ARTICLE

DYNAMIC DECISION MAKING UNDER UNCERTAINTY: A BREHMERIAN APPROACH

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Scandinavian researchers Erik Bjurström and Bjørn Bakken discuss the contributions of the late Professor Berndt Brehmer to the study of dynamic decision making under uncertainty. His approach viewed decision making from a process perspective, framing decisions as events or expressions of an ongoing design process which expands possibility spaces rather than limiting decision making to pre-existing alternatives.

INTRODUCTION

The purpose of this article is to discuss the late Professor Berndt Brehmer's theories on dynamic decision making under uncertainty, thereby also problematising decision making and human rationality from the perspective of uncertainty. While implied in early work in psychology and in the pedagogy of pragmatism, as well as in Simon's notion of 'bounded rationality', uncertainty in decision making was explicitly addressed through Kahneman and Tversky's 'prospect theory' and later developments in behavioural economics. Recent research efforts have further explored decision-making processes per se, considering them in the context of their environment and exploring their relationship with uncertainty. Brehmer's approach to decision making under uncertainty is consistent with this evolution, from conceptualising 'dynamic decision making' as a series of decisions in which sensemaking is central in 'the dynamic OODA-loop' to seeing decision making as a matter of 'design'. In the context of networked command-and-control, Brehmer's theorising in the pragmatist tradition stands out for both its cleverness and practicality.

While many others focus only on information management or the riddle of structural properties of organising in a networked world, a Brehmerian approach deals with the shifting and emergent properties of such a world.

UNCERTAINTY AS IMPLIED AMBIGUITY

Decision making is undeniably central to economic theory, relying on the assumption of rational, utility-optimising individuals. Simon's (1947) observation of the consequences of humans' limited span of attention echoed and further explored in organisational settings the fundamentals of psychology as presented by William James (1890), where attention and the flow of experience – rather than rational optimisation – was at the core of the theory.[1,2] For James, Peirce, Dewey and other adherents of American pragmatism, reflection on the fundamentals of psychological experience was simultaneously an exploration of pedagogy and of the philosophy of science. This trinity of overlapping fields of knowledge was broken by the advent of logical positivism within psychology, eliminating introspection for the sake of scientific ambitions of behaviourism in the early 20th century, reintroduced as meta-cognition in the late 1970s.[3] Simon's findings became associated with the notion of 'bounded rationality', which is interpreted in an overly pessimistic sense of humans being somewhat irrational,[4] or simply making bad decisions.[5] While uncertainty was not explicitly addressed through the notion of 'bounded rationality', it was implied that selective attention might generate different foci and, thus, ambiguity in different observers' perceptions and accounts of one event.

UNCERTAINTY AS AN EXPLICIT ASPECT OF TIME

Kahneman and Tversky's (1979) prospect theory[6] emphasises uncertainty in its empirically founded criticism of economic theory's notion of 'expected utility' as the basis for decision making. Their experiments instead showed how emotional tendencies, for example, risk aversion, influence decisions under uncertainty. Of crucial importance here is the question of how uncertainty is addressed as a consequence of time (the future) and incomplete information (prediction) due to a lack of knowledge (predictive theory). Experiments do not allow for time to resolve any remaining uncertainty, but decisions have to be taken in a once-and-for-all manner immediately.[7] Hence, in prospect theory, as the name indicates, time is the aspect that generates uncertainty, first as future time, but second by imposing an immediate decision point in the present, in which itself is not allowed to resolve any uncertainty. This arrangement has legitimacy for exploring the questions asked by Kahneman and Tversky,[8] but is by no means the only way of framing and stating the problem and possible solutions to uncertainty in decision making.

TIME AS A SOLUTION TO UNCERTAINTY

At the risk of stating the obvious, time is not only a problem in decision making but also opens up dynamic solutions to uncertainty. According to Simon's 'scissor metaphor', in judging the rationality of a decision, the decision process is one blade, and the structure of the environment is the other.[9] Hence, simple heuristics may be more

1. Simon, 1947
2. James, 1890
3. Kolb and Kolb, 2009
4. Ocasio, 1997
5. Kotler, 2022
6. Kahneman and Tversky, 1979
7. c.f. Eriksson, 2004
8. Kahneman and Tversky, 1979
9. Gigerenzer, 2010

functional and rational than ambitious analysis where the situation does not allow for it, for example, because of uncertainty. Consequently, it may be just as rational to make a decision based on scarce information or not to make more decisions than necessary for the moment and let time itself resolve remaining uncertainties, that is, to 'wait-and-see', rather than making any 'once-and-for-all' decision in a balancing act between prediction, control and acceptance of uncertainty.[10] As a solution to uncertainty, decision making is conceptualised as related to timing as a situation develops. Gigerenzer (2010) emphasised the environment's crucial role in decision making in what he called ecological rationality,[11] illustrated by the baseball player's challenge: the point is not to calculate correctly where the ball will touch the ground, but to be there just before it happens, which is achieved by keeping the angle constant by regulating one's own speed. Hence, time should essentially be understood in terms of timing decisions and actions in a dynamic and emergent environment.

