.

BACKGROUND: CRIMINAL INTELLIGENCE ANALYSIS

Criminal intelligence analysis in the context of intelligence-led policing is a relatively new operational concept. It has been developed around a combination of crime analysis and criminal intelligence to anticipate likely areas and types crime and to devise anticipatory policing plans. Crime analysis and criminal intelligence processes overlap and form an approximate continuum of work ranging from the analysis of volume crimes to the support of individual investigations. Crime pattern analysis is "a process that looks for links between crimes and other incidents to reveal similarities and differences that can be used to help predict and prevent future criminal activity". Support of individual investigations refe to the "… evaluation of information and its comparison to other information to determine the meaning of the data in reference to a criminal investigation" ((Morehouse, Peterson, & Palmieri, 2011)).

Crime analysis (Ratcliffe, 2008), describes an aspect of intelligence, where the techniques are based in crime science that includes the use of statistics and crime mapping. Such analyses are carried out in support of crime and disorder problems in general, rather than focusing on investigation support. It involves the "… systematic, analytical processes directed at providing timely and pertinent information relative to crime patterns and trend corrections to assist the operation … personnel in planning the deployment of resources for the prevention and suppression of criminal activities, aiding the investigative process, and increasing apprehensions and the clearance of cases." (Gottlieb et al, 1998).

Criminal intelligence traditionally refers to the activities used to support individual reactive investigations. "The aim is … to gather evidence to support a criminal prosecution" and was often "… a case-specific … tool of crime control" (Ratcliffe, 2008). Criminal intelligence has been described variously, (i) as "… the end product of a process often complex, sometimes physical, and always intellectual, derived from information that has been collated, analysed and evaluated in order to prevent crime or secure the apprehension of offenders" (ACPO 1975, para. 32); or (ii) as a process where "… information [is] compiled analysed and / or disseminated in an effort to anticipate, prevent or monitor criminal activity." (IALEIA 2004, p32).

Within the context of intelligence-led policing these two concepts – crime analysis and criminal intelligence – represent a continuum of processes. This continuum is what we refer to as Criminal Intelligence Analysis. This continuum and its key characteristics have been illustrated in Figure 1.

Figure 1. The Criminal Intelligence Analysis continuum.

At the intelligence end of the spectrum (left in Figure 1), the emphasis here is on the analysis of large volumes of crimes in the areas of responsibility. The analysts carry out various statistical and crime mapping techniques to identify and assess general trends and crime patterns, as well as actively searching for small, statistically insignificant but potentially operationally important events. Such information can be used to anticipate where and when policing resources can be deployed. At the other end of the spectrum is where the analyst carries out a variety of analytic procedures to re-construct situations in order to understand specific crime cases or crime phenomenon. For example, in providing support for investigations into human trafficking, the analyst attempts to find information and piece them together in order than an explanatory narrative can be constructed to explain who are involved, what has gone on to, say, how the offenders have recruited, transported, delivered, transacted and work the trafficked persons, and when did the events occur. The information is collated from a much larger variety of sources that may or may not be available to the routine police officer on the ground. Such investigative support provide the investigating units additional information that can be used to apprehend the key persons in the trafficking network, who may have links to other networks, e.g. drugs, and sex exploitation.

Based on our investigations with a number police forces in Europe, we believe the continuum we refer to as the Criminal Intelligence Analysis process, is consistent with Ratcliffe's (2008) proposed definition of crime intelligence where "analysed information … blends data from crime analysis of crime patterns, and criminal intelligence drawn from the behaviour of offenders, to support intelligence-led policing".

Intelligence-led policing involves "… the interpretation of crime and incident data through analysis, and community information on a range of issues, as well as the more commonly used information gleaned from various sources on the activities of known or suspected active criminals" (Oakensen et al, 2002 p.7). Intelligence-led policing, while constantly evolving, is "… a conceptual model that explains how the business of policing should be conducted, as exemplified by the National Intelligence Model" (Ratcliffe, 2008).

In this context, analysts experience a number of interaction problems. "The purpose of intelligence analysis is to reveal to a specific decision maker the underlying significance of selected target information." (Krizan, 1999). This requires an understanding of the data and the significance of their implications. In complex situations, analysts should also "… make clear the sinews of the reasoning" (Davis, 1997) by accounting for their considerations, how information was used to influenced their assessment, at which points in the analytic reasoning process were the information used, and even the sequence in which the information were used. Ideally, analysts should proceed beyond the descriptive and explanatory levels to synthesis and effective persuasion, to produce action-able intelligence.

In Figure 2, we illustrate only five of the 20 problems interaction encountered by intelligence analysts (Wong & Varga, 2012):

(i) the jig-saw puzzle problem. Analysts are presented with information that may be akin to a jig-saw puzzle. Whilst the task of piecing together the pieces of a jig-saw puzzle is already difficult, in this case, the jig-saw puzzle does not have the box top with a picture of the finished puzzle. Analysts are expected to piece together the different pieces of information without a context. Their job is made more difficult in that analysts often have to work with several jig-saw puzzles at the same time, often not knowing if there are missing pieces and indeed how many pieces are relevant;

(ii) the keyhole problem: This is the problem of only being able to see the data space through a small viewing port of the computer display. This creates a number of problems, such as reliance on memory if data needed for comparison are from different repositories and have separate windows; the lack of persistence can also activate cognitive biases such as recency effects and availability biases;

(iii) it is effortful to find key pieces of evidence and to assemble them into strong arguments or at least as potential explanations to initiate inquiries by the analysts;

(iv) analysts are often unaware of what data exists, missing, and often also not knowing that a need for such data exists;

data overload is another significant problem, overwhelming the analysts' perceptual field of view, and given time constraints, becomes impossible to review all the data. Additionally, as tradecraft has traditionally been a highly individual activity, most systems lack the provenance models and technologies to help the analysts create pathways of their analysis and assessments that may be easily observed or inspected by co-workers and others. This lack of visibility of the analytic process often mean the lack of verifiability and auditability of decisions and choices made. It is against such a background that analysts must operate.

In criminal intelligence analysis, one of the most labour-intensive tasks is the creation of matrices that enables comparison of crime cases across many different dimensions. Such an analytic technique is known as Comparative Case Analysis. This is also one of the more useful techniques where it is used both in the strategic level Crime Pattern Analysis and in support of tactical level individual case investigations. It collates both structured and unstructure rich text descriptions into the matrix. Once collated, it helps the intelligence analysts and investigators identify similarities between cases, posit trends, find geographical as well as temporal clusters. Finalised matrices are also used as evidence in court. Additionally, it can also be used to compute volume crime statistics that can span across hard classification silos. However, the production of such a matrix is laborious. It involves the manual assembly of the information from many different sources, and not all relevant information is available at the same time. The automatic semantic knowledge extraction capability being developed by this Consortium is an attempt at reducing some of the effort required to create such a matrix.

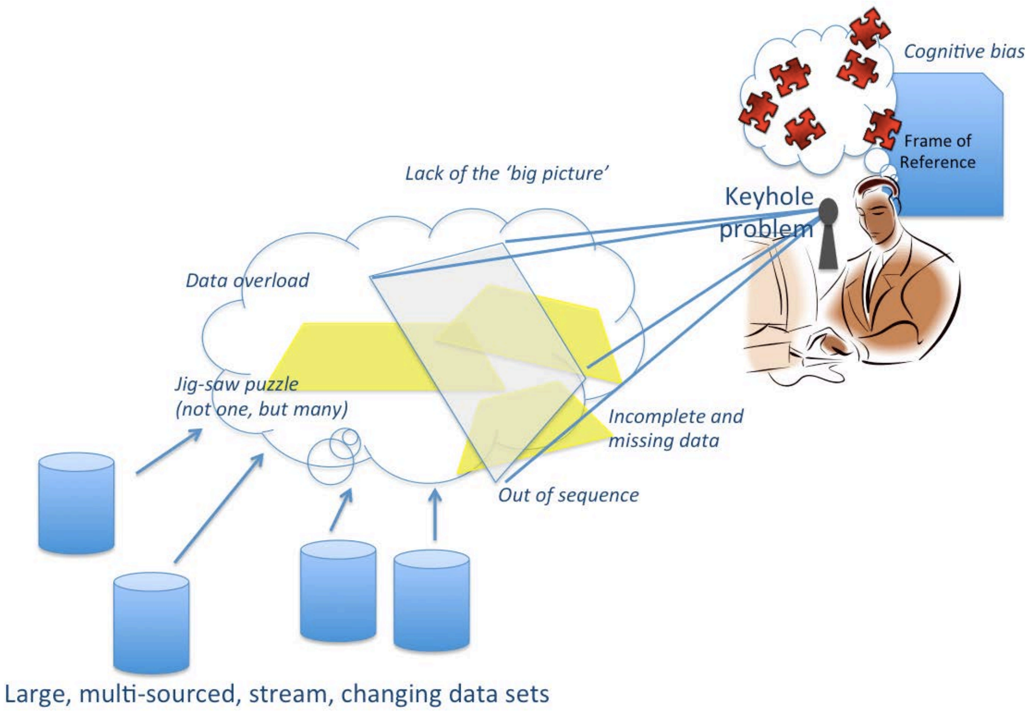

Figure 2. Information problems encountered by an analyst.

