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Hepenstal, S., Zhang, L. and Wong, BL William

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An analysis of expertise in intelligence analysis to support the design of Human-Centered Artificial Intelligence

Sam Hepenstal
Defence Science and Technology Laboratory
Salisbury, UK

Leishi Zhang
Middlesex University
London, UK

B. L. William Wong
Middlesex University
London, UK

***Abstract*— Intelligence analysis involves unpredictable processes and decision making about complex domains where analysts rely upon expertise. Artificial Intelligence (AI) systems could support analysts as they perform analysis tasks, to enhance their expertise. However, systems must also be cognisant about how expertise is gained and designed so that this is not impinged. In this paper, we describe the results of Cognitive Task Analysis interviews with 6 experienced intelligence analysts. We capture themes, in terms of their decision making paths during an analysis task, and highlight how each theme is both influenced by expertise and an influence upon expertise. We also identify important interdependencies between themes. We propose that our findings can be used to help design Human-Centered AI (HCAI) systems for supporting intelligence analysts.**

I. Introduction

Intelligence analysts operate in challenging and uncertain environments, where they need to consider both the analytical requirement and the situation at hand when performing analysis and delivering outputs. The decisions made by analysts are intellectually demanding and do not typically have a clear or obvious answer. Instead, they are informed by experience and expertise combined with their awareness of the situation. Intelligent systems have the potential to aid analysts when making decisions, for example, by speeding up their analysis, improving accuracy, or focussing their attention upon the most important information.

In this paper, we report on our study to identify the expertise that intelligence analysts bring to bear during analysis tasks. We present the results from Cognitive Task Analysis (CTA) interviews with 6 intelligence analysts, applying the Critical Decision Method [1] [2]. We have extended a model developed by Gerber et al. [3] that describes the way that intelligence analysts make decisions through a combination of intuition, 'leap of faith', and insight. Our analysis considered how an analyst develops and uses their expertise throughout their decision making paths. Alongside the model we give examples of Artificial Intelligence (AI) systems and suggest how they could be designed to support the use of expertise, whilst not impinging upon the development of expertise. In the cases described, expertise can be supported by system transparency. Whilst our findings could be interpreted more broadly, we focus examples on the design of AI, given that such systems are typically complex and reduce human autonomy. By considering the role of the human, specifically their expertise, we propose that we can design Human-Centered AI (HCAI) that amplifies and extends human perceptual, cognitive and collaborative capabilities.

II. Related work

Defence Intelligence provides assessments in support of policy-making, crisis management and the generation of military capability [4]. Assessments are produced as a result of intelligence analysis, which is not a straightforward process [5]. It involves unpredictable environments where available information can be vast, ambiguous, and have many gaps that may or may not be possible to fill [6]. There are also complex customer requirements with various influential factors. Expertise is therefore an important requirement for intelligence analysts, involving technical expertise, subject expertise, procedural expertise, and disciplinary expertise [7] [8] [9]. While the many various tasks and approaches performed by an analyst are difficult to describe succinctly, past research provides a model that captures an analysts decision making path. Gerber et al. [3] consider criminal intelligence analysis and present an adaptation of the Recognition-Primed Decision model [10] and the decision ladder [11]. This model presents how experts recognise patterns, use their intuition to deal with uncertain data and explore lines of inquiry, before deriving insights and eventually arriving at a claim.

Artificial Intelligence (AI) systems have the potential to support analysts throughout this process, for example, by helping them to recognise interesting patterns, or assisting them when performing analysis techniques. However, intelligence analysts operate in high risk and high consequence domains where there is a need for analysts to be accountable for their decisions [12]. Analysts must be able to explain the evidence that underpins a claim and articulate why they have taken a particular decision. To do this a system must provide explanations for outputs together with transparency of the underlying system processes, so that a user can inspect and verify the goals and constraints [13]. If it is interpretable, then the system can be described as HCAI that is explainable, comprehensible, useful and usable [14]. The framework for system transparency, presented by Hepenstal et al. [13], shows that an understanding of context is crucial for developing interpretable systems. In order to capture the context appropriately it is necessary to develop a deep understanding of the human cognitive requirements through comprehensive analysis.