DECISION MAKING AS A PROCESS

Decision making is an ongoing judgment about timing, essentially following emergent patterns in an environment. Therefore, managing uncertainty where there are too many unknowns, with occasional exceptions of acts of volition, evokes a process perspective on decisions. Decisions are not isolated but related in an ongoing process indistinguishable from perception as a flow of experience. More generally, this perspective is often associated with Whitehead's process philosophy and American pragmatism, which emphasises changing conditions and thus the need to learn in everyday situations; this has also inspired alternative streams of research in organisation theory.[12] A process view on decision making tends to emphasise its context and continuity to the point where decisions are not made, as much as they happen as a consequence of broader contexts and circumstances and for many different reasons. This has sometimes been emphasised to the point where bounded rationality has become understood as mere irrationality,[13] or used rhetorically to mock beliefs in rationality.[14] Ocasio (1997) argued that this interpretation is overly negative and disregards the organisational aspect of distributing selective attention through the assignment of different tasks and positions, making organisations capable of doing things individuals cannot do through specialisation and division of labour.[15]

MANAGING AS DESIGNING

While the above view of decision making as a process leaves little room for volition or active influence on circumstances, it can also be interpreted in more active ways, consistent with Simon's (1996) call for a design attitude for managers: 'Engineering, medicine, business, architecture, and painting are concerned not with the necessary but with the contingent – not how things are but how they might be – in short, with design'.[16] Simon argues that limited cognitive capacity leaves only a few aspects and alternative solutions to be considered in any situation, but the first step is always to create a representation of the problem, which typically has the solution hidden in it. While a decision attitude has a default idea of the problem, a design attitude starts by questioning how the problem is represented.[17] Hence, despite ambiguity about what aspects are essential and

10. c.f. Eriksson, 2004
11. Gigerenzer, 2010
12. c.f. Tsoukas and Chia, 2002
13. c.f. Ocasio, 1997; Gigerenzer, 2010
14. c.f. Brunsson, 2006
15. Ocasio, 1997
16. Simon, 1996, p. xii
17. Boland and Collopy, 2004

sufficiently attended to, there is a possibility to address this uncertainty and to (re)design both self through organising, decisions and action, and situations as well as aspects of the environment, without claiming predictive power or once-and-for-all permanent organisational 'stovepipe' solutions.

MANAGING AS ENACTMENT

Managing such co-emerging situations will have intellectual, practical and emotional aspects – how we think about uncertainty, how we respond to it, and how we feel about it.[18] As uncertainty or ambiguity will be omnipresent through differences in selective perception, sensemaking processes[19] will guide any understanding and response to situations. Furthermore, responses will influence how environments are enacted and how risk and timing of decisions are perceived.[20] Fostering a critical design attitude that questions assumptions will influence cognition and the perceived flow of experience, thus opening up alternative outcomes over time and increasing variation and exploration.

MANAGING SECOND-TRACK PROCESSES

Brehmer's theorising offers several options for further theorising in line with the research agenda for second-track processes suggested by Massingham (2019).[21] First, Brehmer's ongoing concern over decades was how to cope with dynamic situations of great complexity, which inspired an intellectual journey questioning many fundamental assumptions in management, both in civilian and military contexts. As Boland and Collopy (2004) suggest, the decision-making orientation of established theory has an attitude that hinders the search for new options and solutions instead of assuming the situation is a matter of choice between ready-made alternatives.[22] A design attitude instead seeks to challenge established assumptions, looking for new angles to tackle practical challenges in the real world. It is effective because it takes place in and interacts with the natural world, rather than seeking to implement abstract ideal types. To Brehmer, designing became the solution not only to decision making but also to the ontological matters of command and control (C2) and organisational structure, concluding that structural dimensions must be a matter of ongoing design work to match changes in a dynamic environment. Suppose the purpose and function of organising can be met by a fully distributed and flat form of organising. In that case, the design should be control without a commander,[23] as demonstrated by empirical evidence from experiments and ultimately tested by ongoing experimentation in real life.

In the following, Brehmer's work is presented, focusing on his most cited article on dynamic decision making and his last book, published only in Swedish the year before he died. After that, Brehmer's theorising is illustrated using two cases. Finally, Brehmer's contribution is discussed from the perspective of broader challenges of managing and coping with complexity and uncertainty.