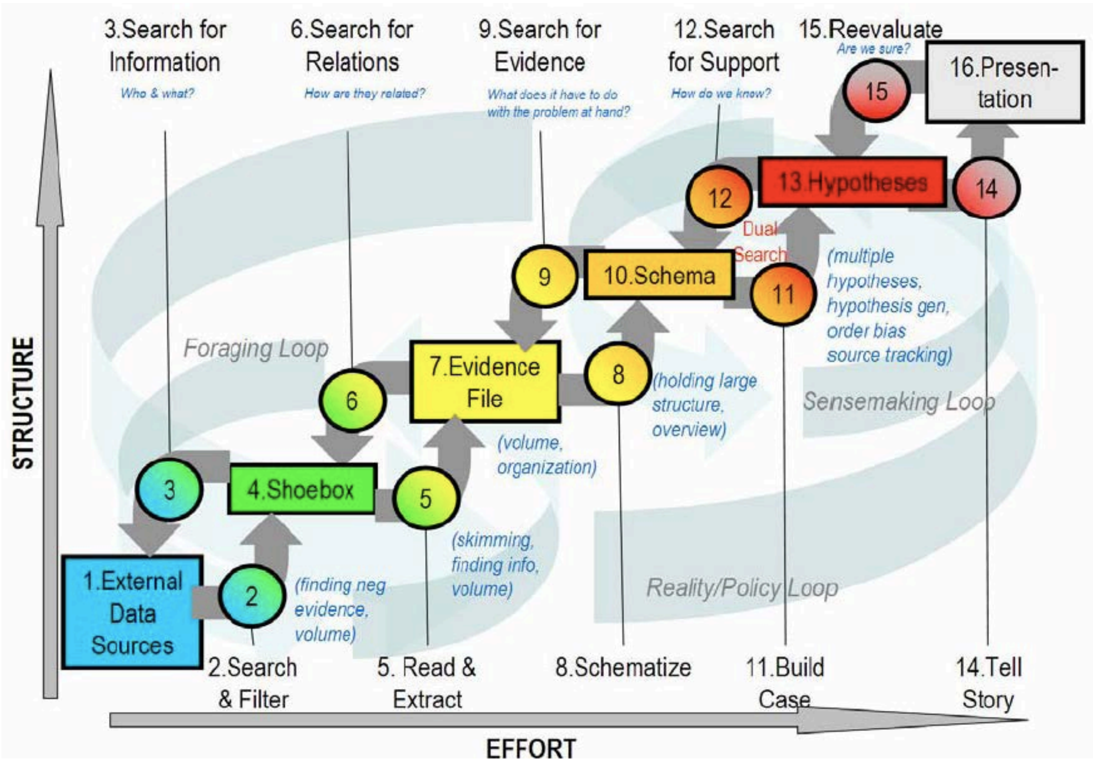

Figure 3. The Pirolli and Card (1995) model of the Intelligence Analysis process.

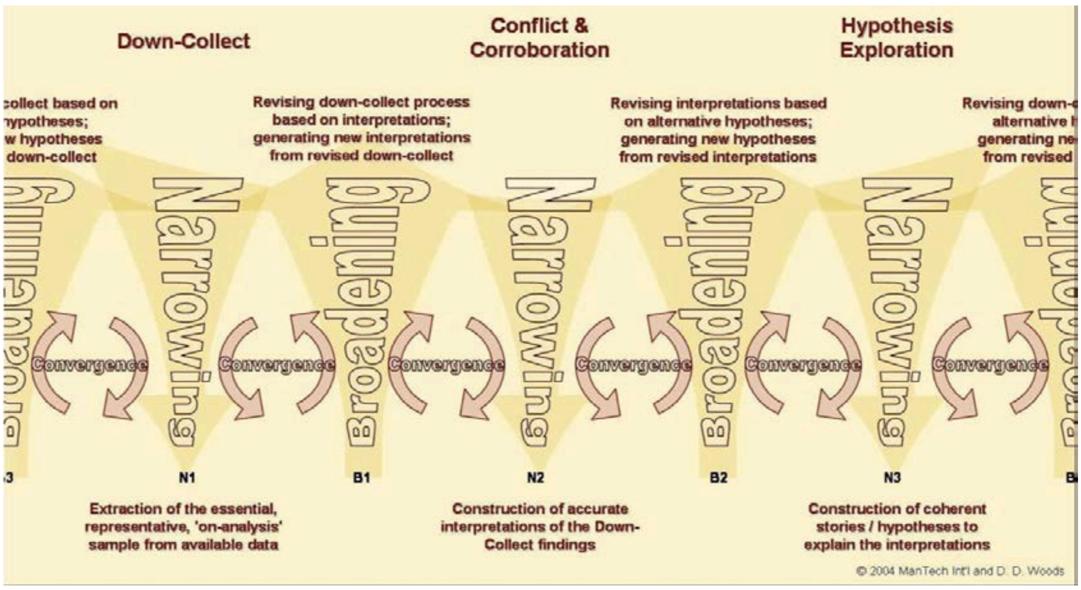

Figure 4. The Convergent Broadening / Narrowing Model of Decision Making for Intelligence Analysis (Elm et al, 2005)

HOW DO ANALYSTS THINK IN SUCH A CONTEXT?

There are several models of intelligence analysis – but in this very brief review, we will describe two models that are illustrative of attempts to describe the analysis process. We have included the well known Pirolli and Card model as one that reflect models that are more task and data transformation oriented, and the Elm et al model that explains how analysts start divergently with many ideas, and then converge as they narrow down the field of possibilities, and how that process is repeated.

Pirolli and Card (1995) Model of Intelligence Analysis

One of the earliest models to describe the process of intelligence analysis is reproduced in Figure 3. This is the well-known and probably the most frequently cited, Pirolli and Card model (Pirolli and Card, 1995). It is useful for showing how information is handled through the process of searching and retrieving relevant information, organising, indexing and storing the information for later use, structuring the information to create a schema or a way to explain what has been observed, the formulation and testing of hypotheses, which then leads to the determination of a conclusion, and a sharing of that conclusion.

While useful, it principally describes the data transaction, information handling and transformation processes, "… rather than how analysts work and how they transition" (Kang and Stasko, 2009). Kang and Stasko makes the point that the model does not reflect the thinking and reasoning processes. It describes how information is handled, organised, collated, and transformed.

The Convergent Broadening / Narrowing Model of Decision Making for Intelligence Analysis

Rather than focus on the transaction and handling process flows, Elm et al (2005), Patterson, et al (1999) attempted to analyse on the thinking processes. Through a series of cognitive task analyses, Patterson et al (1999) discovered that analysts engage in a narrowing and broadening process as they learn more and refine their understanding of an intelligence problem or situation. Their findings eventually culminated into the Elm et al Convergent/Divergent model.

One of their insights is that analysts are often faced with missing data. Sometimes they are aware of this, but often not. Because of missing elements of the needed data, analysts have to make guesses and adductive inferences to create plausible explanations that are developed via the Broadening / Narrowing model, rather than having access to "a full set of undisputed findings that are in a format that eliminates conflicts with each other and makes it easy to compare their relationships to explanatory hypotheses." Paterson, et al (1999) p108.

While both models have their uses, these models are limited in their ability to explain how analysts make sense of the data. How do they join the dots? How do they decide which dots to join and which not? How do they make the leap of faith? How do they come up with explanations for seemingly un-related data? Perhaps another framework for explaining the nature of the thinking and reasoning during intelligence analysis could be described by the ideas of sense-making.