III. Study

We conducted Cognitive Task Analysis (CTA) interviews with 6 intelligence analysts, of similar seniority, working in the domain of Defence Intelligence. We initially interviewed 7 analysts, however, one analyst had a significantly different role to the others. We have therefore included data from only 6 analysts in this study, using identifiers A1, A2, A3, A4, A5, and A7. Each analyst had multiple years of experience working across numerous analytical environments and domains, including delivery of both strategic and tactical requirements. The analysts could therefore be considered experts. There was a single interviewer for all interviews and they used the Critical Decision Method (CDM) to explore a particular analysis task with each analyst [1] [2]. Interviews took place over remote video conferencing software and took between approximately 30 and 45 minutes. Analysts were first asked to introduce their role and a typical day, then to describe a memorable analysis task from start to end. For this study, we were most interested in capturing the processes involved throughout the analysis activity, including what the analyst did and the considerations they made. With this information we could envisage how a system could support an analyst with an appreciation of the cognition required for effective performance.

IV. Analysis

The utterances made by analysts were transcribed and analysed using Emergent Themes Analysis [15] [16] by a single researcher. Conceptually related comments were identified, indexed and collated into broad themes. Analysts'utterances conveying the same or similar sentiment or intent were grouped together and mapped to the main aspects of Gerber et al's [3] analytic reasoning decision making path. New themes also emerged that did not clearly map to these aspects, for example, to capture the specific drivers that signalled when an analysis activity was required. For each analyst, an individual diagram was produced to convey how their utterances had been summarised and mapped to the aspects in the decision making process. References to the original utterance data were preserved and the diagram was verified for accuracy by the analyst. Fig. 1 shows an individual analyst diagram with references to utterance data. The themes within the individual diagrams were overlaid and summarised and we drew upon existing models where possible to identify sub-themes. Each collated theme is traceable back to the individual diagrams and the underlying transcript data. The analysts identified similar core cognitive processes, despite working on different domains at a mixture of strategic and operational levels. The collated themes overlap and the process is not linear, for example, at any point a new driver may emerge. Additionally, there may be multiple routes between themes, for example, many lines of inquiry may lead to a single insight, and a single claim may capture multiple insights. In this study, we focused on identifying (i) the range of cognitive demands that the intelligence analysis task places on the intelligence analysts we interviewed, and (ii) the nature of the expertise that these analysts bring to bear on the reasoning, inference making and problem solving tasks. Examples for each of the themes are shown in Table I. The nature of expertise has been summarised for each theme and interdependencies between themes have been captured.

V. Results and Discussion

Here we describe each of the core collated themes in turn, with focus upon the role of expertise, and we provide some design considerations for systems that support analysts throughout the process.

A. Drivers

The 'drivers' are signals that indicated to an analyst when an analysis activity was needed and could be both reactive and proactive. An analysis task was triggered if an analyst was able to identify intelligence gaps [Analysts who described this : A3, A7]. For example, "*if lots of people are writing reports and they have the same intelligence gap, you might put your heads together with other analysts and say 'there is this intelligence gap', we can write and hypothesise about what is going on.*" [A3; at 29 mins 30 seconds in audio transcript] Horizon scanning resulted in analysis tasks [A3, A4, A5, A7], for example, when analysts identified something that a customer (an individual, role, or organisation, using the product to make a decision) "*might want to think about in the future.*" [A7; 10:15] Tasks were also driven by the ability of an analyst to spot interesting events that could be significant for a customer requirement [A2, A3, A4, A7]. For example, one analyst described how they received "*all the information for that day... and (said) that could directly affect (the customer), that could indirectly affect them.*" [A4; 3:40] Analysts also responded to specific questions from customers [A2, A3, A4, A7], sometimes through a formal process such as a "*central coordination point... (to) capture the majority of questions as a process, through a form.*" [A1; 42:20] Expertise was a crucial factor as it allowed the analysts to interpret or refine a driver for a customer, identify nuances and important changes, to be aware of capability gaps, and to predict future requirements. Experience of drivers and customer requirements helped analysts to develop expertise for spotting future drivers, even in cases where "*they (the customer) probably don't realise exactly what is required*" [A3; 6:40].