BREHMER'S THEORISING

Berndt Brehmer (1940–2014) was a professor of psychology at Uppsala University, who established C2 science at the Swedish Defence University in 1997. He was a renowned academic and member of The Royal Swedish Academy of Letters, History and Antiquities and The Royal Swedish Academy of War Sciences. Brehmer's somewhat idiosyncratic theorising in decision making and organising, especially in crisis management and military C2, was recognised by the international community and received the Enduring Achievement Award at the International Command and Control and

18. Drehborg et al., 1994
19. Weick, 1995
20. Weick, 1995
21. Massingham, 2019
22. Boland and Collopy, 2004
23. Brehmer, 2009

Technology Symposium (ICCRTS) in Santa Monica in 2010. As an intellectual, he continuously revised and developed his thinking, and his last book was published in Swedish only in 2013, shortly before his death. While Brehmer published numerous articles in English, his theorising was never summarised for an international audience.

In contrast to the more one-sidedly negative theme of irrationality and decision biases, Brehmer's theorising developed through his most cited article on dynamic decision making in uncertain environments, exploring sensemaking via Boyd's OODA-loop (i.e., the cycle of 'Observe-Orient-Decide-Act'), which dominates military C2 thinking. He formulated C2 to design interaction within and concerning the organisation's environment. Hence, adaptation to dynamic and uncertain environments was at the heart of his theorising, interpreting organising and C2 both for the internal system and the external system, thus addressing the fundamental strategic question about adaptation to the environment. While formal hierarchical structure and authority are dominant in the military heritage, they also feature in civilian administrative theory, not least through Fayol. Brehmer instead defined C2 as a function, that is, what comes out of organising efforts, leaving it open for contextual conditions to decide what form it may take, hence: first 'purpose', then 'function' and last 'form'. This thinking paved the way for an award-winning paper with the provocative title 'Command without commanders', where several experiments in a computerised setting showed that firefighters were more efficient when working without any specific orders.

Both the attitude towards theory and the emphasis on testing theories, for example, through experiments, were guided by Brehmer's background in pragmatist traditions of thought and the insistence on the empirical testing of ideas. However, these were approached without positivist claims of representing reality and validating the conceptual frameworks that generated the tested hypotheses. He was deeply sceptical of simplified, linear models of cognition of behaviourism. Brehmer's research into decision making and risk spans a broad field of subjects, from road traffic safety and control of industrial processes to military and crisis management. Furthermore, while his later theorising was strongly associated with military, civil/military or crisis management applications, Brehmer claimed his C2 theory to be generally applicable in different fields with sufficient complexity and uncertainty, including advanced medical care.[24] Below, Brehmer's theorising is presented through his most cited article and his last book, which appeared in Swedish in 2013.

DYNAMIC DECISION MAKING

In his most cited article, 'Dynamic decision making: Human control of complex systems',[25] Brehmer reviewed the research on decision making under conditions requiring a series of decisions that are not independent of each other, where changes in the environment occur both autonomously and as a consequence of the decision maker's actions, and where decisions are made in real time. He remarked that it was challenging to find normative theories for this situation and that research had mainly become descriptive. Consequently, he suggested a general approach based on control theory to organise research in the area, as well as an experimental paradigm of computer-simulated microworlds for the study of dynamic decision making. However, 'Humans make decisions in increasingly complex, highly uncertain, and dynamic environments that evolve over time in intricate ways... Surprisingly, the area of behavioural decision research has little to offer in terms of theoretical principles and practical guidelines on how people make decisions in dynamic situations'.[26]

24. see Lagerstedt, 2016
25. Brehmer, 1992
26. Gonzalez, 2022, p. 15

The experimental approach suggested by Brehmer (1992)[27] aimed at assessing the effects of system characteristics on decision makers' behaviour in dynamic tasks. This required a taxonomy of tasks according to aspects affecting performance as the first step towards further theorisation, namely: complexity, feedback quality, feedback delays, the rate of change, the relation between the characteristics to be controlled and those of the process used for control, and finally, the extent to which the decision-making power in the system can be delegated or distributed among persons in the system. One of the general findings from these early experiments was that decision makers are poor at handling systems with long feedback delays.[28] Brehmer (1992) commented that feedback delays are inevitable in most complex systems and that the ability to cope with such delays is a central feature of handling complex dynamic systems.[29] He furthermore concluded that since feedback delays and side effects are common aspects of real-world systems, decision makers dealing with complex dynamic systems should be expected to show a suboptimal level of performance.

