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Untangling the Mystery of Intuitive-Analytic Interactions in Crisis Response Operations: A Dual-Process Perspective**

Abstract

Whilst it is often claimed that experienced crisis responders are likely to adopt the intuitive and analytical thinking styles when solving complex problems in time-pressured crisis situations, scholarly efforts to explicate the nature of interactions between the intuitive and analytical modes remain sparse. To bridge this gap, we review four duality-based cognitive models and draw evidence from the Hudson River case study to better understand the patterns of the interplay between the intuitive and analytical information processing modes in time-pressured crisis situations. We found support for the dual-process theory, and note that although intuition is frequently deployed as the default cognitive mode in crisis situations, experienced crisis responders can exploit some features of the analytical mode to *validate* their intuitive tendencies when required. Based on evidence from the Hudson River case study, a range of intuitive-analytic tension points that largely explain the nature of interactions within the duality framework are identified. The paper concludes by discussing the implications of the dual-process information modes for crisis decision-making.

Keywords: intuitive-analytic interactions, crisis decision-making, dual-process theory, intuitive expertise, Hudson River
(JEL: D81, D83, D91, H12, H22, M53)

Introduction

The dual-process literature within the safety critical domain is differentiated on the basis of scholars who strongly advocate for a reliance on intuition as a valid form of knowledge (Klein, 2003; Dane & Pratt, 2007; Betsch, 2008; Salas, Rosen & DiazGranados, 2010; Dorfler & Ackermann, 2012; Okoli, Watt & Weller, 2022), scholars who seem sceptical about the reliability of intuitive knowledge and favouring a more analytical approach to decision-making (Meehl, 1954; English, 1993; Lamond & Thompson, 2000; Stanovich, 2009; Tversky & Kahneman, 1983; Kahneman, 2011), and scholars who acknowledge the strengths and weaknesses of the

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intuitive and analytical modes and argue in favour of their combined application (Dunwoody *et al.*, 2000; Epstein, 2010; Bakken et al., 2024). This polysemous view of decision-making in the volatile, uncertain, complex and ambiguous (VUCA) crisis environment has resulted in a lack of agreement regarding the dynamics and sequence of operation between the intuitive and analytical decision modes, with efforts to synthesise these divergent viewpoints continuing to prove problematic (See Hodgkinson *et al.*, 2009; Epstein, 2010; Gore & Conway, 2016 for a review).

The limitations of the analytical mode are often emphasised as a key obstacle in fulfilling the requirements of the VUCA environment (e.g. Wong, 2000; Bakken, 2011), and a key argument against the analytical mode in this regard is the view that crisis response operations would undoubtedly be improved if conditions were less fast-paced and allowed sufficient time. Unfortunately, this is hardly the case in crisis situations where variables such as time, knowledge and computational ability are sadly in short supply (Greitzer *et al.*, 2010; Sadler-Smith, 2016; Okoli, 2021). As Spender (2008) puts it: there is no other option left but to think outside rationality's box in these VUCA conditions. For this reason, intuition optimists remain adamant that the intuitive mode is perhaps the only viable approach that offers the type of flexibility and creativity required to aid effective performance in crisis situations (Johnson *et al.*, 2009; Bakken & Haerem 2011). Whilst the debate regarding the veracity of intuition in fast-paced environments remains unresolved, the growing consensus is that the intuitive mode offers more flexibility to crisis responders in time-pressured environments, enabling decision-makers to process information in a rapid and compensatory manner and protecting the working memory from data inundation (Khatri & Ng, 2000; Klein et al., 2010).

Despite the plethora of theoretical models that currently exist in the field of emergency and crisis management, spanning the preparedness to recovery phases (e.g. Turner, 1976; Fink, 2002; Roux-Dufort, 2009), models and theories that explore the dynamics of the interplay between the intuitive and analytical thought processes have painfully remained scanty in the context of crisis management (Dhami & Thompson, 2012; Okoli et al., 2022). Beyond the assumption that intuitive thinking is an important consideration in crisis response effectiveness, we strongly advocate the need to articulate and consolidate the relevant body of evidence linking intuitive decision-making to analytical thinking in crisis response operations. Hence, the focus of this paper is to critically examine the role of intuitive and analytical decision-making in the VUCA environment and to investigate how both thinking modes co-exist and interact in crisis response operations. Our intention is to better understand the inter-operability of the intuitive and analytical systems in real-life emergencies, characterised by rapid decision-making, holistic processing of information and a huge reliance on tacit (as opposed to explicit) knowledge. Research in this area currently appears fragmented, disjointed and unresolved (see Pretz, 2008; Evans, 2010; Rusou et al., 2013), thereby necessitating a critical

evaluation and possible reconciliation of the range of divided evidence in the dual-process literature.

Against this backdrop, the current paper aims to answer the following overarching research question: How do the intuitive and analytical styles interact within the duality framework, and how do crisis responders balance the tensions that emerge from both thinking modes in a time-pressured VUCA environment?