B. Recognition of Analysis Requirement

The Recognition-Primed Decision model [10] captures the key aspects described by analysts related to recognition of the analysis requirement. For example, the analysts picked up on cues informed by the respective driver such as the customer requesting the product [A1, A3, A4, A5], the specific domain and entities [A4, A5], nuances, or interesting changes against a baseline narrative [A2, A3, A7], the data involved, including an appreciation of the expertise required to interpret the data [A3, A7], and input from peers [A1, A3]. Analysts formed expectations about the customer [A2, A3, A4, A5], such as "*the sorts of things (customers) are interested in*" [A5; 4:20], "*what they did and how they did it... what would*

TABLE I

IDENTIFYING EXPERTISE FOR EACH STAGE OF ANALYTIC REASONING PROCESS DURING A LINE OF INQUIRY

Analyst Statement	What expertise is required?	How could expertise be developed?
Driver: "*By going through them (reports) and saying, that's ok, that's unusual, that's slightly different… there were probably 2 things that really stood out, either it's a new capability.. Or something is happening in an area where we haven't seen it before.*" [A7; 2:00]	An analyst would need to have domain knowledge to understand what 'unusual' looks like. They would need to know what old capabilities there are to identify a new capability, or what has happened in an area, to know whether it has not been seen before.	By reading reports, domain knowledge is built over time.
Requirement Recognition: "*The right question really depends upon the task and the customer, it is something you really need to understand very well.*" [A3; 4:40], "*you would often go back and try to work out what questions they are trying to answer, you'd say, 'what are you trying to do with it?' 'What don't you need to know'… 'What have they already read?'*" [A3; 5:10].	An analyst would need to have an understanding of the customer, so they can form accurate expectations about what the customer will find interesting and important, and appropriate actions such as the 'right' question to answer, or to seek further clarifications.	By working with customers, receiving and refining requirements.
Intuition: "*I looked at my previous products and made some notes. I started to come up with some drivers, what might change, what were the most important factors that would have the most impact, what was expected to change?*" [A5; 20:10] "*(I had) conversations with other people… the ability to respond was another (factor)... I was thinking about the root cause of the problem, I was thinking about the response, and from the perspective of the actors themselves - what might the changes mean to them?*" [A5; 26.30]	An analyst would need expertise in order to perceive the key elements in a situation and fill in gaps, comprehend their meaning, and predict future possibilities e.g. to interpret importance of factors, how to define and prioritise impact, consider possible changes. This informs their opening lines of inquiry.	Through experience i.e. production of analytical products and discussion with peers.
Follow Lines of Inquiry: "*(for scenario generation) If you get some information that the (person of interest) is going to change to so and so, first of all, you'd look at who it is, find out what their background is, what their prejudices might be, say if he has been educated in a foreign country…*" [A4; 4:45] "*depending upon what level the database is at, we would have access to go back through old reports… (or) glean from open source.*" [A4; 8:00]	An analyst requires expertise to proactively seek out connections, or implications. This requires an understanding of possible patterns to explore and their significance e.g. that the schooling of a person of interest could be relevant to the analysis, that this information may exist and where and how it can be gathered, and how to interpret the meaning when it is retrieved.	This could be gained through experience of performing analysis and discussion with peers, for example, being involved in previous situations and knowing what information could be relevant and from where it could be retrieved.
Insight: "*you can't physically research everything. It is something that comes over time… if you are confident you have researched everything you think you can, then you report this is what I have done, this is what I have found.*" [A1; 34:00], "*you submit your assessment to a colleague… if you are reading something and you are missing the 'so what?', then clearly there is a gap.*" [A1; 35:10]	An analyst would need to be able to assess their product to develop confidence, based upon an understanding of what is expected with an appreciation of what 'enough' looks like.	Through experience and feedback from a peer review process.
Claim: "*peer review in this process is important… recognising caveats and assumptions is key… keeping a record of this is important for due diligence on a day to day basis, to understand how to challenge assumptions.*" [A2; 33:00]	An analyst needs to understand how to capture their caveats and assumptions in an audit trail, so that they can interpret the significance of their findings and explain themselves should they be challenged at a later stage.	Involvement in the process and experience of being challenged and justifying claim, could help develop expertise.

