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Uncertainty and information causality in opportunity-as-artefact driving entrepreneurial actions

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Abstract

Purpose – Entrepreneurs prioritise and act on purposeful endeavours instigated to actions by the visions of profits and benefits in the perceived opportunities. In the state of maximum entropy, with disorderliness and disequilibrium, entrepreneurs select the preferred pathway, through the profit-sensing mechanism, with the best probability of success to bet on. Therefore, this paper unpacks the forces at work in the mechanism to explain how entrepreneurs respond to opportunity and interpret the signals to coalesce into organised actions.

Design/methodology/approach – This research is primarily a conceptual paper on entrepreneurial action and the mechanism leading to that action. It refers to thermodynamic principles and biological cases to explain the forces at work using mostly analogical comparisons and similarities.

Findings – This paper aims to present an alternative theoretical scaffolding for entrepreneurship researchers to explore non-rational entrepreneurial behaviours and actions in uncertain, unstable and non-equilibrium environments, thereby creating new and competing hypotheses under the backdrop of adaptive evolution and thermodynamics phenomena.

Research limitations/implications – The discussion featuring instinctively and naturally forming responses cannot fully explain the real entrepreneurial action as there is an element of free will and choices that are not discussed. While strategic choice and free-will shape decisions, they are preceded first by the attraction of the gradients and the biased motion in the direction of profit-attractant.

Practical implications – There remain essential links and issues not addressed in this "natural science", constituting life science and physical science, oriented entrepreneurship research and exploration. Conceptualising opportunity-as-artefact and entrepreneurship as design, significant incidences of entrepreneurial actions can be explained by the presence of gradients stimulating entrepreneurial actions.

Social implications – This viewpoint of information causality in opportunity-as-artefact casts a new look at the venerable question of what causes entrepreneurial actions. Shane and Venkataraman brought into focus this conversation, initiating the conceptual definition of opportunity. To have entrepreneurship, entrepreneurial opportunities must come first. Figuring the signals arising from these opportunities and cueing entrepreneurs to action is the main focus of this study.

Originality/value – Considering the "mechanism" at work and the thermodynamical forces at play, the entrepreneurial design process appears to hold considerable promise for future research development.

Keywords Entrepreneurship, Opportunity-as-artefact, Information, Thermodynamics, Entropy

Paper type Conceptual paper

Introduction

Yet if we have learned anything from engineering, biology and physics, information is just as crucial an ingredient. The robot at the automobile factory is supplied with metal and plastic but

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> can make nothing useful without copious instructions telling it which part to weld to what and so on. A ribosome in a cell in your body is supplied with amino acid building blocks and is powered by energy released by the conversion of ATP to ADP, but it can synthesise no proteins without the information brought to it from the DNA in the cell's nucleus. Likewise, a century of developments in physics has taught us that information is a crucial player in physical systems and processes (Bekenstein, 2003, p. 59).

Information is crucial to driving action and processes and any synthesis of systems. In information theory, the entropy of any random variable at any given time is the average constituted "information" or "uncertainty" in the variable's possible outcome (Shannon, 1948). "Information theory, on the other hand, teaches us about our physical ability to store and process information" (Vedral, 2002, p. 1). For example, business venturing constitutes a series of decisions that have to be made, consciously or unconsciously, by assessing the feasibilities, evaluating the alternatives and drawing out the consequences of the various alternative actions (Vedral, 2002). The underlying driver is the information processing capacity and capability of the entrepreneurs. Gomes, Seman, Berndt and Bogoni "analyse the mediating role of organisational learning capability and service innovation within entrepreneurial orientation and organisational performance relationship in knowledge-intensive organisations" (Gomes, Seman, Berndt, & Bogoni, 2022, p. 39). Entrepreneurs' learning capabilities and performance are driven by information. It has to do with the entrepreneurs' informational frames of reference; their entrepreneurial orientation dictates how they process and make sense of the information. Information and uncertainty are integrally associated with complexity. Uncertainty grows with too much information, or uncertainty appears when information is scarce. The core idea in information theory is in the communicated message's "information value" and the degree to which the information value generates uncertainty. In any case, the amount of information impacts the moderation of uncertainty. Therefore, information has to be considered to reduce uncertainty (Klir, 2006).