Sense-making

Sense-making has been explained as (Ancona, 2012)) (i) the process of "structuring the unknown" (Waterman, 1990), p. 41) by "placing stimuli into some kind of framework" that enables us "to comprehend, understand, explain, attribute, extrapolate, and predict" (Starbuck & Milliken, 1988) p. 51; (ii) the activity that enables us to turn the on-going complexity of the world into a "situation that is comprehended explicitly in words and that serves as a springboard into action" (K. E. Weick, Sutcliffe, & Obstfeld, 2005) p. 409; and (iii) an articulation of the unknown, because, sometimes trying to explain the unknown is the only way to know how much you understand it.

(Karl E. Weick, 1995) in his studies of how people in organisations make sense of situations, also observed sense-making can be characterised by seven key properties, including being "driven by plausibility rather than accuracy". (Patterson, Roth, & Woods, 1999) also report that when decision makers are faced with inaccurate representations of the real-world, they often fill-in the gaps. They use strategies such as 'story-telling' e.g. (Klein, 1997). The stories link the pieces of data together to create explanations that can be used to understand the situation. The stories are the glue that hold the data together in a sensible way. We have also observed such practices in simulated investigative exercises we carried out (Baber, Attfield, Wong, & Rooney, 2013).

Sense-making and the Data-Frame Model

(Klein, Philips, Rall, & Peluso, 2007) proposes one approach to describing the sense-making process called the Data-Frame Model of Sense-making (Figure 5). Klein et al explains that people make sense of a situation by interpreting the **data** they are presented with in relation to their basic or general understanding. They refer to this understanding as a **frame**. This frame can be any sort of prior knowledge based on one's experiences such as training, socio-cultural background and so forth, that helps them interpret what the cues of a situation mean. In this process, people learn what the situation means, which in turn contributes to developing their frames, which in turn guide the person in determining what other cues can or should be considered. This process is known as **connect**, i.e. when a connection is made between the data that one see's and one's frame.

As the person understands the situation better, connecting with more data that informs him of the situation, the person embarks on the process of **elaborate** – searching for more relevant information that can add to his understanding of the situation, learning that there may be other dimensions to the problem than originally thought, therefore driving the demand for more information. As they understand the situation better, they then realize that perhaps some aspects of their understanding is incorrect, leading them to ask **questions** about their conclusions or the assumptions they made in order to arrive at those conclusions. If their understanding is flawed, they may **reframe** their understanding. Although described in a linear fashion, the Data-Frame Model does not describe a linear process – depending upon one's knowledge and understanding of the situation, the sense-making process can start at any point in the Data-Frame Model.

We find that this approach to explaining sense-making affords clearer indicators about the nature of the process that systems designed for intelligence analysis need to support. In our study with a number of intelligence analysts, our observations suggest that Klein's et al Data-Frame model of sense-making is a good approximation how people learn and understand what goes on in the minds of the analysts. Analysts also talk about the 'light-bulb' or 'ah-ha' moment – that point in their thinking when the answer to their puzzle or predicament suddenly becomes obvious. That moment of realisation is the moment of insight.

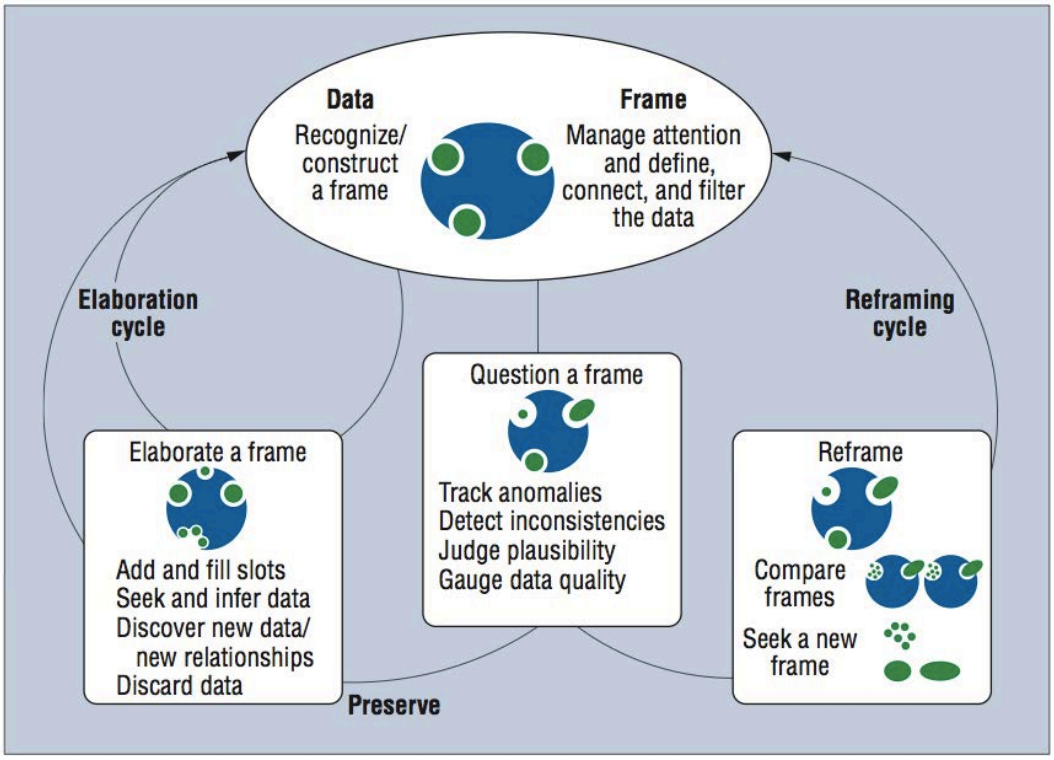

Figure 5. The Data-Frame Model of Sense-Making (Klein et al, 2007).

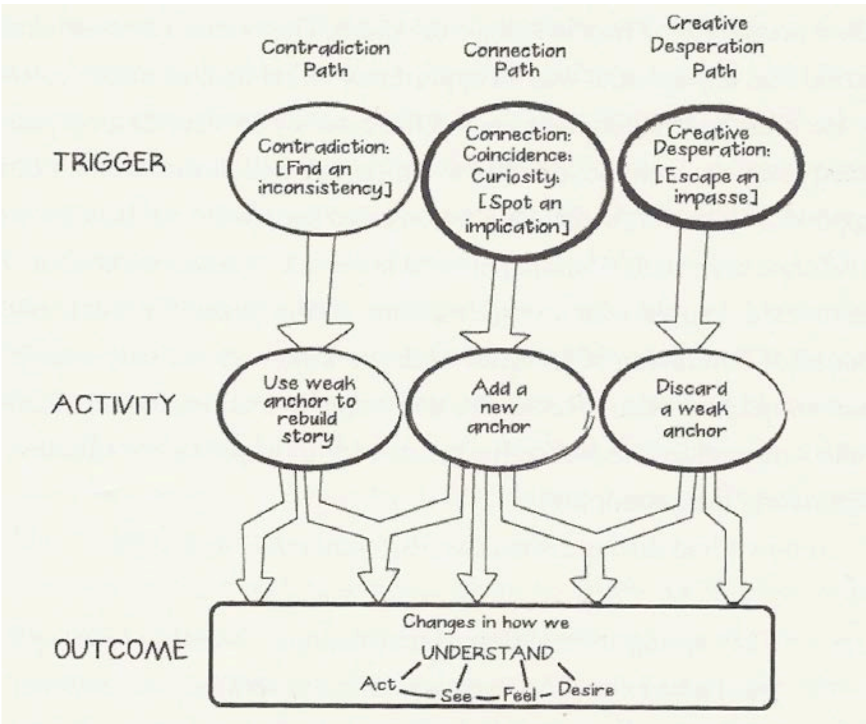

Figure 6. Klein's (2014) Triple Path Model of Insight.

Insight

There are several accounts of how insight works. Wallas (1926) presents a 4-stage model and is probably the most well-known: preparation, incubation, illumination, and verification. Wallas also recommended "… that we have a specifically prepared mind by making deliberate preparations to solve a thorny problem."

Klein (2013) found that this model did not apply well to all the 120 cases he had studied. These cases reported how people in very difficult and demanding situations discovered ingenious solutions to their problems. Klein also observed that these people often "… shift[ed] to a better story about how things work … the shifts changed some of the core beliefs that the … people initially held. During this transition shifts some initial beliefs were abandoned or replaced. The shifts were *discontinuous discoveries* – unexpected transitions from a mediocre story to a better one." (p23). These shifts in our beliefs enabled those people to gain "… a new story, a new set of beliefs that are more accurate, more comprehensive, and more useful." (p23). These insights change how we understand, how we act, how we see, and how we feel.