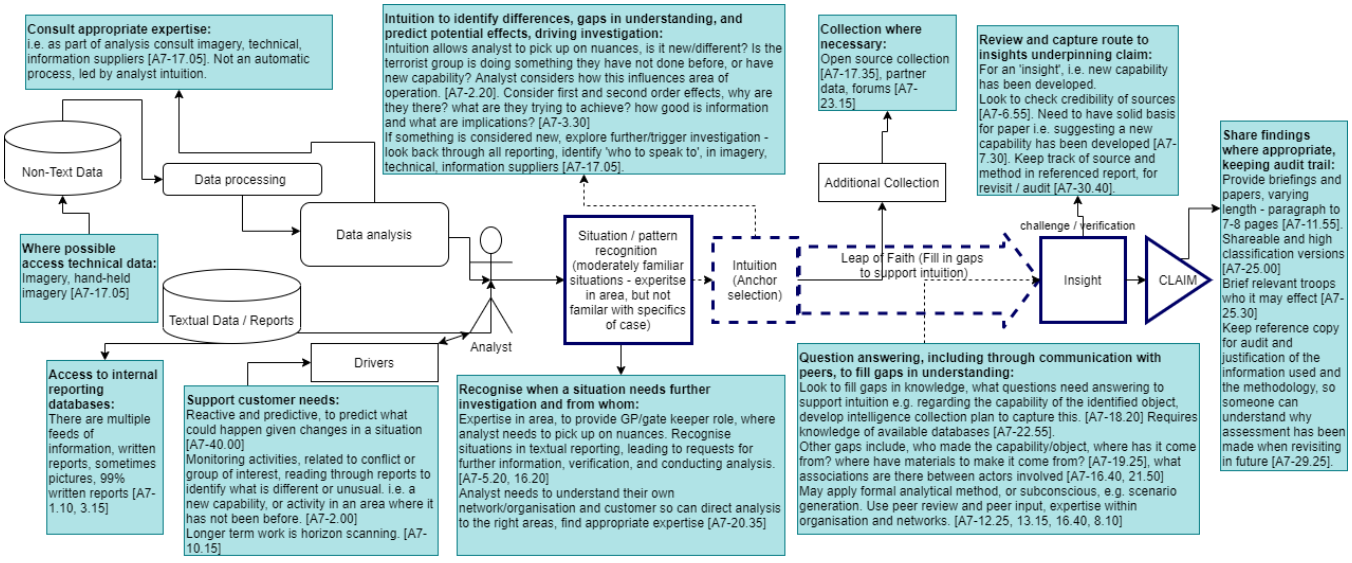

Fig. 1. Example of an individual analyst diagram showing detail for 'lines of inquiry', with the Decision Making Path [3] at the core.