Addressing the above question is deemed necessary for a number of reasons. First, despite claims that effective crisis decision-making may, in some instances, involve the combined use of the intuitive and analytical styles, little consensus has emerged regarding their preferred sequence of operation (Kahneman & Klein, 2009; Calabretta et al., 2017; Hine *et al.*, 2018). Second, it is hoped that by clarifying the nature of interactions and complementarity between both thinking styles, a stronger case can be made for intuitive thinking, which is still perceived by some as inferior to analytical thinking (e.g. Kahneman et al., 1982; Lamond & Thompson, 2000; Kowalski-Trakofler et al., 2003). Third, it is hoped that insights from this paper will help advance theoretical understanding of the cognitive mechanisms that aid crisis response effectiveness. This aligns with existing claims that the outcome of managing any major crisis will mostly depend on how the proceeding of events is handled on-scene rather than on the causes or scale of the incident itself (Flin, 1996; Okoli & Hatami-Marbini, 2021).

The remainder of this paper is structured as follows: First, we discuss the dual-process theory and examine the nature of interoperability between the intuitive and analytical modes in the context of crisis management. To assess the contextual application of intuitive and analytical decisions in time-critical situations, we then attempt an evaluation of four dual-process theories that help to strengthen our claims regarding the dynamics of interactions within the duality framework. Next, drawing on evidence from the reviewed theories and insights from the Hudson River case study, we critically evaluate the relationship between intuitive and analytical thinking styles and answer the important question of how both decision modes complement each other in the VUCA environment. Finally, the practical implications of the research are discussed in relation to the development of intuitive expertise.

The Intuitive and Analytical Thinking Modes

Research on intuition dates back to the early part of the 20th century, when initial works on the subject were primarily focused on asking basic questions, such as the meaning of intuition and how much of it managers employ in their decision-making (Sinclair, 2010). Over time, research advancements in the field of psychology and the birth of the naturalistic decision-making community in 1989 eventually opened the floodgate for new streams of research on the subject in the later part of the 20th century (Salas et al., 2010; Gore & Conway, 2016).

One of the most cited definitions of intuition was proposed by Dane & Pratt (2007), which conceptualised intuition as 'affectively charged judgments that arise through rapid, non-conscious, and holistic associations. Weick (1995) also viewed intuition as "the preconscious recognition of the pattern and/or possibilities inherent in a personal stream of experience" (p.25). Ultimately, most scholars agree that intuition represents an integral part of our daily experiences of memory, incurs limited information processing costs, and enables individuals to quickly integrate multiple informational cues in a compensatory manner (Hayashi, 2001; Betsch, 2008; Hodgkinson *et al.*, 2009; Epstein, 2010). According to Sinclair and Ashkanasy (2003), intuition is often accompanied by a sense of assurance and confidence, which is what differentiates it from mere heuristics (i.e. cognitive shortcuts). To appreciate the potency of intuition, scholars such as Hayashi (2001) portrayed it as an inherent part of human cognition that can hardly be replaced with data or algorithms, suggesting that although intuition can sometimes be influenced by emotions, it is hardly an offshoot of emotion neither is it a magical sixth sense or a paranormal process. In fact, there are claims that individuals who mistrust their intuition tend to make poorer decisions in general (Dijksterhuis, 2004).

In contrast, the analytical mode operates strictly in a logical step-by-step manner, whereby the decision-maker is able to consciously and deliberately control the sequence and direction of the processing of information (Julmi, 2019). Thus, while intuitive decisions generally follow an overall impression of the decision problem, analytic decisions typically favour a logical decomposition of the decision problem and then sequentially recombining its elements (Hogarth, 2010).

In the quest to better understand the interplay between intuition and rationality in strategic decision-making and hopefully limit methodical and philosophical differences between both schools of thought, a growing body of research has recently emerged, which advocates a paradoxical approach to dual-process scholarship (Smith & Lewis, 2014; Calabretta et al., 2017; Keller & Sadler-Smith, 2019; Tabesh & Vera, 2020; Hallo & Nguyen, 2021). Here, paradoxes imply contradictions that persist over time, and although these contradictions require ongoing responses, they are not fully resolvable by compromise or by adopting the contradictory viewpoints simultaneously (Calabretta et al., 2017). To appreciate the inherent benefits of the intuitive-analytic systems, it is therefore suggested that these contradictions are accepted rather than dismissed (Smith & Lewis, 2014). Within the context of our research, the existence of a paradox seems evident, since the intuitive and analytic systems represent two fundamentally different but interrelated thought processes (e.g., unconsciousness vs. formal analysis; holistic associations vs. cause-effect logic), with both needed to enhance the quality of decision outcomes in crisis environments (Smith & Lewis, 2014). Through illustrative examples from the Hudson River case study, we will later show how embracing this paradoxical thinking can aid our understanding of the nature of intuitive-analytic interactions,

as well as how ensuing tensions within the dual systems can be favourably harnessed in practice.

Dual Process Models

The dual process theory, in a nutshell, posits that information processing is accomplished by two distinct yet complementary systems — the intuitive and analytical systems (Stanovich & West, 2000). While terminology varies between approaches (e.g. the *type*, *mode*, *styles,* and *systems* debate; see Evans, 2010), it is widely accepted that one system is automatic, holistic and fast, while the other is conscious, rule-based and slow (Epstein, 2010; Kahneman, 2011; Sadler-Smith, 2016). Hence, in our quest to pursue a more holistic understanding of the interplay between the intuitive and analytical cognitive modes and assess their practical application in crisis decision-making, the current paper draws on four distinct dual cognitive models/theories, namely the recognition primed decision (RPD) model, the recognition/metacognition (R/M) model, the cognitive continuum theory, and the cognitive experiential self-theory (CEST). We developed a clear set of criteria that aided our selection of the four cognitive models in line with meeting our research objectives (summarised in Table 1).