Through his analysis, Klein observed five types of behaviours that seem to have been instrumental to helping the people he studied come to the insight they needed to solve their problems. He calls them Connections, Coincidences and Curiosities, Contradictions, and Creative Desperation. These are the triggers that force the shifts in our thinking that lead to activities such as using the weak anchor to rebuild our story, to discard the weak anchor, or to add a new anchor. Anchors are key data elements that serve to create understandings that guide subsequent inquiry. By repositioning, discarding or creating new anchors, this leads us to change the way we understand the problem, enabling us to change the way we act (e.g. search in different directions), see and interpret the data in different ways, or feel a greater sense of urgency or desire.

Inference Making

Analyst make use of the various inference making strategies - induction, deduction and adduction – depending upon what data they have, the rules for interpreting the data, and premise they are starting with and the conclusions they would make or would like to make. Furthermore, very often they would test the validity of the propositions they arrive at by practising critical thinking – where they attempt to assess the quality and validity of their thinking and the data they use, the criteria they use for forming judgments, and so forth. In fact, critical thinking is so important that many intelligence analysis training schools have introduced it into their training.

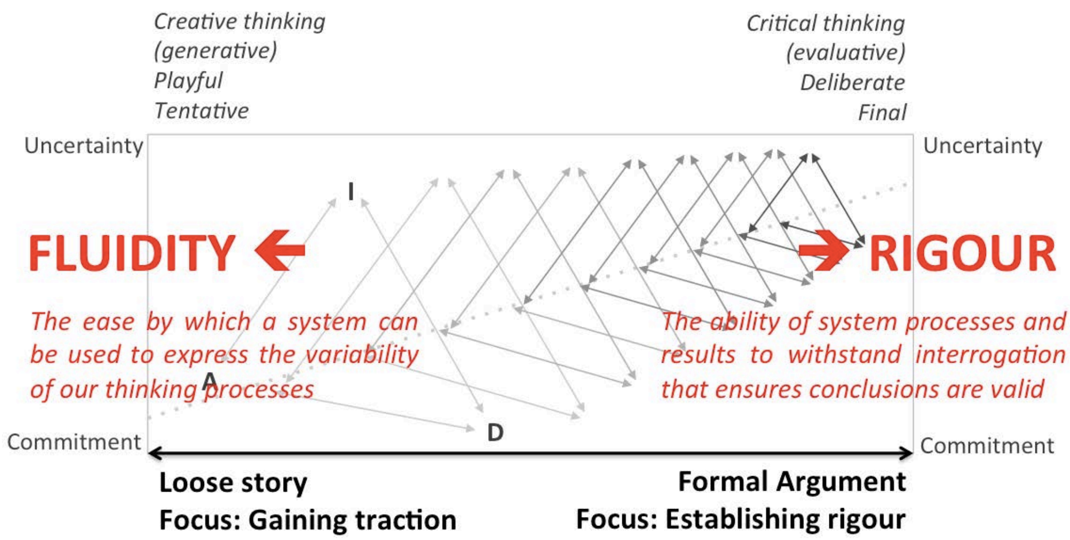

Figure 7. The fluidity to rigour model: How analysts think(Wong, 2013)

One behaviour we observed that happens alongside all of this is somewhat more subtle: Analysts are constantly trying to explain the situation, sometimes re-constructing the situation from pieces of data and from inferential claims; and then carrying out searches or further analysis to find necessary data back the claims. This process of explanation is crucial to making sense and how it is used to link data, context and inferences.

The process often starts off as a highly tentative explanation that is based on very weak data or hunches. As the analyst explores this possibility, making conjectures, suppositions and inferential claims, from which they then connect with further data (testing their relevance and significance), elaborate, question, and often reframe and discard, their ideas, and eventually building up the story so that it eventually becomes robust enough to withstand interrogation.

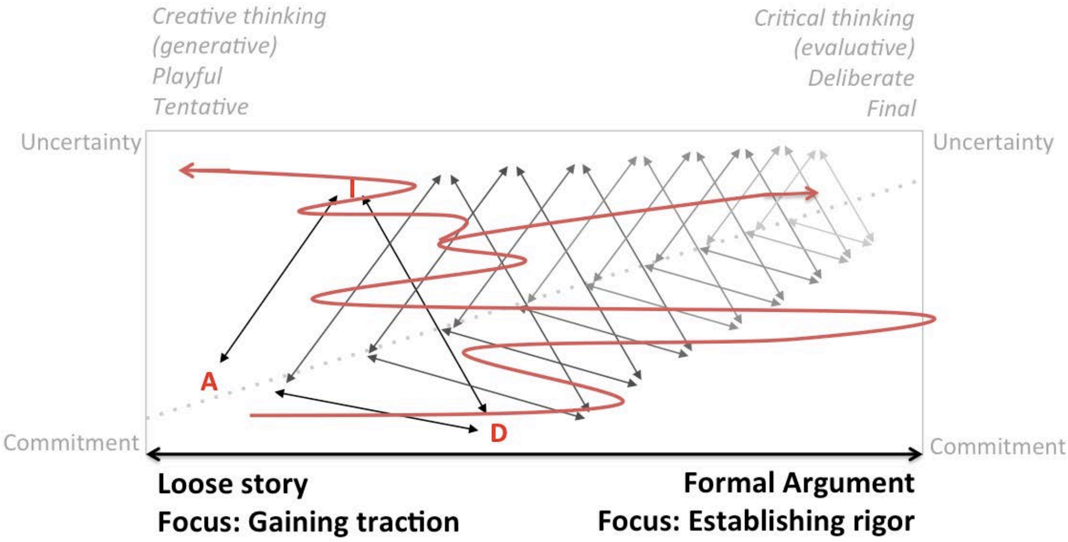

Figure 8. How analysts think (?). Early reasoning is often based on incomplete data emphasising abductive inference making to gain cognitive traction (Wong, 2014)

At the 'formal argument' end of the continuum, the loose story would have evolved into strong and more formal arguments that are rigorous. The thinking here is more critical, deliberately evaluating and focusing on minimising uncertainty and finalising the argument. The analyst is more definite about what the data and their relationships mean, and very likely have become more committed to a path of investigation. At this end, the emphasis is on verifying that the data used to construct the conclusions, the claims being made based on the data, and the conclusions themselves, are valid. Towards this end of the spectrum, the analyst would also be much more committed to their chosen propositions. At this stage they would be using techniques such as Analysis of Competing Hypotheses (ACH) to critique and rigorously test the claims and supporting arguments.

The red line in Figure 8 attempts to illustrate the back and forth trajectory of the abductive – inductive – deductive inference making 'triangle'. The trajectory is unlikely to be a linear path (used in the diagram to reflect the iterative abductive – inductive – deductive inference making that occurs as new information becomes available that may change one's understanding of the situation, leading to new explanations that can re-direct one's search for information. The red line also shows branching that spawns new subjects for investigation – some of which may lead to dead ends. New information does not necessarily come from external sources such as intelligence collection systems, but also through the process of inference. For example, abductive inferences are considered ampliative (Josephson & Tanner, 1996), i.e. they generate new information in a way that inductive and deductive reasoning do not. Experts will have perhaps shorter or more direct trajectories in comparison with, for example, a novice analyst.

We see a progression – not necessarily in a linear manner – where initial explanations reflect tentative, creative and playful, and generative thinking, and then these explanations are then subject to thinking strategies that are more critical, evaluative, and deliberate, to arrive at explanations that exhibit a sense of being final. If we assume a continuum where at one end we have a tentative explanation we call a "loose story" that accounts for the data, and the other end where the loose story has evolved into a strong and more formal argument such that it is rigorous and able to withstand interrogation, say, in a court of law.

At the "formal argument" end of the continuum, there is much lower uncertainty. The analyst is more definite about what the data and their relationships mean, and very likely have become more committed to a particular path of investigation. At this end, the emphasis is on verifying that the data used to construct the conclusions, the claims being made based on the data, and the conclusions themselves, are valid. Towards this end of the spectrum, one would also be much more committed to the propositions, using techniques such as ACH (Analysis of Competing Hypotheses, Heuer, 1999) and other techniques such as Wigmore charts (Wigmore, 1913; Goodwin, 2000) to critically and rigorously test the claims and supporting arguments.