COMMAND AND CONTROL AS A DESIGN SCIENCE

Brehmer's last book, *Insatsledning*, discussed and clarified the C2 science he had established at the Swedish Defence University. It summarised his research effort and revealed that he believed he had more work to do: 'The purpose of this book is to introduce command and control science as it developed during its first fifteen years at the Swedish Defence University. The book should be seen as a status report, a description of how far the work to establish the subject has come and not as a final report. Much remains to be done.'[30] He immediately clarified that the intention was not to describe C2 as it was performed in Sweden or any specific country but to describe the character of C2 science, its fundamental problems, current solutions and at what price they come. In other words, nothing less than to lay the theoretical foundation for science about and for C2.

C2 science, like many other disciplines, has emerged with a practical intent – in this case, to support the development of new C2 systems that are possible through the progress made in information technology. This also puts C2 science in the realm of the design sciences.[31] Unlike natural or social science, the purpose of which is to study what already exists, design sciences aim at what does not yet exist. The practical context is the ambition to tear down traditional hierarchical 'stovepipe' organisations in the pursuit of 'network centric warfare', not least through the US Department of Defence's Command and Control Research Program 1994–2011, which also had its counterpart in Sweden and other countries. As a research discipline, C2 science should follow pragmatist criteria for scientific endeavours, namely, to achieve its goals via a design solution, with generalisability through the formulation of more general design suggestions, expressed in terms of their functions to be adapted in local applications. Hence, the purpose of C2 science is to formulate general design rules and describe how these can be adapted to specific conditions.

From a design perspective, C2 is nothing but a response to the requirements of the environment. Contrary to the civilian use of the term 'command-and-control' mainly as shorthand for 'bad hierarchical management', the term C2 in this context does not say anything about what form it takes – it may or may not be hierarchical and should always be functional.

27. Brehmer, 1992
28. Gonzalez, 2022
29. Brehmer, 1992
30. Brehmer, 2019, p. 9, author's translation
31. c.f. Simon, 1996; Boland and Collopy, 2004

The construction of an artefact (such as C2) has five levels, which designate the knowledge needed to perform the design work. The upper level concerns the purpose of the artefact, that is, why it should exist and what should be achieved by constructing it – in the case of C2 building systems that contribute to direction and coordination of efforts. On the next level, the design criteria should characterise how the artefact fulfils its purpose. These are founded on the demands of the external system. The environment presents to the artefact – in the case of C2 agility, whether it can cope with complexity and handle frictions and delays. The third level is the function, which describes what the artefact should do to fulfil the purpose. Functions stem from a theoretical analysis of what is needed to achieve the artefact's purpose. The analysis results are then tested in the design to explore whether a satisfactory artefact can be constructed given the functions specified by theory or by using theory to explain existing artefacts – in the case of C2, the functions are effects, data collection, orientation and planning. The fourth level of general processes represents the general scientific knowledge from which ideas can be retrieved concerning how the functions could be realised in form. Finally, the fifth level – form – represents the final artefact – in our case, the C2 system.

Brehmer insisted that C2 science does not promote any specific design or form per se. Instead, it is driven by the need to find new and better ways of organising, new methods, and roles or support systems that contribute to the C2 systems' ability to cope with complexity, handle frictions and delays and create greater agility than before. As the environment is constantly changing, with the development of new technology, new tactics, and new communication systems, as well as new forms of conflicts, disasters or accidents, the study of the external system, the environment and its requirements for C2 will never end. Identifying new requirements that the C2 system should meet or defining the design criteria is an ongoing challenge so the questions will reoccur:

- Why? (purpose)
- In which way? (design criteria)
- What? (function)
- What can be used? (general processes)
- How? (form)

There is no single scientific discipline that can answer all these questions. Instead, answers and suggestions may be found in engineering, behavioural sciences and social sciences alike. Another source of inspiration may be other artefacts constructed for purposes other than C2. Network-centric warfare, as well as social media, may be such examples.

COMPLEX UNDERTAKINGS

On the international C2 stage, Brehmer stood out for his somewhat idiosyncratic way of theorising, not least about complex undertakings, such as civil-military collaboration and similar situations of multi-agency collaboration where no traditional hierarchical management solution was applicable for reasons of legality and legitimacy. In the face of crisis, legal arrangements for formal collaboration may not be in place. For many civil organisations, such as the Red Cross, it could be devastating for their reputation and trustworthiness to subordinate themselves under other organisations' commands. Much of the theorising around the ambitions of network-centric warfare focused on how different military branches should be able to collaborate across hierarchical borders in stovepipe-like organisations, hence developing classifications of different levels of collaboration.