This viewpoint of information causality in opportunity-as-artefact casts a new look at the venerable question of what causes entrepreneurship? Ultimately, how well entrepreneurs can distinguish opportunities-as-artefacts is determined by how much information they can encode in the artefacts and how quickly they can manipulate them to spur themselves into actions. Entrepreneurship builds and nurtures learning through the ingestion of information and knowledge to enable the formulation of innovative strategies that lead to better performance (Gomes *et al.*, 2022). Shane and Venkataraman brought into focus this conversation, initiating the conceptual definition of the idea of opportunity. "To have entrepreneurship, you must first have entrepreneurial opportunities" (Shane & Venkataraman, 2000, p. 220). Opportunity, as a concept, is elusive and ambiguous as it is argued amongst scholars if the opportunity objectively and independently exists before discovery or if it is created (Alvarez & Barney, 2007). Is opportunity real or artificial (Sarasvathy, 2003)? More importantly, the question is what in opportunity spurs action in entrepreneurs? We argue that the informational value within the opportunity instigates entrepreneurs to action. Hence, to provide interpretive flexibility to the notion of opportunity, we suggest that opportunity be contextualised as an artefact.

> Opportunity represents an artefact, a viewpoint that challenges existing views of how opportunities are formed. The conventional emphasis tends to be on either discovery (i.e. entrepreneurial opportunities exist independent of the perceptions of entrepreneurs, just waiting to be discovered) and creation (i.e. opportunities are created by the actions of entrepreneurs) (Leong, 2021, pp. 2150021–1).

Therefore, opportunity-as-artefact is a convenient artificial construct that can be perceived as independently existing or existing "in the mind" of the entrepreneur interpreting

the information embedded in the artefact. It is the information that finally matters. Uncertain conditions can be ameliorated by acquiring and evaluating information (Petrakis & Konstantakopoulou, 2015). "Reading signals and deciphering information embedded in the opportunity-as-artefact is crucial for venture continuation because entrepreneurs must deal with uncertainty of various types, nature, scale and degree" (Leong, 2021, pp. 2150021–11).

One persistent core puzzle is why entrepreneurial opportunities appeal only to some individuals, not others? (Shane & Venkataraman, 2000). Do opportunities appear the same to entrepreneurs and non-entrepreneurs? Therefore, we argue it is not the appearance of the opportunity, per se, but the interpretation of the information in that opportunity-as-artefact that leads to the varied responses by the different observers. Opportunity needs to make economic sense and can only be interpreted from the information relating to that opportunity. Even when the opportunity is recognised, the non-entrepreneurs will not enact it since the seduction of profits appeals differently to them. Sense-making of the same opportunity differs amongst individuals (Weick, Sutcliffe, & Obstfeld, 2005). Making sense does not lead to the spontaneity of actions. It needs conviction of the opportunity's meaning with a deep personal commitment (Balog, Baker, & Walker, 2014). The pull of the vision or profitable endpoint must be so compelling that measures are taken to pursue the opportunity despite uncertainty. An entrepreneur's uncertainty-bearing and risk-taking propensity is a constitutional attribute (Brockhaus, 1980). "Yet, at the heart of the recognition and pursuit of opportunity is uncertainty and how it is dealt with" (Leong, 2021, pp. 2150021–3).

This paper attempts to provide a re-casted definition of opportunity as an artefact and the conundrum and clumsiness of the notion of opportunities propounded in extant literature. Many scholars urge a more explicit explanation of the concepts of opportunities. Dimov discusses the elusiveness of the concept of opportunity (Dimov, 2011). Berglund, Bousfiha and Mansoori seek to build opportunity with the design tradition's view of artefact (Berglund, Bousfiha, & Mansoori, 2020), describing it as:

> . . .opportunities-as-artefacts iteratively develop at the interface between organised individuals and their environments, where more or less concrete instantiations are used to drive the process forward. By conceptualising entrepreneurship as artefact-centred design, we provide an alternative to accounts inspired by economic theory, which have proven conceptually problematic and of limited practical use (Berglund *et al.*, 2020, p. 825).

Davidsson argues to ditch discovery-creation for a unified venture creation research (Davidsson, 2021).

This paper presents a theoretical research model contributing to the on-going dialogue on the opportunity. The method used offers a systematic construction of model narratives to synthesise Shannon's information theory (Barnum *et al.*, 2010; Gell-Mann & Lloyd, 1996; Shannon, 1948), Bohm's (1980) "Wholeness and the implicate order" and thermodynamic principles and critically examine and compare their similarities of the related concepts. The research intends to contribute to a clearer understanding of the antecedents and consequences of opportunity-as-artefact.

Finally, this paper reflects on how the information within the opportunity-as-artefact makes the construct of opportunity accessible with interpretive flexibility so that entrepreneurial action can be better explained with uncertainty and information. Uncertainty and information can be represented by the entropy concept between the environment and the entrepreneurs as they seek their opportunities under conditions of uncertainty. Information theory and thermodynamics, including entropy, provide helpful explanations to explain the entrepreneurial phenomena. This paper discusses how thermodynamic concepts and information theory inform this research.