VISUAL ANALYTICS: DESIGNING FOR THINKING AND REASONING IN INTELLIGENCE ANALYSIS

In VALCRI, we have adopted Visual Analytics as the way by which we design and develop the analytics, visualisation and interactivity. Visual analytics is the "… science of analytical reasoning facilitated by visual interactive interfaces" (Thomas & Cook, 2004). It combines "… automated analysis techniques with interactive visualisations …" (Keim, Kohlhammer, Ellis, & Mansmann, 2011) that are specially designed to support the interactive dynamics required to enable real-time analytic interaction with data (Heer &

Shneiderman, 2012), "… for effective understanding, reasoning, and decision making on the basis of very large and complex datasets" (Keim et al., 2011).

Visual analytics is the combination of interactive dynamic visualisations to represent results from exploratory data analysis, in a tightly coupled perception-action loop, to support human sense-making. Customarily, visual analytics researchers tend to limit their efforts to the extent of the interactive visualisation of data computation.

We believe it is also important to include the facility to compose "… an entire narrative story, complete with supporting evidence …" and the assembly of "… separate assessments done by multiple analysts" that conveys "… a complete message, a persuasive argument, [with] a sense of fidelity with the evidence" (Thomas and Cook, 2004, p.144). As the analyst understands the data better, such a system should also fluidly support the construction of stories to explain the data and eventually their evolution into rigorous arguments.

Central to visual analytics is the idea of "analytic discourse" or "the interactive, computer-mediated process of applying human judgment to assess an issue" (Thomas & Cook, 2004). This is the notion of interacting with the data in a way like one would engage with another person during a conversation. The to and fro of question and answer, the offers of additional information, the piecing together of information from between the giver and receiver, from which further guesses or conclusions are inferred, and new questions asked. Herein also lies the notion of the data presenting itself in ways that might suggest: "have you considered the data in this way?". This is the 'conversation' with the data that takes place during the intelligence tradecraft thinking and reasoning process that was envisioned to be supported by visual analytics technology.

To design a user interface that supports analytic discourse requires a design that enables analysts to externalise their thinking and reasoning that occurs during the *analytic reasoning process,* i.e. the thinking and reasoning that underlie intelligence tradecraft. In basic terms, it involves the manipulating of problem elements and information to discover a solution or to make sense of the situation. While necessary, it is not just about information search and retrieval or computation, but crucially also about the assembly and construction of explanations that could account for the presented or available data. Depending on their goals of that analysis, the raw data that is available, outcomes from inference making, and the results from various computations, are used in combination with abductive, inductive and deductive inference making, to enable the analysts to construct an understanding of the situation.

Figure 9. A landscape provides an overview of the terrain, it shows context and a variety of places.

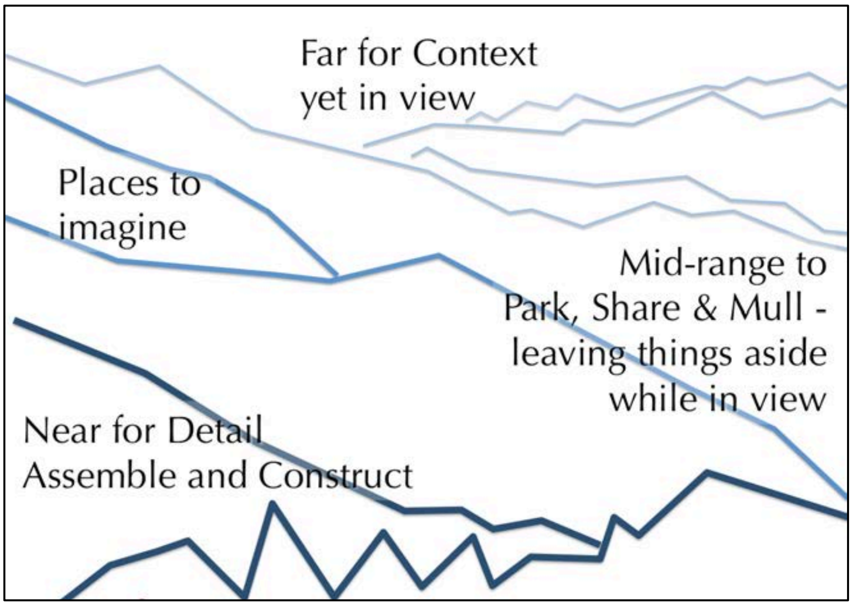

Figure 10. Abstraction of the landscape showing places as they correlate with the work of intelligence analysis.

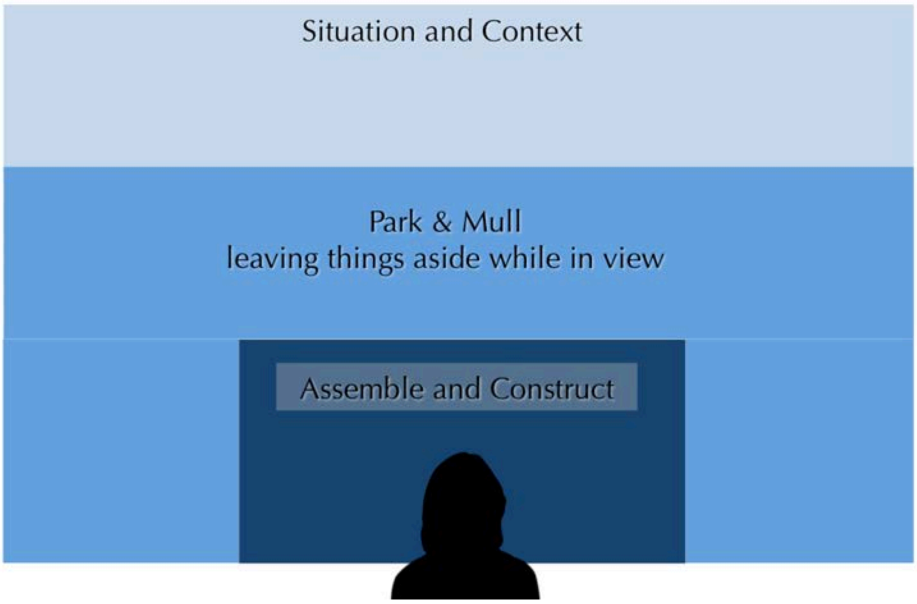

Figure 11. Conceptual organisation of the places in the Thinking Landscape.

THE THINKING LANDSCAPE: DESIGN

The concept of the Thinking Landscape is about creating the means by which analysts can externalise their thinking. The chosen metaphor of a landscape (Figure 9) is intended to convey the idea of a structured space. Nearby spaces enable one to see detail, while farther away spaces provide a sense of context. We intend to design the VALCRI user interface that makes use of the display space in a similar manner. This reinforces human spatial memory and makes places in the workspace semantically meaningful – places and the placement of data objects allow the user to assign meaning to them.

Visualising the Thinking Landscape

Visualisation is needed in three spaces we collectively refer to as the Reasoning Workspace – the Data Space, the Analysis Space, and the Hypothesis Space. We propose Tactile Reasoning as a way of interacting with the externalised world of logic and reasoning.

A landscape provides an overview of the terrain and it also provides context and sets out a variety of places. Figure 10 shows a step before abstraction of this physical space to point out to the reader the different places. We now translate the spaces in functional areas.

Spatial Functions of the Thinking Landscape

The landscape can be divided into a variety of places or functions:

(i) Places to think. Assemble and construct understanding. Aids that help assess the situation, determine what is happening, show relationships, reason, assemble and construct stories

(ii) Places to imagine ("Imaginarium"). Get into the mindset of the criminal. Analysts allowed to imagine low probability outcomes. Places where there are no rules – criminals don't think about rules e.g. evidence, privacy, ethics.

(iii) Places to share. To 'banter', discuss, challenge and to share awareness, and free to ask "I'm not sure, what do you think?"

(iv) Places to park. Incomplete ideas, on-going cases that may have paused.

(v) Stream(s) to show current situation. Dashboard based on data stream

To interact with the data objects that populate places in the display, we will incorporate the concept of tactile reasoning (Takken & Wong, 2015) for information searching and foraging, collation and assembly, data analysis, and sense-making. Tactile reasoning will facilitate actions that cannot be done easily in the physical world, e.g. automatically sorting or grouping the virtual cards, or automatically arranging the cards by some sub-attribute.

Places in VALCRI

The UI of the VALCRI system prototype should cater for at least three places (Figure 11):

Places to Assemble and Construct. This is the working place where its physical size is largely defined by the analysts' need to spread out their work so that the different pieces of information, results, and reports, are readily accessible and persistently visible. This is also where data analyses are carried out, information is gathered and collated, organised, structured and assembled into meaningful sequences that can be used to construct a hypothesis, tell a story, or create explanations of a crime or to justify a decision or recommendation.