Table 1: Criteria for Dual-Process Theory/Model Selection

	Recognition-primed decision model (RPDM)	Recognition/ Metacognition model (R/M)	Cognitive Continuum Theory (CCT)	Cognitive Experiential Self Theory (CEST)
How the Intuitive/analytical systems are portrayed	A holistic theoretical model	An integrated theoretical model	A six-dimensional theoretical framework	A comparative list of the intuitive-analytic operating principles and attributes.
Google Scholar citations of the top two publications (for which the theorist is a lead author)	Klein (1993). 2241 citations Klein et al. (1986). 896 citations	Cohen et al. (1996). 435 citations Cohen et al. (1998) 237 citations	Hammond et al. (1987). 1005 citations	Epstein et al. (1996). 2845 citations Epstein (1998). 1728 citations
Common fields of application	Cognitive psychology, naturalistic decision-making, crisis and emergency management	Military science, naturalistic decision-making, Aviation	Nursing and healthcare, criminology, teaching and pedagogy, aviation	Social psychology, behavioural psychology, personality psychology, clinical psychology
Approximate year of key seminal work.	1986	1995	1981	1990

First, it was expected that each model/theory showcased the duality construct, e.g. through a holistic framework that allows appropriate patterns to be drawn between the intuitive and analytic systems or through a comparative list of intuitive-analytic features — as in CEST. Second, we considered how influential each model/theory was, specifically measured by the total number of Google Scholar citations (see Caon et al., 2020, for a detailed discussion on the use of citation as a measure

of research quality). Whilst it was not realistic to aggregate the total number of citations associated with each model/theory across all published works, we focused on two key publication(s) emanating from the seminal work from which the models/theories were originally developed. Third, we examined the breadth of application of each model/theory to scholarship and practice, specifically measured by their generalisability beyond the original domain from which they emerged. Finally, we considered the relevance of each model/theory over time, i.e., we gauged how much they had withstood the test of time and still remained relevant.

We now discuss each of the dual cognitive models/theory in turn:

Recognition Primed Decision Model (RPDM)

The recognition primed decision model (RPDM) was originally developed by Gary Klein and his colleagues (Klein et al., 1986) and has remained a prototypical information processing model in crisis decision-making. The research that led to the emergence of this model stemmed from Klein's attempt to describe the decision-making strategies used by fireground commanders when managing non-routine incidents. Klein's initial hypothesis was that the fireground commanders would generate a range of options and then systematically reduce them to a pair of options before selecting a final option choice to act upon. But to Klein's surprise, all the commanders generated (and needed to generate) was a single option in almost all the reported incidents. This was possible because the commanders could draw on a repertoire of patterns which they had built during more than a decade of experience to identify a plausible option that was considered first. On this basis, recognition primed decisions are then construed as decisions for which action alternatives are directly derived from recognition of critical information and prior experiential knowledge (Klein, 1993). Decision makers rely on using recognised patterns stored in their memory to solve current problems by identifying the most relevant cues, formulating expectancies, identifying plausible goals, and proposing workable action plans.

Depending on the complexity and severity of the incident, the RPD model spans three basic levels. At level 1 (routine incidents), the decision maker identifies a situation, immediately recognises the most suitable response option and then acts promptly. However, as the incident escalates and grows in complexity, the need for a more thorough diagnosis (assessment) of the situation becomes necessary — captured in level 2 of the model. This stage requires the scanning of informational and environmental cues in order to gain additional knowledge that represents the most accurate version of events prior to deciding on an action plan. Unlike most extreme analytical models, the situation assessment phase described in the RPD model does not require concurrent deliberation and comparison of options. Rather, decision-makers leverage their experience to sequentially assess a single option against a current situation through *feature-matching* or *story-building* (Okoli et al.,

2016). In feature matching, the decision maker thinks of several interpretations of the situation and uses their experience and cue recognition skills to determine the interpretation that provides the best match. Alternatively, the decision maker may have to combine relevant features to construct a plausible explanation for the situation through *story building*.

Finally, level 3 of the RPD model (non-routine incidents) describes crisis events where decision-makers feel uncertain and less confident about a proposed course of action. At this stage, the RPD model recommends conducting a brief mental simulation of future outcomes before implementing a course of action. Mental simulation, which represents a moment of brief analysis, involves a deliberate search for loopholes in a proposed action plan (Klein, 1993).

One of the strengths of the RPD model is its ability to effectively blend intuition (level 1) with a minimal level of analysis (levels 2 & 3), although the model has been criticised for lacking the ability to offer meaningful insights in novel situations where a decision-maker is confronted with unfamiliar events that fail to match existing decision templates (Freeman *et al*., 1998; Johnson *et al*., 2009). For instance, Cohen *et al*. (1996) identified a key limitation of the RPD model in their study with military personnel, namely the possibility that crisis responders might encounter novel situations that would altogether defy prior knowledge. Building on this knowledge gap, the researchers developed an evidence-based cognitive model, which they termed the recognition/metacognition (R/M) model.

Recognition/Metacognition (R/M) Model

Unlike the RPD model, which suggests that proficient decision-makers mostly rely on recognised patterns to solve current tasks, the R/M model purports that simply being recognitionally skilled will hardly be sufficient in managing complex crises. Instead, decision-makers must also aim to be metacognitionally skilled. Metacognitive skills, in this context, refer to the range of strategies used to monitor and assess knowledge, such as the "feeling of knowing" that accompanies problem-solving or the ability to differentiate proposed action plans about which we are confident from those which we doubt (Tarricone, 2011, p.4).