The entrepreneurial journey should begin with a more straightforward question: how should entrepreneurs see uncertainty and information in opportunity (as-artefact)?

Artefact and artificiality

Sarasvathy (2003), in her "Entrepreneurship as a science of the artificial", connect four core themes from Simon's (2019) "The sciences of the artificial": (1) natural laws do not dictate designs though they constrain, (2) refrain the use of prediction in design, (3) locality and contingency provide the boundaries to the sciences of the artificial and (4) near-decomposability is a critical component in design (Sarasvathy, 2003). These four core themes help describe opportunity-as-artefact. Exploring artificiality in artefacts must avoid ontologising (Krippendorff, 2007). Instead, it must be centred on the entrepreneur-centred design perspective and interfaces around their environment. The interfaces include natural interactivity, understandability, reconfigurability and adaptability at one plane, and when engaged across the different hierarchical levels, it provides connectivity, accessibility and directionality (Krippendorff, 2007). By "making artefacts central to how we understand entrepreneurship as a practice, where such artefacts function as evolving boundary objects of sorts that relate individuals and environments as part of design-oriented practices" (Berglund & Glaser, 2021, p. 5). Opportunity-as-artefact becomes a convenient concept without the clumsiness and unbearable elusiveness in describing entrepreneurial opportunities (Dimov, 2011). Exploring artefacts from this perspective clarifies the phenomena and offers practitioners and scholars insights into the perplexing puzzle of what causes entrepreneurial actions. Information embedded within the opportunity-as-artefact, subject to interpretation and sense-making by entrepreneurs, leads to various actions or inaction. We overcome the clumsiness of definition by conceptualising opportunity as an artefact and an alternative conceptual anchor in entrepreneurship.

> Time represents a major piece of the puzzle in our understanding of opportunity from both an ontological and an epistemological perspective. At what point is opportunity to be deemed as opportunity? Is it when its profits are actualised or a venture proves to be profitable? Or is it before? If the opportunity enacted leads to a business failure with wasted resources and effort, does it still constitute as an opportunity if the failure happens as a result of execution failure (i.e. is it a true positive)? Or, let's say the initial opportunity belief turns out to be a false positive, is it still deemed as opportunity in spite of wasted resources and motion (Leong, 2021, pp: 2150021–6)?

Thus, the opportunity is hard to be grappled with and is "very difficult to establish since whatever profitable venture is actualised will, in fact, have depended on an unknown set of complexly interacting empirically unobservable generative mechanisms" (Berglund & Korsgaard, 2017, p. 3). Moreover, the complexly interacting emergent mechanisms with intervening levels of reality make it difficult to ascertain *ex ante* if the opportunity is real or false (Leong, 2021).

Fostering entrepreneurship ecosystems requires agentic (entrepreneur-as-agent) intervention, and a design approach may help understand why some ecosystems flourish, and others perish (Molina & Maya, 2017). The artificiality in artefacts embraces the perspective that the entrepreneurship ecosystem is a complex system, with interdependent and dependent interactions of agents at the various hierarchical levels. "The environment includes both the industry in which the business operates and the macro environment, including government and its policies. Based on, the environment in which a business operates affects the success of its idea" (Nikraftar, Hosseini, & Mohammadi, 2022, p. 91). The impact of the environment on the entrepreneurial venture is such that the entrepreneur responds to it creatively by abstracting and sense-making as much information from the environment as possible.

Therefore, the entrepreneurial journey is an emergent hierarchical system of artefact-creating processes (Selden & Fletcher, 2015) involving many agents and artefacts. The emergent process involves complex interactions of artefacts and agents that present opportunities and challenges. We argue that opportunity-as-artefact guides and informs

entrepreneurial actions with embedded information, and entrepreneurs respond creatively and adaptively.

Opportunity-as-artefact

To Berglund and Glaser, the concept of opportunity is the most abstract entrepreneurial artefact (Berglund & Glaser, 2021, p. 5). Shane and Venkataraman's "individual-opportunity nexus" shapes entrepreneurial dialogues. It is based on the behavioural outcomes premising on utility-maximisation and choices within a given means-ends framework (Shane & Venkataraman, 2000). However, even their description of the "individual-opportunity nexus" employs the use of a "nexus" artefact. They describe the boundary and the interaction space. Still, this view of the entrepreneur situated in the nexus fails to explain the "microdrivers of entrepreneurial actions" (Dimov, 2011, p. 61). The notion of opportunity as the impetus for entrepreneurial action is crucial. It must be clarified that opportunities are not all the same to all other observers and are not known to all persons at all times.