Places to Park and Mull. This is a place slightly beyond the arm's reach of the Assemble and Construct workspace. It is an important space as it permits the analyst to 'park' incomplete ideas or assemblages of data and partial explanations, or created explanations that "I'm not sure", on-going cases that may have paused. By keeping them in persistent view, the analyst can continue to mull over the data. Also because the data in this place would be visible, it would allow the analyst to 'banter' and discuss explanations they have created, to challenge them and to share awareness.

Places for Situation and Context. Just as the terrain in the distance helps orientate a traveller with observable landmarks such as mountain peaks, the Situation and Context place is where situational and contextual information will be located. Situational information can include overviews of crimes committed in the last 1-3-7-14 days, the crime situation in priority districts of the region, crime hotspots on a map of the area, important notices such as duty commanders, information about on-going operations, and "Please note" notices.

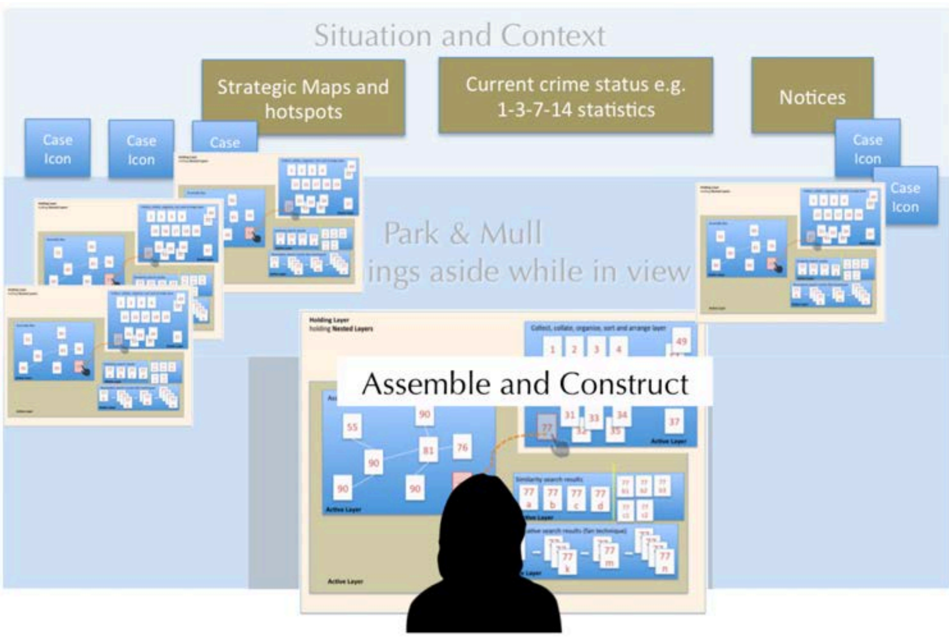

Figure 12. From abstract landscape to design concept: The working spaces showing how the Active Layers can be organised: (i) Assemble and Construct View, (ii) Minimised View, and (iii) Iconized View.

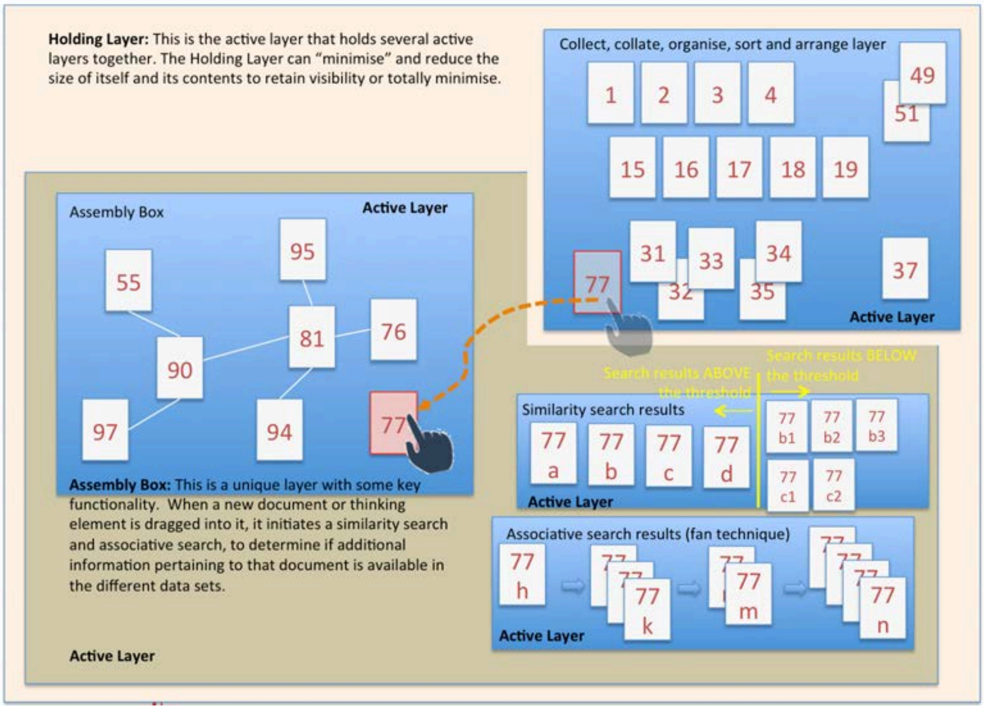

Figure 13. Active Layers, Nested Layers and Holding Layers

OPERATIONALISING THE DESIGN CONCEPT

Assemble and Construct View: this view is the working size view – the document objects etc need to be large enough to work with. The analyst will interact with many widgets. The widgets can be organized in Active Layers (more later). These widgets will include Document Objects and Fragments of Documents, results from data analyses. The widgets – documents and fragments of documents (information snippets taken from a document), can be assembled, arranged in some way meaningful to the analyst rather than in a default list set by the system. The intention is to support the reasoning and thinking that occurs during the early stages of the investigative or intelligence analysis process. At this stage the need is for the capability to arrange information in a way that can support creative, playful and generative arrangements of information using the widgets. The ease and speed with which information object widgets can be re-arranged and re-organised is necessary to allow different combinations to be thought about and reasoned through, and if not appropriate, for that arrangement of information to be discarded.

Minimised view is to *Park and Mull* over the case material. The objects are significantly reduced in size, and information will be summarized with techniques to show key information rather than only made to look physically smaller. The analyst cannot operate on this minimized view – its purpose is to keep key information visually persistent. The analyst can expand the minimized view back to the Assemble and Construct View to continue working on it. In the Minimised View, the analyst can however, make or indicate links between data from across different Minimised Views, and make annotations and have those annotations associated with the Minimised View widget, or with contents within that view.

Icon View: is a representation of a case. It contains all the information and relative spatial positions and relationships as contained in an Assemble and Construct view. As an icon, it does not show any key or summary information, but can have information annotated, such as current status of the case. Acts as a handle for storage. Case Icons can be filed away into folders.

Active Layers, Nested Layers And Holding Layers

Consider a person working with a jig-saw puzzle. Serious players would have a jig-saw puzzle mat on which partially completed jig-saws are assembled and left. When the table space needs to be cleared, one simply rolls up the jig saw puzzle mat together with the pieces of jig-saw in it, and puts it away. We can think of Active Layers in a similar way. They are widgets in the form of a semi-transparent sheet (layer) that can hold other widgets such as other Active Layers and data objects such as document objects, fragment of documents, results from data analysis. A Holding Layer is the Active Layer widget that is holding several Active Layers that contain information relevant to a case that the person is work on. The information objects are spatially organized in a way that is meaningful. Active Layers can be held within other Active Layers to create Nested Layers. All these Layers can be held together in a Holding Layer. A Holding Layer (as well as any Active Layer) can be moved around the screens such that the content widgets retain their relative spatial positions within the Active Layer. This is intended to assist the analyst to manage the many widgets on the screen.

The top right Active Layer in Figure 13, show how Active Layers can be used to collect, collate, organise, sort and spatially arrange information objects. The information objects are directly manipulated in a free-form manner. The objects – documents or fragments of documents – can be place in any order that would assist in the triaging and the considering of the data, and how they might relate to each other.