be a threat to them, what could aid them doing what they were doing" [A4; 19:15]. The analysts identified possible actions to take, such as to construct a research plan and look further into a situation [A1, A2, A3, A4, A5, A7], or to seek clarification from the customer [A1], the source [A7], or peers [A1, A3, A7]. It was the analysts role to assess whether action was necessary, as described by one analyst, "*it is a bit like being a GP (General Practitioner), you look at something and say there is nothing wrong with that, or you see something and say there is something different here - you investigate it further.*" [A7; 5:20] The analysts also recognised goals that would help them to address the requirement, for example, to understand the "*key exam questions*" [A3; 14:00] [A1, A2, A3, A4], the timescales [A1], what peer support and data was available [A1, A3, A7], and how the product should be delivered and what has been delivered previously i.e. format and distribution [A1, A3]. For the analysts to recognise the analysis situation effectively, they required expertise to pick up on cues, identify appropriate goals, form accurate expectations, and have an awareness of beneficial actions to take. With experience, peer support, and by refining questions with a customer, they develop expertise that allows them to understand the customer, domain, and possible actions to take in future situations. This expertise is vital, for example, without a deep understanding of the customer together with the domain, it would be difficult to form expectations about what is interesting to a customer, appropriate, or the 'right' question to research. There are important interdependencies between themes and the development of expertise when it comes to situation recognition. The drivers both influence situation recognition and are influenced by situation recognition. As analysts are involved in more situations over time this will influence how they pick up on drivers, for example, by gaining a better understanding of customer goals and expectancies, and specific domains. Situation recognition gives a frame of reference for intuition.

C. Intuition

Once an analysis situation had been recognised, there was a need for analysts to form an appropriate awareness of the state of the environment. Their initial awareness of the situation was partial where there were gaps, or areas of uncertainty. To fill the gaps and help guide their analysis, they used their intuition to form a narrative, or pattern, that described the environment. As one analyst explained, "*you get a brain dump then the more you get into it you pick up on subtleties of the group, and understand what to expect. A combination is experience and intuition, based upon your knowledge as an analyst to build up that reservoir of knowledge. You can bring in things from other jobs you have seen before... your job is as a gatekeeper to be that predictive person to say 'we havent seen this before', then to tell the senior people about the implications of what you are looking at.*" [A7; 4:10] We can capture the key aspects required for analysts to use their intuition, as explained by the analysts, in the Model of Situation Awareness in dynamic decision making [17]. Situation awareness was crucial for analysts to be able to use their intuition, for example, to identify that something is routine or not. The analysts needed to perceive important elements in the environment i.e. the key information, or details of the question [A1, A2], including important anchors, attributes, geographies, and search terms [A1, A2, A3, A4, A5, A7]. They needed to comprehend the current situation, to inform the immediate goals and objectives for their analysis i.e. they devised a research plan that would gather the information required, with an awareness of the sources of information that could be drawn upon [A1, A2, A3]. They prioritised areas to search and terms [A3], and identified peer expertise that could provide support [A1, A5, A7]. This would allow the analysts to plan routes for analysis. For example, as described by one analyst, "*Initially you would get a customer question, you would read through what they were asking for then you'd develop your research plan off the back of that. You would identify the sources you would actually need to read through. It could be just written resources, it could be data resources. It could be a combination of both... There will be a set amount of resources you have access to at different levels. It is down to the individual analyst and how they decide that they plan to respond to a particular question.*" [A1; 1:50] Analysts also needed to project future states and events. They needed to use their intuition to predict potential meaning, for example, why an entity was behaving how it was, what it was trying to achieve, what implications could there be [A4, A7], was it significant [A2], and what if any threats could emerge [A4]. Expertise is crucial for analysts to use their intuition, for example, to select important elements from the environment and to construct lines of inquiry, with an appreciation of what information is available and from where. The use of intuition to derive situation awareness in turn influences expertise, where analysts learn about a domain and can better perceive key elements, more effectively form goals and objectives for their analysis through peer consultation and advice from technical experts, and acquire a firmer grasp of possibilities in terms of the projection of future states.