Some see it yet do not deem it an opportunity and are not convinced to act. Some see it, recognise it as an opportunity and do nothing about it. Some do not even see it at all. Some see it and put their best effort into pursuing the opportunity. Hence, it is not just the objective, independently existing opportunity waiting to be discovered. Klein prefers not to argue on ontological claims about the nature of opportunities but instead to refer to opportunity as a metaphor (Klein, 2008). Entrepreneurs often stand in the realm of uncertainty and have no complete foreknowledge of the future and their payoffs. As in Bohm's (1980) "wholeness", complete information is not accessible, and entrepreneurs abstract whatever information they can to make sense of the situation. Short of information, "people cannot be deemed to have acted rationally on the expectation that they would gain what cannot yet be fully or reliably defined before the action takes place" (Dimov, 2011, p. 61). Klein suggests that opportunities are best characterised as imagined as these deemed opportunities can be wrongly ascribed when a venture fails with losses or profits do not materialise. Therefore, opportunity cannot be seen as disappeared; it can only be deemed a "false-positive", and the entrepreneur is mistaken. "Entrepreneurs do not, in other words, create the future, they imagine it, and their imagination can be wrong as often as it is right" (Klein, 2008, p. 182).

Klein's conceptualisation that opportunity as a latent construct manifested in actualised actions is essential in many respects. He is not approaching and seeking to define opportunities on what they are but rather what they do (Klein, 2008). This is a helpful way to deal with the intractable arguments of whether opportunities are waiting to be discovered or created from the design perspective. However, these dialogues can be distracting and misleading once veered in that direction, since arguments are mainly semantics and meanings. It is, instead, what the opportunity does that is crucial. Entrepreneurship scholars should care less about the ontological pivot but instead focus on what opportunity can do to explain economic behaviour and entrepreneurial phenomena. Or, rather, what is it in opportunity that actually draws entrepreneurs to action?

> An opportunity epitomises the symbolic aspect of the interaction between entrepreneurs and their environments. It can be regarded as an evolving blueprint for action, synthesising the entrepreneur's sense of, expectations about, and aspirations for the future, and can help us understand what the entrepreneur does at every step of the way from within the worldview that the entrepreneur holds. As such, it can evolve with each subsequent entrepreneurial action (Dimov, 2011, pp: 62–63)

Under uncertainty, the study on entrepreneurial actions arising from an entrepreneur's sense of expectations about and aspirations for the future must be understood from how entrepreneurs interact with the environment and discover/create opportunities during their

interactions with the environment. Therefore, the fundamental purpose of this paper is to review and explore the various research streams that constitute the information problems (due to the differing interpretation of information embedded in the opportunity-as-artefact) at the boundary between the entrepreneur and the environment. Therefore, identifying the critical boundary condition of uncertainty and understanding the inherent ambiguity and complexity is crucial in entrepreneurship research.

Uncertainty, information and entropy

Townsend, McMullen and Sarasvathy explore entrepreneurial actions under ambiguous, uncertain, complex contexts to identify the critical boundary conditions of uncertainty as an analytical construct. "And yet, nearly a century since the unveiling of Knightian uncertainty as a precursor to profit-making, the identification, description, and operationalisation of uncertainty as a construct continue to exhibit conflicting definitions, tautological measures, and unwitting conflation with more precise constructs along the spectrum of ignorance and unknowingness" (Townsend, Hunt, McMullen, & Sarasvathy, 2018, p. 659).

From ignorance to unknowingness, entrepreneurs operate under such boundary conditions of uncertainty and yet have to make sense of it to develop their ventures further. Fundamental to our understanding of uncertainty is the need to know that all outcomes lie in a probability distribution (Vedral, 2002).

Cognitively constrained, entrepreneurs generally are unable to understand the universe of information available. They can only abstract from Bohm's wholeness (Bohm, 1980) owing to cognitive limitations by abstracting, bracketing and sense-making. There will be a discrepancy between expected and actual probability distribution because many unknown variables interact in any given situation, rendering the case to the point of "unknowing"/ ignorance. Such discrepancy frequently exists in real life, and the fact is that it is very rare for entrepreneurs to have complete information about any events. "Yet, despite these practical and theoretical challenges, uncertainty cannot be ignored" (Townsend *et al.*, 2018, p. 659).

> Uncertainty emerges as one has less information than the total information required to describe a system and its environment... It may be pertinent to point out that uncertainty manifests itself in several forms, and various kinds of uncertainties may arise from random fluctuations, incomplete information, imprecise perception, vagueness etc. (Karmeshu, 2003, p. 1).