The R/M model generally follows a two-tier process:

- An activation stage where action plans are developed through the process of pattern recognition, more like the RPD model.
- The *critiquing* and *correcting* stage, where the outcomes of pattern recognition are probed for fitness.

Critiquing entails a deliberate act to search for gaps and faults in one's mental model and finding ways to address them in the quickest possible manner. During critiquing, potential action plans are queried for completeness, reliability, and conflict, with any discrepancies subsequently amended in the correcting phase. As a result,

the crisis responder may then see the need to make further observations, collect additional information, generate additional options, or revise current assumptions.

The strength of the R/M model lies in the fact that decision-makers are encouraged to conduct a series of cognitive tests before implementing a final course of action. Thus, through the iterative processes of critiquing and correcting, decision-makers continue to improve and refine their understanding of a situation or even develop novel ways to solve the problem. Also, through these iterative processes, attempts to implement a proposed action plan could subsequently reveal an unforeseen (underlying) problem that may potentially compromise decision outcomes. One of the criticisms of the R/M model, however, is the notion that regulated thought processes, such as metacognition, can easily threaten intuitive thinking since they hinder one from thinking freely (Baylor, 1997).

Cognitive Continuum Theory (CCT)

Developed by Hammond (Hammond *et al.*, 1987; Hammond, 2000), the Cognitive Continuum Theory (CCT) is a descriptive theory that examines how judgement situations and task performance relate to cognition. The theory contends that human cognition is comprised of both intuitive and analytical modes and focuses on environmental features that induce each cognitive style (Julmi, 2019). CCT explicitly refutes a dichotomous view of intuition and analysis and suggests there are other modes of cognition arranged along a continuum, ranging from pure intuition at one end of the spectrum to pure analysis at the other. Put differently, the theory views cognition not strictly as analytical or intuitive but as falling between both cognitive ends and, thus, being quasi-rational. Quasi-rationality, therefore, refers to the region of cognition between the extremes of the continuum, which shares both intuitive and analytical properties (Dhami & Thompson, 2012).

The degree of informational cues associated with judgement tasks is crucial in Hammond's view. Hence, the theory classifies task characteristics as "intuition-inducing "and "analysis-inducing" (Dunwoody *et al.*, 2000; Rusou et al., 2013). The intuition-inducing class includes tasks that are not easily decomposable within an ill-structured environment, featuring unreliably measured cues, whereas the analysis-inducing class includes decomposable tasks performed in a relatively stable environment with reliably measured cues (Shapiro & Spence, 1997). The more structured a task is, the more analytically induced the decision-making mode would seem (and vice-versa). Thus, one of the strengths of the CCT lies in its ability to predict possible conditions under which managers are likely to move from one cognitive mode to another. In general, the cognitive continuum theory supports the notion that the amount of information at the disposal of the decision-maker, the presence or absence of competing demands, as well as the level of urgency associated with a decision task, will often influence the cognitive strategy that a decision-maker might eventually adopt (Hammond *et al.*, 1987).

A meta-analysis of dual-processing studies by Wang *et al.* (2017) has, however, challenged the tenets of the CCT, with the authors finding substantial evidence through their comprehensive review that the intuitive and analytic systems are, in fact, two uncorrelated constructs, representing two distinct modes of operation. The conclusion reached was that intuition and analysis are independent constructs rather than opposite ends of a bipolar continuum, as assumed by CCT.

Cognitive Experiential Self Theory (CEST)

Developed by Seymour Epstein, the cognitive experiential self-theory (CEST) is a global information processing theory that explains how people perceive and utilise information to make decisions. CEST is categorised as a personality theory and, similar to most other dual-processing theories, holds the view that individuals process information typically through two distinct systems: a conscious rational system and an unconscious, emotion-laden experiential system (Epstein, 1991). A person's attitude, behaviour, and, ultimately, personality are essentially developed through the combination of these two systems, both interacting within the individual's social context. CEST purports that although the intuitive-analytic systems operate by different rules and possess different attributes, they both influence each other, and neither is completely independent of the other (Epstein, 2010). It is noteworthy that in conceptualising CEST, intuition is often defined as a subset of the wider experiential system (Epstein, 1998, 2010); however, for the purpose of this article, we will limit the boundary domain of the experiential system only to intuition.

The experiential system is emotionally driven and adapts by experience as opposed to logic. It is used predominantly to adapt to changing social environments and situational demands, something it achieves through the automatic association of stimuli and their subsequent response outcomes. The experiential system is thus able to quickly establish connections holistically and influence everyday behaviour almost unconsciously. Through the experiential system, individuals develop and maintain schemas about the world, about self, and about others (Epstein, 2010). While the rational system is better designed to explain and justify the basis of these schemas, it is the experiential system that hosts the automatic application and situational adaptation of schemas across contexts. The rational system, on the other hand, processes information slowly, analytically, and consciously and often seeks to find cause-and-effect connections with external stimuli. On the basis that the rational system is analytical by default, it is more suited to support an individual's understanding of rules and evidence since it acquires its beliefs through logical inference. Similar to the experiential/intuitive system, the rational system learns from experience but does so through deliberative reasoning rather than through automatic associative learning. But unlike the experiential system, the rational

system is too effortful and slow to efficiently direct everyday behaviour: people do not deliberate over every single choice they make on daily basis; they simply behave.