Brehmer's design methodology led to a different way of thinking, starting with the requirements of the environment and first then asking questions about what *form* could best meet those. Consequently, his award-winning paper 'Command without commanders'[32] may have appeared

32. Brehmer, 2009

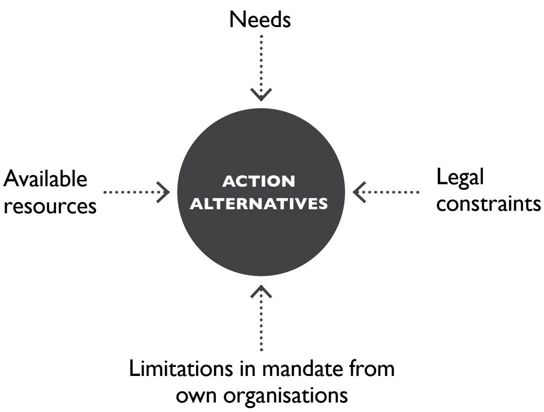
counter-intuitive if not shocking to a military audience to which hierarchical organising is mostly an axiomatic belief. Brehmer's experiments, however, showed repeatedly that firefighters without commanders were more efficient in their tasks than those having to follow the commands of a superior.

Complex endeavours involve collaboration between different organisations or parts thereof, typical in national emergencies, international disaster relief efforts or a comprehensive approach to civil-military collaboration. According to Brehmer, such situations differ from ordinary direction and coordination within one organisation in five ways.

1. A complex endeavour has several foci (or centres of gravity in military terms), and the criteria for success involves that every part should be able to bring their service.
2. Complex endeavours focus on a totality rather than one.
3. A complex endeavour often starts with several parallel efforts and the need for coordination and possibly a common direction appears as the situation evolves.
4. The focus of coordination is on independent organisations rather than on individuals.
5. There is no unity of command across different organisations and no simple hierarchical order as an organising principle.

In such situations, collaboration is the only possible way to achieve coordination and direction. In line with the design logic presented above, collaboration is seen as the *function* that achieves coordination and possibly direction. The question of *how* collaboration is achieved is specific to each situation since it all depends on the actors involved and what legal and other circumstances define it. At any rate, the design methodology remains the same: to achieve direction and coordination (purpose) within the limits of legal frameworks, negotiation mandates, possible influence on the complex endeavour (design criteria), effect, data collection and orientation (function). Of crucial importance is the ability to create and make choices within what Brehmer, inspired by Rasmussen (1997),[33] called the possibility space, that is, the degrees of freedom to be resolved according to subjective preferences. The possibility space is constructed through the information available, and the choices filling this space should represent alternatives available for the collaboration partners. Figure 1 shows what such a possibility space may look like:

FIGURE 1. THE POSSIBILITY OF SPACE IN COLLABORATION BETWEEN ORGANISATIONS[34]



As the possibility space in Figure 1 is the result of considering all limitations, it will consist only of available action alternatives. Given the circumstances, the possibility is that space may as well be wholly empty or non-existing, for example, if some of the restraints make it impossible to generate any alternatives. In such cases, there is nothing to agree on. When action alternatives are available, they need to be complemented with value functions for making a choice between them, which is a matter of negotiation between collaboration partners. In complex endeavours, the planning function does not typically exist in

33. Rasmussen, 1997
34. Adapted from Brehmer, 2013, p. 147

the coalition's design hierarchy but within the respective organisations themselves. However, such a joint planning function may develop over time. A related notion is one of harmonisation of efforts, where collaboration is made in the spirit of cooperation, by the method of negotiation and in substance, means the management of interfaces.

Despite the challenges to the internal system in complex endeavours, the fundamental challenge to match the external system remains the same. Therefore, the notion of possibility space remains crucial. In the case of antagonistic threats, such as in military applications, the possibility of space is limited by seven factors:

1. the task given;
2. own resources;
3. available time;
4. terrain;
5. rules of engagement;
6. adversaries' possibility of space;
7. doctrine, which also includes training.

The possibility of space exists only for a given time – after only a short while, the situation may have changed. Consequently, it is crucial to know that time influences the possibility of space and how much time is available. To discover action alternatives within the limitations of any situation is a matter of creativity. Unfortunately, an adversary will have a corresponding possibility space and creativity to extend it according to their skills and initiative. Hence, in real-world situations, the awareness and management of the possibility space are decisive for developing the situation.

In non-antagonistic disaster relief situations or applications in other domains, time may still be crucial as situations develop, influencing the possibility of the development of space. Wise and timely management of the possibility space may extend it and the range of action alternatives for all collaboration partners. The management of the possible development is described as a case of dynamic decision making or with an emphasis on the generation of new alternatives – an illustration of managing as designing.[35]

DYNAMIC DECISION MAKING – TWO CONTEMPORARY CASES OF CRISIS MANAGEMENT

When Professor Berndt Brehmer pioneered the research field that was grounded on the application of system dynamics and system thinking to military command and control, it was with an intent to gain an understanding of why and how managerial and strategic decision making seemed to be associated with significant difficulty among the practitioners of crisis management. These were typically 'first responders', such as firefighters, police officers, paramedics and military commanders. He found that dynamic decision making (DDM) research could provide important insights into these difficulties and highlight possible remedies. Not surprisingly, these remedies were closely tied to how training and exercises among first responders were conducted. As mentioned earlier in this paper, decision making at a strategic level of command is no different from lower levels, operational and tactical, when handling the dynamic complexity of typical crises.