Fuzziness, vagueness and blurriness are various linguistic terms used to define uncertainty. Townsend, McMullen and Sarasvathy use the word "unknowingness", which spans the entire landscape of human consciousness lying between ignorance and certainty—truly is ubiquitous, uncertainty is merely a subset of "unknowingness" (Townsend *et al.*, 2018, p. 660). "Uncertainty is central to entrepreneurship" (McKelvie, Haynie, & Gustavsson, 2011, p. 273) and "looms large within the domain of entrepreneurship research, colouring virtually every condition, context and level of analysis" (Townsend *et al.*, 2018, p. 661). Fuzziness, vagueness, blurriness and the indeterminacy of the future are a constant scourge in business venturing. Here, we discuss and define information in relation to fuzziness, vagueness, blurriness and indeterminacy and show how information co-relates to disorderliness. The measure of disorderliness involves the concept of entropy, derived initially from thermodynamics. Entropy represents a thermodynamic quantity often interpreted as the degree of disorder or randomness. The lack of order or predictability, with a gradual decline into chaos, is common in business venturing. Ventures, subject to contingencies, progress through cycles and phases and complexify with broader and deeper interactions (with the environment, other stakeholders, artefacts and agents). We argue that business venturing is moving away from determinism and predictability. Bruyat and Julien add that entrepreneurship "is much more

complex and heterogeneous than was thought in the 1980s" (Bruyat & Julien, 2001). "A major challenge facing entrepreneurship researchers in the 1990s is to develop models and theories built on solid foundations from the social sciences" (Bygrave & Hofer, 1992, p. 13). "The scientific world, however, is moving away from increased certainty, linearity, and simplicity and is grappling with issues associated with chaos and complexity" (Ofori-Dankwa & Julian, 2001, p. 427). We argue that entrepreneurship should be seen through the lens of chaos and complexity, information and entropy. "Entropy and information are very closely related" (Gell-Mann, 1995, p. 219). In fact, entropy can be regarded as a measure of ignorance. "Entropy is the basic measure of disorder in physics and information theory" (Khrennikov & Watanabe, 2021, p. 18).

> Given the opposite relationship between information and entropy, the diversity of socioeconomic structure (information in its aggregate way: H) reduces internal socioeconomic entropy to promote economic development by means of non-equilibrium market exchanges in which every price is a mix of information and entropy. Their respective proportions depend on disparities between supply (s_p) and demand (d_m) that fluctuate over space and time: a higher proportion of superfluously valued entropy is included in price formation when $d_m > s_p$, and vice versa (Rodríguez & Cáceres-Hernández, 2018, p. 74)

where $d_m > s_p$ or $d_m < s_p$ in the demand-supply fluctuation, the values of d_m and s_p are information. Information theory is neither concerned with the content of the information nor the amount of information the message conveys; instead, it is the informational value that matters. The subject of interest is the size of the message, also known as the "essential message". Shannon's (1948) "A Mathematical Theory of Communication", a seminal paper published in 1948, marked his information theory conceptualisation. This paper argues that information entropy is but missing information. The relationship is proportionate – the higher the entropy, the higher the missing information (MI); hence, the higher the uncertainty. "This principle of maximum entropy states that the equilibrium distributions are obtained by maximising the entropy (or the MI) with respect to all other distributions" (Ben-Naim, 2008, p. 24). Information theory thus sets the foundation by constructing probability distributions based on incomplete information/missing information (MI) that will lead to statistical inference called the maximum-entropy estimate (Ben-Naim, 2008). In maximum-entropy estimate, entrepreneurs act on the current circumstantial information and bet on the range of probabilistic paths.

The notion of entropy based on disorderliness, disorganisation and chaos relates to thermodynamics. The interpretations of entropy based on order-disorder correspond to the concept of information or missing information. Where information is complete and symmetrical, orderliness prevails. Where information is asymmetrical, uncertainty arises (McCain, 1985). Entrepreneurs act on the availability of information, social and material networks, resources and means to get from the intention stage to eventual enactment with a maximum-entropy estimate. The increase of entropy implies a decrease in information, diminishing orderliness; on the contrary, the reduction of entropy means an increase in information and orderliness. The level of information access improves the degree of self-organisation (Khrennikov & Watanabe, 2021).

The effects of sense-making of information uncertainty and information asymmetry impact entrepreneurial actions. In this case, entrepreneurs are information processors interacting with the information environment. Behavioural change arises from a shift in information state resulting from signals' recognition and interpretation. Uncertainties due to a lack of information have imputed risk premium. The empirical results of the Lu *et al.* study show that investors charge a significant risk premium for information uncertainty and information asymmetry (Lu, Chen, & Liao, 2010, p. 2265). In thermodynamic entropy, "(probability) distributions follow maximum entropy subject to constraints, where maximum

entropy is equivalent to minimum information" (Frank & Smith, 2011, p. 469). Put another way, the minimum information from the maximum entropic environment poses risks to entrepreneurs.