To assess the nature of intuitive-analytic interactions in practice, we now turn to a high-scale incident from the aviation sector, colloquially termed the "Miracle on the Hudson River". The Hudson River case analysis is focused on how an experienced pilot (alongside his co-pilot) successfully leveraged their domain expertise to demonstrate intuitive competence, supported and complemented by intermittent flashes of analytical thinking in an extremely dynamic, volatile, time-pressured, and high-staked environment. The case study was chosen for its strategic relevance, i.e. not only did the series of events surrounding the Hudson incident disrupt what appeared to be conventional knowledge in the aviation sector at the time, the case study also aligned well with the objectives of the current paper, namely that it met all the key requirements of a complex incident that occurred in real-life VUCA environment (Okoli, 2021).

Case Study: Miracle on The Hudson River

On 15th January 2009, Chesley "Sully" Sullenberger ditched a US Airways 1549 jet in the Hudson River after a huge flock of Canada geese hit the plane at a high altitude (about 3000 feet), thereby rendering both plane engines inoperable. If one of the cockpit engines was unable to continue to generate thrust, the aeroplane might still get enough power from the other engine to reach an accessible runway safely. But what made this incident unprecedented was the fact that both engines suffered a sudden and simultaneous loss of thrust, thereby negating the engine certification criteria, as well as exceeding the N-1 engine performance threshold. From this point, there would only be a timeframe of 208 seconds between hitting the birds and reaching the Hudson River. With the full picture of the proceeding of events looking extremely blurred and the future looking increasingly more uncertain, it became clear that Captain Sullenberger had an almost impossible task in his hands. Decisions would have to be made extremely quickly, yet with a near-zero margin for error, decisions made at this point would likely be irreversible, too. With one hundred and fifty passengers and five crew members aboard and with a copious array of emotions swirling through the cabin area, Captain Sullenberger and his co-pilot knew they had to show exemplary leadership in what has now become a life-death situation. In the absence of any accurate or reliable reference point, the only beacon of hope available to the pilots is their domain knowledge, decades of experience, airmanship, and, quite crucially, their gut feelings about the situation. After assessing other possible alternatives, ditching the plane on the Hudson River was deemed the most plausible option. However, landing a plane the size of Flight 1549 on the water remains a highly risky adventure, probably riskier considering the ditching airspeed was at about 130 knots. Thankfully, the ditching and evacuation of passengers was a delightful masterpiece of teamwork between the

cabin and cockpit crew. Despite the sight of boats on the sea, no boats were hit during the landing. Instead, many boats were readily available to assist with the rescue. In the end, all passengers and crew members were safely evacuated.

But what does the Hudson case study mean within the context of the current paper, and how does the case study advance the intuitive-analytic debate? We analyse these points next.

Case Study Analysis

Despite claims from the dual-process theories that crisis responders are able to switch between the intuitive and analytical styles as conditions warrant, it still appears unclear how this sequence is followed and coordinated in practice (Sinclair & Ashkanasy, 2003; Sayegh et al., 2004; Rusou et al., 2013; Gore & Conway, 2016). Building on this knowledge gap, we draw insights from the Hudson River case study to probe for evidence that delineates the nature of interaction between the intuitive and analytical modes in time-pressured crisis situations. Specifically, we analyse key factual information from a range of credible scholarly sources that reported on the Hudson incident (Potter, 2010; Paries, 2011; Hollnagel, 2013; Miller, 2018; Okoli, 2021) and draw collective insights from the four dual cognitive models/theories earlier discussed (i.e. RPDM, R/M, CCT and CEST). As shown in Table 2, we identified four key paradoxical (tension) points that continue to spark debates amongst scholars regarding the dynamics of interaction between the intuitive and analytical systems in time-pressured crisis situations. For clarity, our conceptualisation of these four tension points was informed in part by the works of Epstein (2010) and Sinclair (2010) and in part by the collective insights gleaned from the four dual cognitive models/theories earlier discussed. Since each of our four cognitive theories/models addressed these intuitive-analytic tensions in varying dimensions, it was deemed necessary to match each tension point against the four cognitive models/theories and then inductively check for narratives from the Hudson case study that might help address these grey areas. Table 2 shows the intuitive-analytical tensions in the first column, with excerpts drawn from the incident accounts presented in the second column. The third column then shows how each theme connects to the dual cognitive models/theories.

Table 2: Analysis of the Intuitive-Analytic Interactions in Relation to the Hudson Case Study