The primary theoretical basis for DDM is common ground concerns about interdependent decision making. This takes place in an environment that changes over time, either due to the previous actions of the decision maker or due to events that are outside of the decision maker's control. Typical for emergency response and crisis management, decisions need to be made in real time: the decision maker has to consider the dimension of time explicitly. It is not enough to know what should be done, but also when it should be done, to achieve optimal results. As an analytic tool

35. c.f. Boland and Collopy, 2004

ideal for DDM, system dynamics provides the language that visually demonstrates how seemingly simple model structures could result in highly complex (even chaotic) behavioural processes when subjected to mathematical/numerical simulation in a computer program.

Brehmer argued that a crisis and crisis management process undergo two critical points during its timespan.[36] The first is, of course, the outbreak or 'trigger event'. At this point, it is critical to detect and interpret correctly the weak signal[37] that is usually associated with the outbreak. If the crisis is not successfully handled at this early stage, usually by some first-response measures, the next critical point will be at the intersection of resources needed and resources available (Figure 2). This is where the demands of the crisis management situation (for example, a fire spreading) overshoot the resources (for example, firefighting units) we have at our disposal to 'combat' the crisis.

Beyond this intersection, which we might call the 'tipping point', it is no longer possible to attack the crisis using direct approaches. Instead, one needs to apply resources under indirect control and indirectly attack the source of the crisis. For example, with a forest fire, a direct approach would be for the firefighters to use water hoses to spray water directly at the base of the fire. An indirect approach would be to clear the area's flammable material before the fire spreads to that area.[39] Conversely, the additional resources needed may not be under direct control. Instead, the fire chief may have to call on off-duty reserves and perhaps voluntary firefighters from nearby stations.

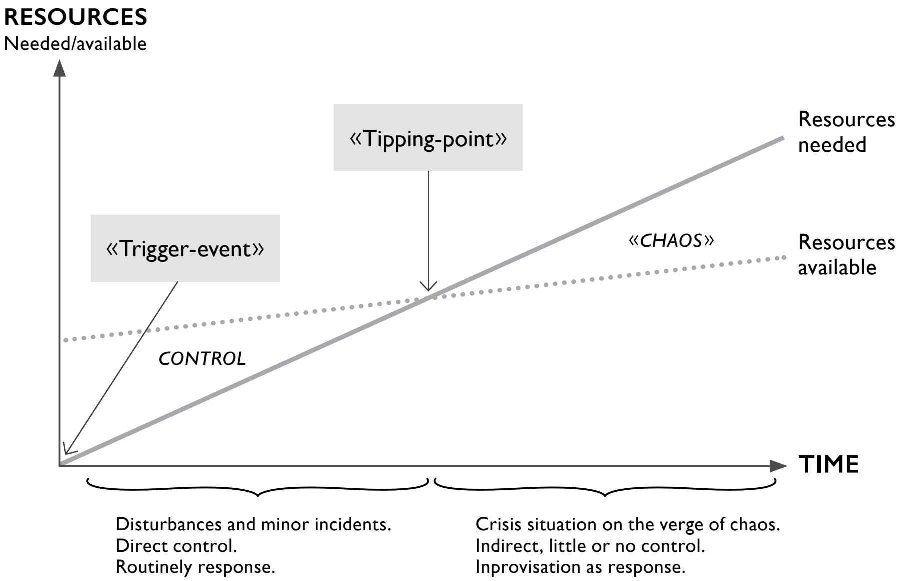


FIGURE 2[38]

36. Brehmer, 2002
37. Ansoff, 1975
38. Adapted from an original Bakken and Hærem (2020) (Norwegian language) publication; this version adapted from Brehmer (2000)
39. Brehmer, 2002

These resources may take longer to deploy because of extended travel and preparation time. It is also uncertain whether these additional resources are available or occupied elsewhere.

It is unarguable that when crisis management is situated in the region to the left of the tipping point, it has the character of day-to-day routine, following procedures familiar to most first responder units – with few or no surprises to the decision maker. The structure of a 'left-side' decision-making process may follow the OODA loop, which emphasises quick, routine decision making in a domain where familiarity, experience and expertise will be helpful if not necessary. In a typical combat situation, making the optimal decision is usually associated with thinking and acting faster than the enemy. In addition, Gary Klein's (1997) RPDM model[40] (recognition-primed cognition) will be of relevance here – the decision making is triggered by almost instant recognition (from previous experience) and allows quick and decisive handling of the crisis.