Document objects may be moved from the collect and collate layer to the Assembly Box. The Assembly Box is also an Active Layer widget. Document objects, document fragment objects or results from analyses, can be organised to create a structured argument that can be used to reason and explain a crime. The rules by which the data is organised is still being investigated in WP3. These rules will be guided by the concepts of anchored narratives (Wagenaar, Koppen, & Crombag, 1993) and the theory of argument (Toulmin, 1958). When data objects are brought into the Assembly Box, this action will initiate searches in the databases for similar records. This is important in assisting the analyst to gain an awareness of similar data and reports that may exist within and across the different data sets. The similar records when retrieved can be presented in a different Active Layer for the purpose of managing workflow. At the same time that a similarity search is initiated, an associative search can also be activated to bring other potentially interesting associations to the attention of the analyst. Again, the results from the associative search can be presented in another Active Layer, and the associative searching can be carried out in this separate layer.

All of these different Active Layers can then be placed within an Active Layer which will become the Holding Layer for this collection of work. This Holding Layer together with the contents can be minimised and placed in the Park and Mull zone, or iconized and annotated for storage.

The X-Y Display: A Two-Screen Configuration

Subject to a user and human performance evaluation, we intend to deploy the concept of the Thinking Landscape in a two-screen configuration we will call the x-y display. One touch sensitive monitor oriented along the x-axis, and the second along the y-axis. The x and y displays should be abutted to minimise the separation caused by bezels. The intention is to make the two screen areas appear as a single contiguous display space. (More details below).

The purpose of a dual screen approach in VALCRI is:

To have more display real estate in order to ensure the ***persistent visibility*** of important pieces of information, partially completed work, work that has been set aside to mull over, pieces of data that one may be uncertain of its value

Based on the ***tactile reasoning*** approach of supporting cognitive work by externalising cognitive concepts and artefacts and by being able to directly manipulate the data objects, display space is needed for touch interaction and to allow movement of data objects around the display as the data objects are arranged to provide explanations.

Display Y is vertical, and if we use a 40-inch display for both the X-display, then it is likely that the touch surface for the Y-display will be beyond arm's length. This will therefore require 3D gestures or alternative techniques (such as the 'swap screen' function) for interaction.

Display X is to be inclined at a slight angle of approx. 10-15 degrees from horizontal. A 30 degree angle of inclination would be too steep for comfortable long-term use with touch interaction. Plan in place for testing and evaluation the physical ergonomics of the work space, e.g. place to rest the arms, room for the keyboard, interaction techniques (such as the Holding Layers) to facilitate UI management.

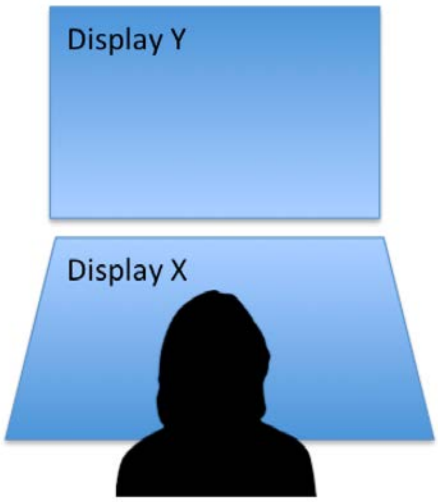

Figure 13. The x-y display configuration.

The following sections will describe the overall User Interface concept, and the interaction design concept. As a user interface is required for most of VALCRI's functions and capabilities, there will be examples described in this Technical Note where the UI designs may appear to be more relevant to work packages WP5, WP6 or WP7. This should not be a concern, as the work in WP4 is intended to provide overarching guidance to WP5, WP6 and WP7.

It should be noted also that this is work in progress.

UI DESIGN STRATEGY

In the following sections, we describe the UI design strategy based on touch interaction as the primary input method. This method will be supplemented by a mouse and keyboard operation as secondary input method. The touch interaction will also be complemented where appropriate by hand air gestures. A more detailed touch interaction design strategy for VALCRI has been reported elsewhere.

Selecting a dataset from many: Activating the Data Drawer

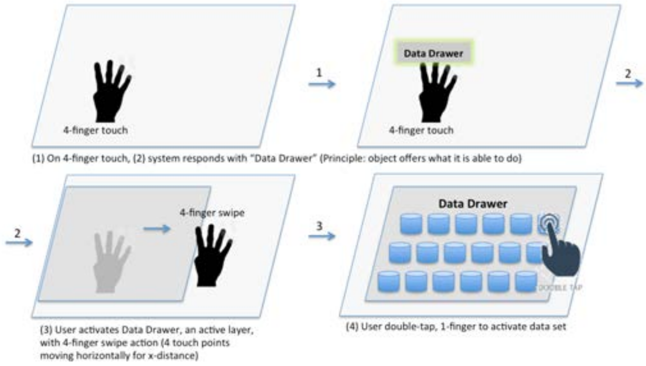

Figure 14. Sliding out the Data Drawer (an Active Layer widget) to select dataset to work on.

The Data Drawer is an Active Layer widget that contains icons of the different data sets or databases that the user has access to.

A 4-finger touch on anywhere of the display or Active Layer will activate the “data drawer” symbol as feedback to the user, and activates the ‘Data Drawer’ Active Layer widget. By continuing with a 4-finger swipe, the ‘Data Drawer’ Active Layer opens fully and presents the user with all the databases he or she is allowed to access. (In line with information access and privacy control policy – data sets for which the analyst has no permitted access will not be visible to the analyst. So the analyst will not know that he or she does not have access to a dataset). Actions such as double-tap the desired data set will activate it; a press and hold will allow the analyst to “dwell through” the dataset to discover what is in the data set (the dwell through will produce a summary of the data in the data set such as a ‘word cloud’ or a user perspective of meaningful data groupings and attributes), and how the data elements are related to one another. Such a display also supports WP5.

Selecting Documents and Data Objects

Using the dwell through filter method (described elsewhere), the analyst will be able to filter and select a segment of the dataset to investigate. In Figure 15, the records from this data set are retrieved and automatically presented in a new Active Layer widget. The records in the form of individual cards can be moved to the canvas or onto another Active Layer. For the purpose of this discussion, the following interactions are assumed to be performed on one Active Layer.

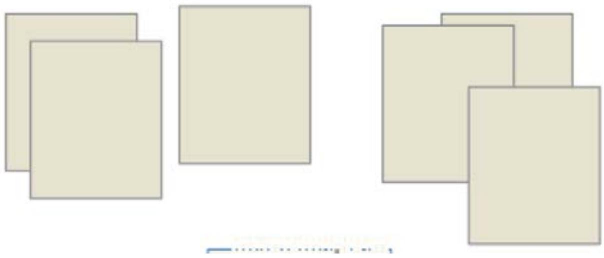
Figure 15. Records from the dataset are retrieved and by default presented as individual cards on an Active Layer widget.

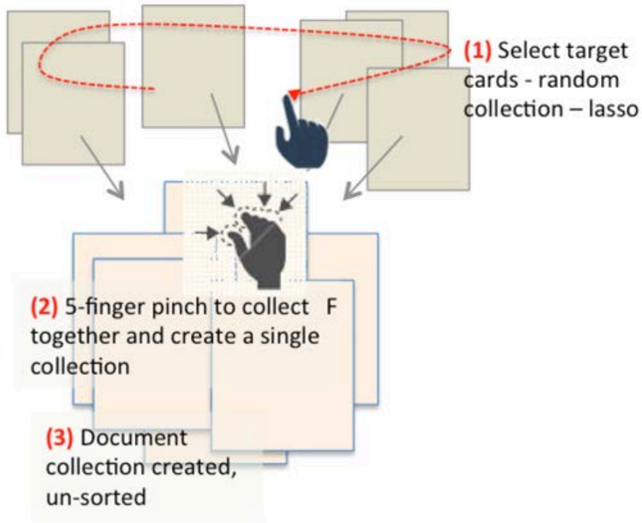

Figure 16. Grouping the cards together to create a pile of unsorted documents.

Automate tedious jobs: Grouping the Documents and Data Objects

Not all the retrieved cards (records) may be relevant or interesting, but at least a few might be. The analyst therefore needs a way to select several cards at a time. An interaction method such as a “lasso” select the cards that are probably laid out in a possibly haphazard manner on the active layer. Once selected, the analyst can perform 4-finger pinch gesture on the selected cards to bring the cards together into a pile. This facilitates movement and reorganisation of the workspace on the Active Layer. Once the pile is moved to a desirable location on the same Active Layer or another Active Layer, the analyst uses a 3-finger horizontal swipe gesture to spread the cards out (Figure 17).