Thus, entrepreneurship is in a constant state of uncertainty, with evolving entropy. The entrepreneurial behavioural responses are based mainly on the interpretation of the information. The sense-making of the information and the successive enactment determine the degree of success or failure. Entrepreneurs are complexly adaptive and self-organised during the entire time, while situated in uncertainty in the entrepreneurial process.

Entrepreneurs operate in a "pluralistic set of environments than is typically imagined in the Knightian universe of risk and uncertainty. Because these environments operate under different decision logic (i.e. the logic of consequences versus the logic of appropriateness) and are impacted differentially by information (i.e. more information helps resolve uncertainty/ambiguity while more information exacerbates complexity and equivocality)" (Townsend *et al.*, 2018, p. 677).

One striking similarity in the extant literature on uncertainty is the role of information and the amount of it affecting the degree of uncertainty. "It appears as if everything is built of information" (Valentijn, 2021, p. 2). Particularly, when opportunity-as-artefact has information nested within it, how entrepreneurs relate to and interpret it impacts their reality and the subsequent entrepreneurial actions.

Discussion

As an abstracted object, opportunity-as-artefact contains information that triggers entrepreneurs to action. In the development of this narrative artefact (Berglund & Glaser, 2021), the use of analogies, metaphors including proven scientific laws and principles that emphasise and explain similarities with phenomena and concepts can be helpful since such directive notions facilitate communication and understanding under general ambiguity of the subject matter (Berglund & Glaser, 2021).

The information contains past experience, prior knowledge, present understanding of existing circumstances, availability of means and entrepreneurs' idiosyncratic interpretation of future prospects and size of profits based on their best estimates.

> Therefore, opportunity-as-artefact is an artificial construct that exists "in the mind" of the entrepreneur interpreting signals from the opportunity-as-artefact. The perception arises from the asymmetrical information from the market, which forms the signal. Therefore, entrepreneurs are constantly scanning and interpreting the signals in the face of uncertainty and adversity in their pursuit of opportunities (Leong, 2021, pp. 2150021–11).

Through the multitude of information strands, information somehow directs the entrepreneurs in a certain direction in the environment through signalling visualisation methods. The embedded information in the opportunity-as-artefact aggregates as information strands from the past (experience and knowledge) to the present (current contextual circumstances like competition, global economic conditions or events like the COVID-19 pandemic). Information shapes entrepreneurs' perceptions of their realities. Linking recognisable patterns of information from myriad sources form the basis of entrepreneurs' view of the situations including opportunities (Vaghely & Julien, 2010). The constructionist perspective of information processing is primarily trial-and-error or heuristically derived. In such an approach, entrepreneurs process information interpretively where they construct their worldview based on the information they abstract from their environment. These approaches rely on abstractions from Bohm's "wholeness" to make sense of their circumstantial realities-abstractions manifested to their senses.

They are limited by their cognitive ability to grasp the hierarchical information structure and relations. Entrepreneurs generally abstract information from the wholeness by bracketing and sense-making the information into a certain artefact to achieving local optima (as best as they can possibly understand). This artefact can endure over time by changing and morphing into circumstantial contingencies and the emergence of new information. As opportunity-as-artefact morphs along with the venture, it can differ from the initial belief (McCann & Vroom, 2015).

> Sometimes, it may take a few appearances of the opportunity under various conditions and at varying times to convince the entrepreneurs that enactment is worth the effort. It must be noted that each opportunity-as-artefact that appears is independent, but they conjure a similar impression on the entrepreneur. The frequency of their appearances signals certain potentialities the entrepreneurs would choose to capitalise on. Therefore, the observability of that opportunity in terms of its signal intensity, visibility, frequency, strength and clarity become critical to tilt the balance in favour of purposeful actions. Strong signals are more likely to compel entrepreneurs to enact with such consuming obsession and burning desire to actualise the end goal. (Leong, 2021, pp: 2150021–12).

The observability of opportunity-as-artefact signalling entrepreneurs to action depends on how these entrepreneurs observe and interpret the information in the signal. The signal's strength, frequency, intensity and clarity affect the quality of the information necessary to prod entrepreneurs to action. We start by developing an action description for the non-deterministic actions in a dynamic environment. Then, explore the different possibilities of interpreting information leading to entrepreneurial actions. We argue that the sense-making and interpretation which allows for exploiting as much information as possible for optimal leverage of the situation depends on effective abstraction from the uncertainty and indeterministic information. Still, entrepreneurs remain "uncertain about the effects of particular actions" (Bornscheuer & Thielscher, 1997).