To the right of the tipping point, however, the relevance of routine, experience and established procedures may fall short, and instead, improvisation may be vital for handling the crisis. When the decision maker discovers (eventually) that their experience is not valid in the situation, the process of sensemaking[41] becomes vital. In particular, proactive sensemaking is crucial for crisis management in which a quick response is of the essence when there is significant uncertainty and there is much value at stake. Being proactive in a crisis requires that the proper mental models, encompassing the dynamic complexity of the situation, are in place beforehand (usually a product of massive training and exercises). This is because the great paradox in crisis occurs when the situation is most urgent (and intensifying), and the critical resources needed are farthest away (and diminishing).

Hence, decision making on the verge of chaos entails agility of command. While static top-down hierarchical command organisations may do the job to the left of the tipping point, moving beyond the intersection requires a dynamic or agile organisation where the command authority is pushed downward in the ranks, opening up for mission command or command by intent. This also emphasises the potentially crucial role of the 'strategic corporal' and command without commanders, as already noted. The problem with this dynamism is that it is seldom, if ever, exercised at a larger scale and, therefore, mainly unknown to the personnel. Hence the strategic surprise element of crisis management.

The crucial point is that a decision maker should be trained in strategic decision making and sensemaking to have acquired complex mental models (of non-linear delayed feedback) to be successfully proactive.[42] The idea is to 'foresee' the tipping point and engage in processes that involve indirect control regarding the supply of resources and how the resources are applied. In this crisis management phase, improvisation may be necessary, as the alternative is the total loss of control and chaos.

We argue that the most common source of a surprise in crisis management comes from not having undergone broad and deep crisis management training, which also triggers elements of indirect control.[43] The indirect courses of action (right side of the tipping point in Figure 2) are by nature less frequently encountered in real-life crisis management and, therefore, in greater need of training and exercises to be successful, compared to more routine, everyday situations. This kind of training is more challenging and resource-intensive because both types of strategies (direct and indirect) may be applied

40. Klein, 1997
41. Weick, 1995
42. see Gonzalez et al., 2017
43. see Brehmer and Dörner, 1993; Bakken and Gilljam, 2003a, 2003b

simultaneously. However, indirect strategies tend to be more costly financially and inconvenient to the public than direct strategies. In addition, they may take longer to apply (and therefore yield more significant losses) if not prepared in advance.

To illustrate a crisis that entails direct and indirect strategies, we can take the ongoing energy crisis as an example from the recent COVID-19 pandemic.[44] The Russo-Ukrainian war has allegedly triggered the energy crisis, in which Russia's strategy has been to cut off much of the energy supply to Europe. This is combined with sanctions from the EU countries to ban much of the Russian energy supply to Europe. This has led to a price surge, making it extraordinarily costly for households to keep up their energy consumption for heating and cooking and a price increase in other sectors as industry and public services are also faced with steeply increasing prices.

The dynamics can be analysed as follows: in a normal situation, there is an instantaneous balancing between the supply and demand of energy through the pricing mechanism in the market. Energy is produced in a process where the marginal production cost over time equals the average production cost. Prices may fluctuate in the short run but do not dramatically deviate from the long-term average, and not for a longer time.

Now for the crisis: a pivotal point occurs when the influx of 'raw materials' (water, gas, oil) is no longer enough to replenish the volume used in production, and the projection indicates that this situation may endure. This pivotal change takes us to the tipping point, where marginal production costs rise dramatically and possibly in an exponential growth fashion. Since consumers of energy (in the short run) have few alternatives to electricity or gas, prices to consumers also skyrocket (prices to be inelastic).

The industry and public services also face these higher prices, which feed into the process of consumer goods, leading to inflation and higher interest rates. The problem is aggravated by energy production companies wanting to harvest the high prices and sell out whatever energy is left in the reservoirs or storages at the highest possible prices. This positive feedback loop will inevitably lead to an accelerating drain of energy reserves until power has to be cut off and consumers and industry have used reasonable alternatives to electricity or gas. The remedies are, of course, to apply indirect control strategies, as illustrated in Table 1 below.

TABLE 1: DIRECT AND INDIRECT CONTROL DURING THE ENERGY CRISIS

ENERGY CRISIS – ELECTRICITY (national perspective, waterfall source)		RESOURCE AVAILABILITY AND SUPPLY (type of control)	
		Direct	**Indirect**
Resource application (type of control)	**Direct**	Supply and demand are balanced through a pricing mechanism.	Overseas/cross-border cables for international exchange of excess electricity.
	Indirect	Alternatives to receiving electricity from the national and regional power grid: solar power, wind power, sea turbines, heat pumps, energy conservation.	Alternative, renewable energy sources are also connected to an international grid for exchange. Nuclear power. Cold fusion (future?)