Intuitive-analytic tension point	Evidence and/or excerpts from documented Hudson incident account	Is this tension explicitly addressed in the dual cognitive model/theory?			
		RPD	R/M	CCT	CEST
The role of experience and domain expertise (To what extent does domain experience influence decision-makers' adoption of an intuitive or analytical style?)	The combined flight crew had a significant amount of experience. Captain Sullenberger had more than 19,000 flight hours, his co-pilot Jeffery Skiles had more than 15,000, and the three Cabin crew members had between 26 and 38 years of professional experience. The Air Traffic Controller had ten years on the job and had worked on 10 to 12 emergency situations, although none like the Hudson.	X			X
Option generation and rapid evaluation of options (How do crisis decision-makers generate and analyse potential choice options while still striving to deliver prompt judgments? In other words, can quick and accurate decisions be achieved simultaneously within the context of dual processing?)	One of the bravest decisions arguably made by Captain Sullenberger was the decision to ditch the Hudson River. In one of his post-incident interviews, the captain revealed some of the cues that supported his situation assessment: "I quickly determined that we were at too low an altitude, at too slow a speed, and therefore we didn't have enough energy to return to La Guardia, because it's too far away and we headed away from it" (Hollnagel, 2013, p. 18). After briefly considering the only other nearby airport, which was Teterboro in New Jersey, I realised it's too far away ..."	X	X		X
Thinking and acting concurrently (How do crisis responders determine when to think, when to act, and when to think and act some more?)	According to the transcript of communication between the crew and the LaGuardia departure controller, Captain Sullenberger's initial plan was to return to LaGuardia Airport once the engines were confirmed wrecked. The Air Traffic Controller offered him runway 13, but shortly afterwards, the captain realised it would not be possible to return to LaGuardia. He then briefly considered going to Teterboro Airport and rejected this option as well. He then eventually decided that ditching in the Hudson River was his quickest and safest option.	X	X	X	
Rule-based vs skill-based behaviour. (Are decision-makers guided predominantly by domain rules or mostly reliant on experiential knowledge? Can both be used together?)	Scholarly evidence from the incident report showed that successful ditching entailed a good balance between adhering to standard operating procedures (SOPs) (e.g. following all aviation safety procedures) and thinking outside the box (e.g. the first officer's decision to start the APU, even though this was not an operational requirement at the time).	X	X	X	X

***The role of experience and domain expertise*:** The accuracy of intuitive judgment, or any decision outcome for that matter, would likely weigh heavily on the quality of domain knowledge (Hine *et al.*, 2018). This is even more true in dynamic situations where the pace and novelty of events can easily throw novices off track. As was discussed in the RPD model, the logic here is that experts, through the mechanisms of their well-developed schema, are better poised to understand when to deliberate on an action plan and when to act instantaneously (see Okoli &

Hatami-Marbini, 2021 for a detailed discussion of the role of expertise in intuitive-analytical decision-making). Our view here supports existing claims that experts, in contrast to novices, understand the boundaries of their skills and know when their intuition is likely to betray them (Dunning *et al.*, 2003; Kahneman & Klein, 2009). In the words of Kahneman and Klein (2009):

> "True experts, it is said, know when they don't know, and non-experts (whether or not they think they know) certainly do not know when they don't know" (Kahneman & Klein, 2009, p.524)

Therefore, with the quality of professional experience amongst all the cockpit operators (Table 2), it seems highly plausible that experience and domain expertise played a crucial role in the successful handling of the Hudson incident.

***Option generation and rapid evaluation of options*:** A question that is often asked in the crisis response literature relates to how crisis decision-makers are able to rapidly sift through a range of options and still reach a final judgment rather promptly (Suss & Ward, 2012; Calabretta et al., 2017; Okoli & Watt, 2018). As seen from the Hudson case study, the pilot had a list of plausible options across the incident timeline, each with the possibility of changing the trajectory of the incident altogether. Whatever may have ensued through the minds of the pilots on the day, a detailed evaluation of options was certainly not part of the strategy. Considering the fast pace through which events unravelled, it was almost impossible to deliberate on any option choice for much longer than necessary. This seems like a logical argument if we consider that the ditching happened at approximately 3:31 pm local time, just 210 seconds after the bird strike and less than 360 seconds after take-off (Potter, 2010). Thus, building on the tenets of CEST, the RPD and R/M models, we can infer that the chief pilot leveraged his extensive domain knowledge to choose a single option that potentially had the highest success rate whilst also sub-consciously interrogating other plausible options in case the preferred option runs into trouble.

***Thinking and acting concurrently*:** Intuition scholars have argued that a pure reliance on analytical thinking is almost impossible in a typical VUCA environment since tasks are largely unstructured and critical information is hardly readily available (e.g. Pretz, 2008). Again, as shown from our analysis of the Hudson River case study, crisis responders can simply not afford to rely on the slow, effortful, low-capacity and resource-demanding analytical style in these fast-paced conditions. Instead, a more befitting strategy is one that allows crisis responders to think and act simultaneously. Documentary evidence from the Hudson case study buttresses this claim in that the pilots were closely assessing the unravelling of events and checking that their proposed actions matched the current reality. In other words, the pilots were checking the weather conditions and other environmental factors such as wind movement, weather visibility, and traffic on the Hudson River; and then mentally projecting the potential impact of their actions against these situational cues.

Rule-based and skill-based behaviour: A key test of expertise entails balancing the need to adhere to bog standard operations on the one hand and thinking creatively and making improvisations to existing protocols on the other hand. According to CCT and CEST, the former is a rule-based activity that thrives in the realm of consciousness, while the latter is a skill-based activity belonging to the realm of experiential knowledge. Evidence from the Hudson case study suggests that the pilots had a measured understanding of when to strictly adhere to the relevant aviation rules and when to improvise — even if they had to (justifiably) defy operational instructions. For instance, the chief pilot reportedly defied clear instructions from the Air Traffic Controller (ATC), opting to land on the Hudson River rather than accept the ATC's offer to take a U-turn back to LaGuardia Airport. This singular action eventually proved a significant turning point in the successful handling of the incident (Miller, 2018).