D. Follow Lines of Inquiry

Upon using their intuition to derive a partial situation awareness, analysts performed analysis activities. Various methods were applied, some formal, depending upon the requirements and the situation. In general, the analysts explored, questioned, challenged, and manipulated the 'anchors' within the initial narrative they had formed through intuition. They did so seeking insights, and we have captured the key statements made by analysts within the Triple Path model for insight [18]. Analysts sought connections or implications by gathering new information and building upon 'anchors', by filling in gaps, exploring new and historic resources for information, and seeking guidance from peers [A1, A2, A3, A4, A5, A7]. For example, one analyst explained that "*your initial search will inevitably open up other avenues, sometimes they are rabbit holes and you can't go down all of them, but it is likely you will discover other angles... other depositories of information, or reports.*" [A3;

18:00] Another important insight seeking behaviour, which helped mitigate the risks of going down rabbit holes, was to be able to escape impasse or apply 'creative desperation' [18]. This allowed the analysts to approach a question with a fresh perspective, for example, by removing pieces of information that were "*from a different jigsaw*" [A2; 12:00]. Analysts actively sought contradictions and inconsistencies within their developing hypotheses, for example, through sense checking with mathematical models or peers [A1, A2, A4, A7], by seeking corroboration or counter arguments [A1, A2], and by collating and comparing information [A3, A5]. One analyst described how they actively sought contradictions by deriving and comparing different scenarios, for example, "*I thought about what was most likely to change… (to create) a most plausible scenario. Then, at the other end, I considered what was the worst case scenario, but still possible. I changed a couple of the drivers i.e. what if this went wrong and that went wrong, then what, and came up with a scenario based upon that to coordinate my thinking. I also came up with a best case scenario, what if this got better and that got better.*" [A5; 22:20] Expertise is vital when seeking insights, for example, so that an analyst knows how to seek and interpret connections and implications. One analyst described how "*it is only by knowing which databases to interrogate that you realise there is more information out there… not only have you got to get the information, but you then have to try to make sense of it as well.*" [A7; 22:55] Expertise also informs an analyst's assessment of when there is value to going down a rabbit hole, and when they should stop. By following lines of inquiry, an analyst develops expertise with experience. When an analyst is seeking insights they may pursue avenues to collect additional information. To do this, the analyst needs to understand when a gap exists and how it can be filled, either from gathering more information or by speaking to the right people. The expertise gained from proactive collection also helps an analyst to use their intuition, for example, to comprehend routes to search with an awareness of what has been useful in the past.

E. Insight

As analysts conducted their lines of inquiry, insights and hypotheses emerged. It was important that the analysts challenged and critiqued these insights before they could be used in an analytical product. The analysts described formal and informal ways to assess their confidence, the credibility, and likelihood of a hypothesis [A2, A3, A5, A7]. The role of peers to help challenge hypotheses, for example, through argument and defence was important to test if anything was missing and to understand the significance of a finding [A1, A3, A4, A5]. For example, one analyst described how they "*delegate someone to be devil's advocate, then if you can't justify why you have put something, you probably need to review (your analysis)*" [A4; 24:35]. Expertise allowed the analysts to understand how to assess their hypotheses, for example, about what made a source credible or not, how to test and corroborate information, and when they had done 'enough' to address a requirement. The process of peer review allows for expertise to be gained where by defending a hypothesis, and associated argumentation, an analyst would learn how to recognise a strong hypothesis and the appropriate evidence. This expertise could inform how they construct research plans in the future when using intuition, and gather the appropriate evidence when following lines of inquiry.

F. Claim

The analysts provided an output, in terms of an analysis product, that articulated the claim they were making. This captured their key findings, including the significance and meaning [A2, A3, A4]. The analysts also captured their underpinning judgements and any caveats, preserving an audit trail to source reporting [A1, A3, A5, A7], so they have an answer "*if someone comes back a month later, or 3 years later, ands says 'why did you say that?'*" [A7; 29:25]. The ability to determine the significance of a finding was an important aspect with implications [A7]. Where possible the analysts considered the impact on previous assessments and updated customers, if they felt the findings would be of interest [A2, A3, A4, A5]. Expertise, informed by the recognition of the analysis requirement, was important so that the analyst could accurately consider the significance of their findings and envisage any implications. Expertise also led to an awareness of potential impacts on historical assessments, and helped identify which customers to inform. In arriving at a claim and producing an analysis product, the analysts gained expertise about how to address particular customer requirements, through their experience and participation in a peer review process. This expertise could be fed into future tasks, particularly at the requirement recognition phase.