44. see Bakken and Hærem, 2020

Table 2 below shows examples of combinations of direct and indirect strategies applied analogously to a military campaign depending on whether the resources are under direct or indirect control.

TABLE 2

MILITARY CAMPAIGN EFFECTS-BASED APPROACH		RESOURCE AVAILABILITY AND SUPPLY (type of control) Direct	Indirect
Resource application (type of control)	Direct	Tactical level combat (attrition principle).	Total defence concept; military and civilian collaboration.
	Intermediate	Operational-level warfare (manoeuvre principle).	Joint operations with support from coalition forces.
	Indirect	Network centric warfare (NCW), including Specops, Psyops, Humint, Time sensitive targeting (TST), Hybrid threats, and Long-range missile strikes.	Joint operations with integrated coalition forces. Trans-national measures (DIME), including economic sanctions, diplomacy, negotiations, and information (propaganda).

These examples illustrate the profound challenges that may face organisations in times of crisis, especially when the possibility space has not been correctly estimated or insights of tipping-point character have been missing in doctrine, including training. Gonzalez et al. (2017) referred to results from laboratory experiments using complex DDM tasks as well as cognitive models, arguing for training recommendations that:[45]

1. allow individuals to learn at a slow pace to help them adapt successfully to more significant time constraints;
2. train individuals with a diverse set of experiences to increase the possibilities of effective adaptation to novel situations; and
3. use reflection over an expert's performance during training to reinforce instances of high quality instead of a reflection of self-performance of outcome feedback, among others.

To deal with dynamism and uncertainty, timing in managing or designing the development possibility space is crucial. This, in turn, is a matter of training allowing for such expansion of possibilities through negotiations within collaborative constellations and with the environment.

DISCUSSIONS

The purpose of this article was to present Brehmer's take on dynamic decision making under uncertainty and discuss its broader implications. Essentially, it was an intellectual journey of fascination with the complexities of human logic and its possibilities despite cognitive shortcomings. Brehmer's theorising stood out internationally both in its form, starting in pragmatism in a time where it was just about forgotten and ending in managing as designing, and in its content, delivering counter-intuitive results, challenging taken-for-granted assumptions through award-winning experiments.

45. Gonzalez et al., 2017

All this without losing focus on practicality and reason for the sake of esoteric speculation. Instead, Brehmer's work took on the most challenging novelties driven by technological developments within information technology at a time where it challenged century-old traditions of organising in one of the oldest professions, the military, which has been the role model for hierarchical, structure-oriented ways of organising both industry and administration. The contribution was at once practical and profound and has been characterised as 'directed basic research'.[46]

This journey culminated in exploring situations where hierarchical order and unity-of-command cannot exist or are ineffective, such as in complex collaboration between organisations that by law or legitimacy must be independent or where experimental evidence demonstrated the efficiency of distributed solutions and command without commanders. In this way, Brehmer's work took on the most complex challenge of learning: to unlearn earlier knowledge, often in the form of taken-for-granted assumptions.[47] A design attitude showed to be an appropriate tool for this task of questioning assumptions for the sake of practicality and usefulness of new solutions in pragmatist defiance of tradition, instead making room for human imagination and experimentation. This intellectual play brought about a notion of C2 and managing as designing possibility spaces by boundedly rational humans, yet capable of introspection, meta-cognition, self-reflection and experimentation in the face of uncertainty and threat, as opposed to behaviourist views of humans as cognitively limited, if not faulty, decision automata.

Brehmer's theorising took on many of the challenges nowadays known as second-track processes, not least concerning complexity, cognition, uncertainty and organising, especially regarding the logic of negotiation in complex endeavours. Nevertheless, Brehmer's work also links recent attention to second-track processes to long-standing debates in technology, social sciences and philosophy of science. While Kahneman and Tversky made behavioural economics famous, their take on uncertainty in decision making was not self-evident, and their framing was not innocent in that it excluded the perhaps most common way of handling uncertainties. Namely, use the time to resolve uncertainty in dynamic situations rather than static once-and-for-all decision making. This addresses the roots of thinking about uncertainties and learning the earliest works of American pragmatism towards the end of the 19th century. Already the insights about the selectivity of attention imply ambiguity and, thereby, uncertainty. Time as a solution is the fundamental aspect opening up for dynamic decision making as an ongoing judgment of timing. In extension, a design attitude focuses on the generation of alternatives expanding the possibility space, rather than merely choosing among existing alternatives of action.

As much as this may sound like a recipe for managing second-track processes, it is also a recipe for managing through enactment in direct interaction with the world, albeit a less than objective one understood through the necessity-biased perception of boundedly rational actors.

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46. Johansson and Sahlin, 2015
47. Hedberg, 1981

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