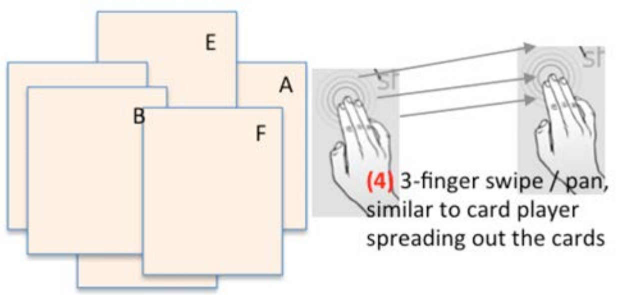

Figure 17. Automatic spreading of the cards using a 3-finger swipe gesture.

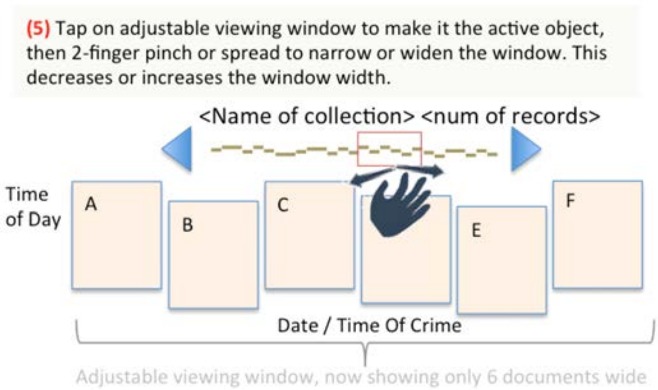

Figure 17. Cards are now automatically organised or sorted

Organise the Documents and Data Objects, and Show Structure

The cards are arranged by the system, by default, horizontally by date and time of the crime, and vertically by time of day. Such two dimension views can provide quite powerful methods for helping the analyst quickly observe any interesting patterns to further investigate. These dimensions can be easily changed by tapping or swiping (TBD) on the labels. Notice that there are no x or y axes visible, although the cards are organised along such a set of axes. Also by default, the system will only display 6 cards (or any number of cards as defined by the analyst). Just above the cards is a scatter plot view of the entire collection arranged along the same x-y axes. Each dot is a miniature of each card in the collection. Near the middle of the scatter plot view is a red box – the interval slider – which indicates to the user which part of the data set are the cards A-F are being displayed. The viewing window of the interval slider can be re-sized by a 2-finger pinching together or 2-finder spreading touch gesture. As the interval slider window is expanded or reduced, the number of cards displayed will either increase (viewing window expanded) or decrease (the width of the slider viewing window is reduced).

Interacting with the Displayed Documents and Data Objects

As the number of cards displayed are increased, the space between cards and the overlap between cards will be adjusted and optimised to provide as much visibility of the text as possible. The scatter plot view also serves as a slider. By sliding the viewing window along the scatter plot view of the miniature cards – the analyst can bring information from different parts of the collection into view.

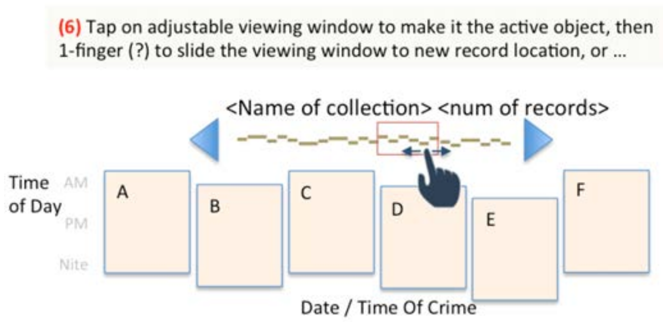

Figure 18. Moving the interval slider to scroll through a collection.

An alternative to moving the interval slider to move / show the remaining cards, we can also swipe the cards left or right, in an action similar to Apple's cover flow concept. (See Figure 19).

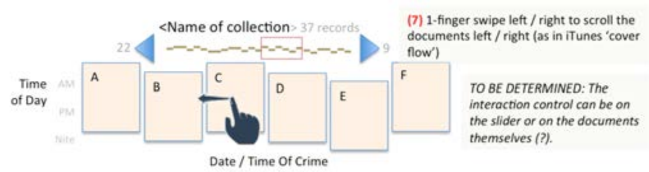

Figure 19. Swiping the cards left to move the collection left to reveal what has not yet been displayed.

Managing Space for Display

In addition, the analyst may choose to show more cards in a smaller physical size where the text only show keywords or concepts. A double tap will enlarge the selected card to normal reading size. As it expands, the remaining cards are pushed out to the left and right.

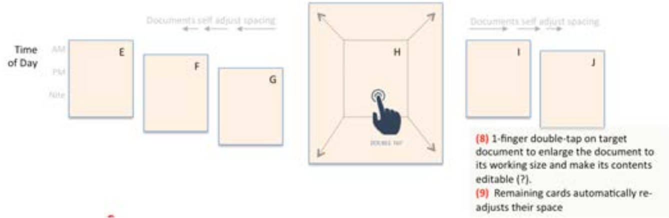

Figure 20. Expanding a card to working size.

Red Dots and Blue Dots: Finding Similar and Associations across the data set

Once at working size, the analyst is now able to read, create and edit the text. The analyst finds an interesting word or phrase, selects it, and double-taps it to activate a search to see where else in the collection the word or phrase appears, in the same collection, or across different collections (perhaps limited by default, to the collections within the Holding Layer. It may make sense to extend the search to all collections in any Active Layer). The search will look for exact words, similar terms, and associated concepts. It will identify the document or record, and highlight documents in the collection(s) in (i) the scatter plot interval slider view, with Red Dots (same/similar words) and Blue Dots (associated terms and concepts), and in the document objects themselves. (Figure 21).

Once the Red Dots and Blue Dots have been highlighted – we need a quick and efficient method to extract them from the collection. A 3-finger down swipe gesture can be designed to pull out all the documents from the collection(s) that have been highlighted with Red and Blue dots. Creating a copy of the documents in the new set is preferred to simply removing the document from the collection. The system would also automatically separate the Red dott documents from the Blue dot documents, organise and sort them in a default order as in Figure 17.

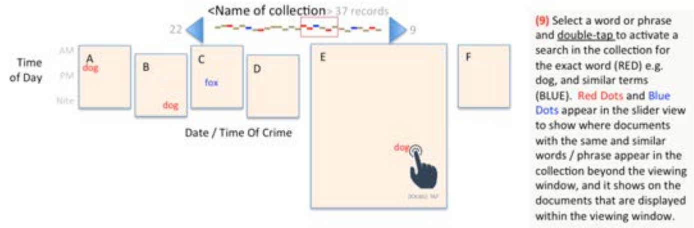

Figure 21. Red dots and blue dots highlighted in the scatter plot interval slider and in the documents, to show where the exact word or phrase or similar (red), or associated (blue) appears in the collection.

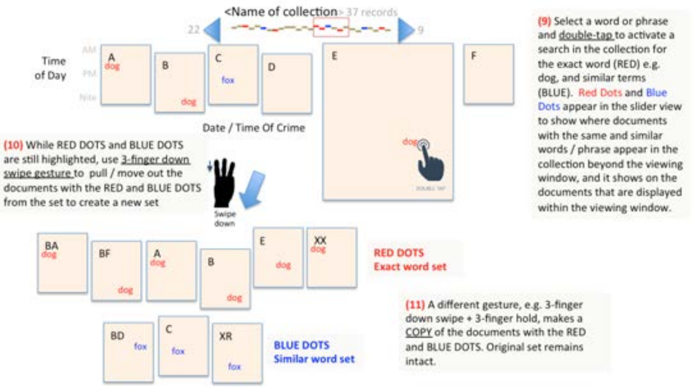

Figure 22. Efficiently extracting the cards highlighted with Red dots and Blue dots for further study and use. The extracted set is a copy.

CONCLUSION

This White Paper has sets out the concept of the Thinking Landscape as the basis, underlying principles and considerations for the design of the VALCRI User Interface.

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EUROPEAN COMMISSION

The research leading to the results reported here has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) through Project VALCRI, European Commission Grant Agreement Number FP7-IP-608142, awarded to Middlesex University and partners.

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7	A E Solutions (BI) Limited Dr Rick Adderley	United Kingdom
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15	Lokale Politie Antwerpen	Belgium
16	Belgian Federal Police	Belgium
17	West Midlands Police	United Kingdom