G. Example System Design Considerations

Table II gives some examples of systems that address aspects of each of the themes, together with design considerations that support elements of the use and development of expertise. The examples described are limited, but they help to demonstrate how our findings can be applied in the design of systems. A key aspect that addresses many of the design considerations is the provision of system transparency, including explanations for results and visibility of the context considered by the system. If a system simply provides a result to an analyst, without transparency of the reasoning involved, then the analyst cannot use their expertise effectively, for example, to form an understanding of potential patterns of interest, lines of inquiry that have been explored, and lines that could be augmented, or the nature of arguments used. Nor can they learn from the system or develop expertise that would inform future analysis tasks.

H. Conclusion and Future work

We have identified the context of expertise throughout the analysis process. We propose that this understanding can guide the design of HCAI systems that extend human perceptual, cognitive and collaborative capabilities. In future

TABLE II
EXAMPLE DESIGN CONSIDERATIONS

Theme Addressed	Description of Example System	Design Considerations to Support Use of Expertise	Design Considerations to Support Developing Expertise
Drivers: Monitoring activity and reacting to interesting / unusual patterns.	A system that extracts entities and relationships from text reports and alerts users to important network patterns.	Present patterns with context, highlighting important cues to consider in further analysis. Provide ability to inspect and build upon patterns and context / identify nuances.	Provide information to support development of domain knowledge, including what is typical / not unusual i.e. the context for why something is unusual.
Recognition of Analysis Requirement: Understand if requirement has been addressed previously.	A system that filters past reports and retrieves those that are similar to current requirement based on attributes (cues), including entities involved, customer, data sources, data type etc...	Present explanation for similarities, including the specifics of the cues involved, so that analyst can compare customer expectancies and semantic relevance, for example.	Provide history detailing cues in past products, to inform understanding of customer goals and expectancies.
Intuition: Projection of future states and events	A system that predicts where and when social unrest events will occur by monitoring news and social media feeds using machine learning methods e.g. Hidden Markov Model [19].	Present predictions with reasoning, so that analysts can verify, guide, and interpret the consequences utilising their domain expertise.	Provide context for prediction, including caveats, information sources used, and missing information that could improve prediction.
Following lines of inquiry: Proactively explore lines of inquiry	A system that automatically recommends and explores lines of inquiry, based upon learning from past analyst interactions.	Allow analysts to inspect and augment lines of inquiry, identify gaps and the need for additional collection.	Show predicted lines of inquiry, even if no data exists, so that an analyst can learn from the system about possible routes to take in the future.
Insight: Peer review and challenge of hypothesis.	A system that challenges a hypothesis through conversation and argumentation.	Allow the analyst to argue their hypothesis, define source credibility, suggest where there is corroboration, or prioritise verified sources.	Involve the analyst in the process, so they actively learn through argumentation and defence of their hypothesis. Show them what is missing.
Claim: Deliver output in appropriate format for customer	A system that automatically generates reports in an appropriate template, informed by the analysis requirement.	Allow an analyst to configure their report i.e. to highlight certain findings underlying the significance.	Provide the analyst with information for why a selected report format is appropriate, and alternatives.

work, we will look to exploit our findings by designing systems that consider expertise.

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REFERENCES

[1] G. A. Klein, R. Calderwood, and D. MacGregor, "Critical decision method for eliciting knowledge," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 19, no. 3, pp. 462–472, 1989.

[2] B. L. W. Wong, *Critical Decision Method Data Analysis*. Lawrence Erlbaun Associates, 1993, pp. 327–346.