In terms of sequence of operation, our present view aligns more specifically with the RPD and R/M models suggesting that seasoned experts typically draw on the intuitive mode as their default strategy, only switching to deliberative mode if and when necessary (Klein *et al.*, 1986; Cohen *et al.*, 1996; Okoli et al., 2016). This includes instances where the intuitive mode struggles to select a definite course of action, where there is a need to consider other possible alternatives, where there is a need to justify one's action, or where the decision-maker feels less confident about their initial intuition. As shown from the Hudson case study, the most effective way to combine both thinking styles is to allow intuition to take the lead where possible (Klein, 2003, p.64), a view consistent with the prototypical RPD model and also replicated in multiple work domains including the Fire service (Okoli et al., 2022), Ambulance (Wong, 2000), Law enforcement (Suss & Ward, 2012), Military (Bakken & Gilljam, 2003), and Clinical settings (Aghajani et al., 2022). The recommendation from the RPD and R/M models regarding the sequence of operations within the duality framework is hinged on the belief that intuition allows patterns to be recognised faster, thereby freeing up additional mental space for decision-makers to react quicker to more pressing task demands. Thus, in contrast to the analytical mode, which has "low capacity" and is easily inundated with large amounts of information, the intuitive mode allows for the integration of complex sets of informational cues relatively quickly through the operation of schemas (Pollock et al., 2002).

Connecting the Dots: How do Intuition and Analysis Interact and Complement?

By drawing on evidence from the reviewed dual-process models/theories, alongside insights from the Hudson River case study, we have thus far explored the nature of complementarity between the intuitive-analytic systems and show how experienced commanders tend to manage a range of intuitive-analytical tensions to remain

cognitively versatile in the heat of crisis. Our goal in this final section is to advance existing knowledge by showing precisely how the intuitive and analytical modes interact in practice. As previously mentioned, existing literature hardly explicates how the analytic system gets co-opted to support the intuitive system in attaining its rapid and holistic information processing functions (Dhami & Thompson, 2012; Rusou et al., 2013). Our intention, therefore, is to show that the analytic system is designed to perform specific functions within the duality framework that helps to keep the intuitive system in check. Next, we discuss exactly what these functions are.

To achieve this final objective, we reviewed the key defining principles from each of the four dual cognitive theories/models that help to demystify the point of inflexion between the intuitive and analytical systems. Specifically, our evaluation draws from the principle of "mental simulation" from the RPD model (Klein *et al.*, 1986), the logic of "quick test" and "critiquing and correcting" from the R/M model (Cohen *et al.*, 1996), the construct of "quasi-rationality" from CCT (Hammond *et al.*, 1987), and the principle of "associative learning" from CEST (Epstein, 2010). By integrating these concepts, we identified at least three distinct, dynamic functions that the analytic system performs within the duality framework.

The verification function: Here, the analytic system seeks to probe, verify and authenticate the activities of the intuitive/experiential system, ensuring that its proclivity to deliver instantaneous judgments is probed for accuracy. A key fundamental strength of the rational/analytic system over the experiential/intuitive system is leveraged at this point — the notion that the former is able to understand the latter, while the latter can only operate outside of conscious awareness and only able to respond automatically to stimuli based on past experiences (Epstein, 2010).

Upon quick reflection, the analytic system may endorse, correct, or override any proposed action plans, although, in most cases, the first option often turns out as the most appropriate choice for experts owing to their extensive years of experience and expansive domain knowledge (Klein, 1993; 2003).

Idrogo & Yelderman (2019) put it this way:

> "Because the rational system operates at a slower pace than the experiential system, it is at a good position to correct many of the processes the experiential system may exhibit. The rational system cannot only work to understand the operations of the experiential system but can understand the underlying schemas established. Such rational processing might include aspects of self-awareness and self-control in which analytical thoughts allow a person to override urges or impulses and make a different decision" (Idrogo & Yelderman, 2019, p.4)

The underlying basis for the verification function is that, if uncorrected by the analytic system, the intuitive system can sometimes generate decision errors, such as optimistic bias, sunk-cost bias, and unrealistic beliefs (Lamond & Thompson, 2000; Kahneman, 2011).

The verification function therefore addresses the oft-discussed tension between making quick and accurate decisions, a combination that the heuristics and biases community believe is often impossible to attain simultaneously (e.g. Tversky & Kahneman, 1983). Evidence from the Hudson River case study also shows that speed and accuracy can both work together, as long as the boundaries of interactions are well understood by the decision maker.

The mindfulness function: The role of mindfulness as a connecting link between the intuitive and analytic systems has been reported in the literature (Herndon, 2008; Dane, 2011; Dörfler & Ackermann, 2012). Mindfulness in this context is defined as a state of consciousness in which attention, both internally and externally, is focused on present-moment activities (Weick & Sutcliffe, 2001). To be mindful, individuals must be attentive to the "here and now" rather than focusing on past and/or future events (Herndon, 2008). This is why revelation is said to occur when the conscious mind finally captures what the subconscious mind already knows (Hayashi, 2011; Dorfler & Ackermann, 2012). Mindfulness attunes individuals to the operations taking place in the subconscious, thereby shedding light on one's intuition, which then activates the discovery of new insights. Without adequate mindful attention to the "here and now" (a key attribute of the analytic system), the outcome of intuitive thinking may be less productive and certainly less aligned to current tasks.