There are two kinds of indeterminism – one arising from limited knowledge and the other where uncertainty is circumstantial (Khalil, 1997). The former variant of indeterminism characterises market disequilibrium dynamics – too large to understand. The latter variant of indeterminism borders is closer to Knight's notion of uncertainty. Entrepreneurs need sense-making to frame their worldview in the chaos, as in uncertainty, whether it is the tolerable Knight's risk or "unknowable" absolute uncertainty. Operating under conditions of uncertainty can be debilitating without any heuristics process or methods, pattern recognition or bracketing method to make sense of the messiness and sometimes senseless emergence. Entrepreneurs make sense of the external inputs at various hierarchical levels of interacting forces-environmental resources, competitive reactions, shareholders' activism, directors' opinions, sources of funds and so forth and enact this sense back into the decision-making process to make it more orderly, with sense-making (Weick, 1995). Sense-making is a critical component as it deciphers discernible patterns and structures them through stereotyping by circling out identifiable groups/clusters/pigeon-holing. Therefore it is a form of noticing and bracketing, both retrospectively and prospectively, to get sharper perspectives from the sense-making (Weick *et al.*, 2005). Stereotyping and the bracketing methods produce motivational bias, prodding entrepreneurs to act on those biases. Some theorists believe that motivational constructs must be invoked to explain certain attributional phenomena, while others maintain that information-processing variables can adequately explain these phenomena (Tetlock & Levi, 1982). The cognitive and motivational approaches to attribution have great relevance to entrepreneurship.

The information-processing explanations clarify the motivated bias (Tetlock & Levi, 1982) to drive entrepreneurial actions toward the opportunity-as-artefact. Our research posits that the entrepreneur's information processing is a dynamic combination of algorithmic and heuristic information treatments. Entrepreneurs use "trial-and-error" and "pattern

recognition" for sense-making and opportunity construction. Sarasvathy sums it aptly: "The essential agent of entrepreneurship, as I argue here, however, is an effectuator: an imaginative actor who seizes contingent opportunities and exploits any and all means at hand to fulfil a plurality of current and future aspirations, many of which are shaped and created through the very process of economic decision making and are not given a priori" (Sarasvathy, 2001, p. 262).

Perception-interpretation-action loop cycle and information flow

This perception-interpretation-action loop sequence is an adaptation of the perception-action cycle. We argue that all goal-directed entrepreneurial behaviours and actions are performed under the broad context of the perception-interpretation-action grounded on a fundamental biological principle: the circular cybernetic flow of cognitive information that links the organism to its environment (Fuster, 2002). Therefore, the perception-interpretation-action loop sequence is defined as this continuous flow of information from the environment, at times, abstracted to form an artefact with retained information of past events and experience (historical embedding) and present circumstantially available information. The entrepreneurs must assimilate and interpret the flow of information through their idiosyncratic worldview lens. Through an iterative process of perception, interpretation, action and adjustment, entrepreneurs either reinforce, extend or build a new schema of understanding this information. The perception-interpretation-action cycle is a feedback loop helping entrepreneurs understand how the ventures can work under uncertain conditions.

Entrepreneurial opportunity is a key to triggering the perception-interpretation-action cycle for the entrepreneurs to create anew and build upon services and products.

> In abstract terms, the notion of opportunity reflects the idea that an economic system never reaches its full potential (i.e. its natural state is one of disequilibrium), and so there is always room for actions that can take it closer to that potential (equilibrium). At this level, it is sufficient to claim that opportunities merely exist, without having to identify specific opportunities (Dimov, 2011, p. 60).

In a way, entrepreneurs thrive and strive in disequilibrium in the marketplace through sense-making of the information. Sandberg and Tsoukas describe more specifically "that sensemaking in organisations has been seen as consisting of specific episodes, is triggered by ambiguous events, occurs through specific processes, generates specific outcomes, and is influenced by several situational factors" (Sandberg & Tsoukas, 2015, p. S6). What is implied here is the ambiguous status of events, processes and outcomes influenced by situational factors. All this sense-making needs the feed of information for entrepreneurs to organise effectively. Sense-making is closely associated with organising throughout Weick's work in "The Social Psychology of Organizing" (Weick, 1979). Weick explains that any enactment is through interaction with the environment. They then seek to make sense, retrospectively, by breaking down their lived experience into memorable historical episodes, labelling them and selectively connecting them. See Figure 1. The historical embeddedness of these episodes and events are retained in their mind as "cognitive maps" (Weick, 1979). Weick and Bougon noted that "organisations exist largely in the mind, and their existence takes the form of cognitive maps" (Weick & Bougon, 1986). The cognitive map or opportunity-as-artefact are convenient artefacts with interpretive flexibility. The information integration or embeddedness process in any artefact still depends on the entrepreneurs' interpretation and sense-making. The informational value is different to different individuals. "Opportunity-as-artefact is not constant and is subject to different interpretations as information becomes available and as entrepreneurs gain experience" (Leong, 2021, pp: 2150021–2).