[3] M. Gerber, B. W. Wong, and N. Kodagoda, "How analysts think: Intuition, leap of faith and insight," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 60, no. 1, pp. 173–177, 2016. [Online]. Available: https://doi.org/10.1177/1541931213601039

[4] "National intelligence machinery." [Online]. Available: https://www.gov.uk/government/publications/national-intelligence-machinery

[5] B. W. Wong and N. Kodagoda, "How analysts think: Inference making strategies," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 59, no. 1, pp. 269–273, 2015. [Online]. Available: https://doi.org/10.1177/1541931215591055

[6] G. Tecuci, D. Schum, M. Boicu, D. Marcu, and B. Hamilton, "Intelligence analysis as agent-assisted discovery of evidence, hypotheses and arguments," in *Advances in Intelligent Decision Technologies*, G. Phillips-Wren, L. C. Jain, K. Nakamatsu, and R. J. Howlett, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 1–10.

[7] J. D. Corkill, T. K. Cunow, E. Ashton, and A. East, "Attributes of an analyst: What we can learn from the intelligence analysts job description." in *8th Australian Security and Intelligence Conference*, 2015.

[8] N. Quarmby and L. J. Young, "Managing intelligence: The art of influence," Sydney: The Federation Press., 2010.

[9] D. M. Allen, "Building a better strategic analyst: a critical review of the U.S. army's all source analyst training program," Fort Leavenworth: United States Army Command and General Staff College., p. 59, 2008.

[10] G. Klein, *A recognition-primed decision (RPD) model of rapid decision making.* Abex Publishing, 1993, pp. 138–147.

[11] J. Rasmussen, "Taxonomy for cognitive work analysis."

[12] D. Leslie, "Understanding artificial intelligence ethics and safety: A guide for the responsible design and implementation of ai systems in the public sector." 2019. [Online]. Available: https://doi.org/10.5281/zenodo.3240529

[13] S. Hepenstal, N. Kodagoda, L. Zhang, P. Paudyal, and B. L. W. Wong, "Algorithmic transparency of conversational agents," in *Joint Proceedings of the ACM IUI 2019 Workshops co-located with the 24th ACM Conference on Intelligent User Interfaces (ACM IUI 2019), Los Angeles, USA, March 20, 2019*, ser. CEUR Workshop Proceedings, C. Trattner, D. Parra, and N. Riche, Eds., vol. 2327. CEUR-WS.org, 2019. [Online]. Available: http://ceur-ws.org/Vol-2327/IUI19WS-IUIATEC-1.pdf

[14] W. Xu, "Toward human-centered ai: A perspective from human-computer interaction," *Interactions*, vol. 26, no. 4, p. 42–46, Jun. 2019. [Online]. Available: https://doi.org/10.1145/3328485

[15] B. L. W. Wong and A. Blandford, "Analysing ambulance dispatcher decision making: trialing emergent themes analysis." *Vetere, F and Johnson, L and Kushinsky, R, (eds.) Ergonomics Society of Australia: Canberra, Australia.*, 2002.

[16] ——, "Describing situation awareness at an emergency medical dispatch centre," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 48. SAGE Publications Sage CA: Los Angeles, CA, 2004, pp. 285–289.

[17] M. R. Endsley, "Toward a theory of situation awareness in dynamic systems," *Human Factors*, vol. 37, no. 1, pp. 32–64, 1995. [Online]. Available: https://doi.org/10.1518/001872095779049543

[18] G. Klein, *Seeing what others don't. The Remarkable Ways We Gain Insights.* Nicholas Brealey Publishing, 2017.

[19] F. Qiao, P. Li, X. Zhang, Z. Ding, J. Cheng, and H. Wang, "Predicting social unrest events with hidden markov models using gdelt," *Discrete Dynamics in Nature and Society*, vol. 2017, pp. 1–13, 2017.