Building on the seminal works of Michael Polanyi (1962, 1966), Tsoukas (2003) sheds further light on the concept of mindfulness and describes the workings of intuition using the analogy of a triangle. Tsoukas likened the first end of a triangle to the subsidiary features of a task environment (e.g. external cues), the second to the focal target (i.e. the main goal being pursued), and the last to a *knower* who makes a connection between the other two ends. It was on this note that Polanyi argued that no knowledge is possible without the integration of subsidiary features and focal targets, a connection we argue can only realistically occur through mindfulness.

The rationalisation function: Since the intuitive mode typically operates outside of awareness, it is able to leverage its tacit nature to "co-op the rational/analytic system to rationalise" (Epstein, 2010, p.302). Rationalisation, in this context, refers to the tendency of the human mind to justify the basis of an action by drawing on previous experiences in a self-serving manner. Scholars have shown that an important role of analytical (rational) thinking is to generate post hoc rationalisations as to why a specific decision was made (Calabretta et al., 2017).

A recap of these functions is as follows: when confronted with a problem task, the intuitive system tends to react automatically with a favourable or less favourable interpretation and then proposes an action plan based on past experiences. Through mindfulness, the decision-maker then projects these tacit signals into the realm of consciousness and then responds accordingly. Unaware of the unconscious determi-

nants of their (conscious) behaviour, the decision-maker then opts to seek a rational explanation, resulting in the most favourable interpretation he or she can muster within acceptable and justifiable considerations.

Implications for Practice

As we draw our discussion closer, it would seem appropriate to examine the implications of our findings for crisis decision-making. First, we reckon that a key task facing most crisis response organisations is the need to devise flexible and cost-effective strategies to aid the training of their operational responders in becoming more cognitively versatile. Given the volatile nature of present-day crises (what we now know as "wicked problems") and the unusual breed of hazards that crisis responders are increasingly exposed to, it has become even clearer that knowledge derived from 'normal' training procedures is no longer sufficient in coping with the constraints posed by the growing number of unprecedented incidents across the world. An example of such an incident has already been addressed in this paper (the Hudson River incident), but other examples would include the rising cases of wildfires in regions where they have historically been classed as low-probability events or the exposure of medical emergency teams to novel diseases such as COVID-19 for which no prior training was previously undertaken. Hence, on the basis that the intuitive mode is typically drawn upon as the default strategy when solving complex problems, our recommendation is to focus on improving the intuitive skills of operational commanders, as well as supporting them to trust their intuitive tendencies when intuiting is deemed safe.

Second, our review underlines the importance of educating the less experienced officers on the need to accept standard operating procedures (SOPs) as a tool for informing rather than for dictating. As seen from the Hudson case study, it is crucial that responders are able to approach novel tasks in ways that are creative, learning to integrate multiple informational cues and formulating new ideas beyond what is taught in books (Eubanks *et al.*, 2010). As domain knowledge increases, decision-makers automatically become more proficient at assessing situations quicker, detecting problems and anomalies well in advance, discriminating more finely between cues, processing and integrating information more efficiently, remaining calmer under chaos, and showing more confidence that their first course of action will work. Again, as shown in Table 2, these activities would require the proficient and simultaneous interplay of both intuitive and analytical approaches, whereby the strengths of the intuitive mode (quick, automatic and holistic processing of information) are combined with the strengths of the analytical mode (focused thoughts, testing of assumptions, intentionality), which in turn compensate for their respective weaknesses. We propose that these dual attributes be given utmost consideration when designing training curricula for crisis responders.

Thankfully, despite acclaimed difficulties of acquiring intuitive skills in practice, evidence shows that the process of gaining intuitive expertise can be propelled through training and deliberate practice (Hoffman et al., 2009; Greitzer *et al.*, 2010; Ohst *et al.*, 2014). As it stands, there are no shortcuts to the development of intuitive expertise; we believe it is fundamentally achieved by giving learners the opportunity to gain real-life experiences and by creating a task environment that supports the use of intuitive and creative approaches to problem-solving.

Conclusion

Integrating insights from our evaluation of the dual-process theory, alongside the illustrative examples from the Hudson case study, we can conclude that intuition and analysis are complementary rather than subservient to each other, with both cognitive modes functioning in their unique areas of strengths through a variety of dynamic interactions. With the aid of their well-developed schemata, cognitively versatile decision-makers are able to draw on their extensive domain knowledge to make holistic associations and integrate complex sets of cues under extreme time pressure whilst also recognising the limits of intuition. Whilst ways to combine the intuitive and analytic modes are not always clear in practice, it is hoped that this paper has provided an additional layer of evidence that crisis responders can make both quick and accurate decisions simultaneously. The key, as summarised in Table 2, is to ensure that the tensions and boundaries of engagement between the intuitive and analytic modes are well understood. Drawing on the three analytical functions discussed in this paper, it is also hoped that the nature of the interaction between the intuitive and analytical modes in time-pressured crisis situations is now more explicitly understood. Future studies can utilise other methods of inquiry (such as experiments or neuroimaging) to test the intuitive-analytic interactions identified in this paper. Whilst the Hudson incident offered a useful case study for analysis in this paper, we make no claim that our findings are inherently generalisable across other domains of practice. Future studies can adopt a multi-case study approach to simultaneously assess the legitimacy of the intuitive-analytic interactions discussed in this paper.

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