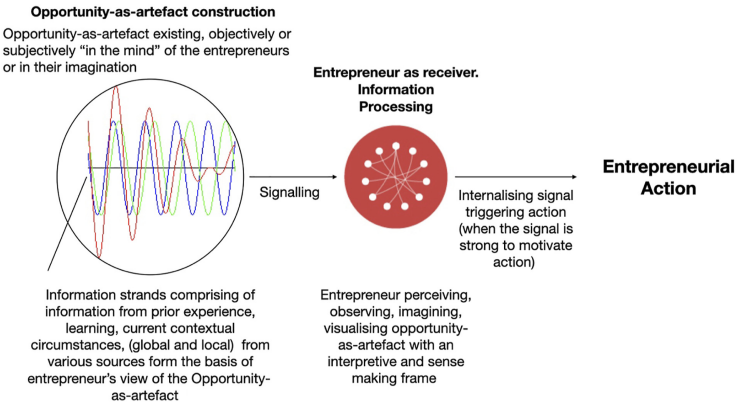

Figure 1.
Conceptual model of information causality in opportunity-as-artefact driving entrepreneurial actions

Thus, the informational treatment of the perception-interpretation-action cycle promises to open a conceptual dialogue to understand the structure of behaviours and information processing in entrepreneurs and how they finally lead to entrepreneurial action.

Conclusion and suggestions for future research

This paper presents an alternative theoretical scaffolding for entrepreneurship researchers to explore the causative effect of information on artefacts like opportunities. Significant incidences of entrepreneurial actions can be explained by information nested in these artefacts stimulating entrepreneurial actions. This study analyses the relationship between uncertainty and information and how this relationship impacts entrepreneurial action. It examines the antecedent influence of uncertainty and information on entrepreneurial action. Concerning uncertainty, undergirded by the amount of information (Frankel & Kamenica, 2019; Menin, 2020; Peterson & Pitz, 1988) described in the literature, this paper contributes by showing that opportunity, by itself, does not provide an adequate trigger for action but is the sense-making of information embedded in the opportunity-as-artefact that instigate action. The observability of the information in the opportunity (strength and clarity), the frequency of appearance and the intensity of belief and conviction drive action. Future research can feature how the dynamic interplay of information and knowledge problems spur action – what is the mediating and energising force that pushes entrepreneurs towards action? This begs new questions in entrepreneurial orientation/behaviours and the rationales for entrepreneurship under this interdisciplinary study. Understanding entrepreneurial orientation and behaviours from the context of complexity science, thermodynamics and even quantum science bring the discussion to a new level of understanding.

While this paper explores entrepreneurship in thermodynamic and entropic terms based on an artefact-centred design practice, it intends to stimulate entrepreneurial research within chaos and complexity, information and entropy as they hold considerable promise for future research development. Opportunity is a pivotal concept within the entrepreneurial field, with the re-casting of opportunity-as-artefact getting traction (Berglund *et al.*, 2020; Dimov, Corbett, & Katz, 2016; Leong, 2021; Selden & Fletcher, 2015). The opportunity-as-artefact is not simply a convenient scholarly assumption as it provides the elasticity in interpretation with demonstrable utility. By conceptualising opportunity as an artefact, we overcome the ontological and epistemic clumsiness on the definition of opportunity, which has proven theoretically problematic. The limitation is that such re-conceptualisation may be refuted as "beyond philosophical extremities and linguistic abuses" (Ramoglou & Tsang, 2017).

> However, with notable challenges on their demonstrated utility, the current concepts of discovery and creation should be deepened with more layers of definitions to include strength of the initial opportunity beliefs, morph-ability of opportunities, frequency of opportunity appearance, multiple interpretations of opportunity, latency of opportunity, observability (intensity, visibility, strength and clarity), distortion of opportunity and false opportunity. These further explorations may sharpen the theoretical precision of the opportunity-as-artefact and the persistent puzzle in the construct clarity (Leong, 2021, pp. 2150021–13).

Leong neatly summarises that the causality in information nested in the opportunity-as-artefact provides construct clarity, reasons and motivations leading to entrepreneurial actions. Eventually, answering the question of what opportunities really are? Berglund answers with a deceptively simple response: "we make opportunities real by treating them as artificial" (Berglund *et al.*, 2020, p. 839).

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