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Probabilistic Interpretation of Observer Effect on Entrepreneurial Opportunity

David LEONG

University of Canberra, Canberra, Australia, david.leong@canberra.edu.au

Background: In quantum mechanics, the observer effect categorically states that observing a phenomenon changes it. This research explores a probabilistic interpretation of entrepreneurial opportunity and explains the observer effect reflecting on Schrödinger's cat thought experiment. This approach addresses opportunity as a "possibility" concept reinterpreting it from multiple observers' perspectives and the cruciality of action to cause wave function collapse to an emergent reality. This paper intends to resolve the epistemological paradox and 'opportunity' war by re-contextualising opportunity as an artefact and positing it as a probability wave with a range of possibilities until alert entrepreneurs act on it.
Method: This conceptual development relies on literature review as a research methodology, using reasoning by analogy for the progress of theory and metaphors for theorisation.
Results: This conceptual narrative strengthens the epistemological foundation focused on possibility and probability (illustrated through wave function) to sharpen the definition of opportunity and action theory. The observer effect in opportunity is underexplored in entrepreneurial scholarship. This study features how the observer effect influences the evolving state of opportunity. Opportunity is affected by other observers and the entrepreneur's imagination, social construction and effort. Each involved agent relates and interacts to give rise to possibilities in opportunities. The interrelations and interdependence are complex, giving rise to superposition with a mixed state with many possibilities.
Conclusions: The contribution of this research is manifold from a theoretical and practical level. It presents a quantum-like model where an 'un-acted' opportunity is in superposition (multiple possibilities emerging simultaneously until it is enacted), expanding on Ramoglou and Tsang's (2016) view on propensity. The interactional effects – interfering and entangling between agents observing the same opportunity generate possibilities. The potentiality and the many-possibilities states in the opportunity artefact hold great promise in entrepreneurial research.

Keywords: *Observer effect, Quantum mechanics; Quantum theory, Wave-particle, Opportunity, Entrepreneurship*

1 Introduction

The mere observation of a phenomenon impacts the phenomenon itself and necessarily changes it (Baclawski, 2018). Cranford (2021: 2571) defined it "as the disturbance of an observed system by the very act of observation). This paper argues that opportunity is presented as a wave of possibilities when unobserved. Upon being observed by multiple observers, the observation interferes with the competitive state and becomes an inevitable reality. The "observation complexifies the situation since the interaction involves an unavoidable "disturbance" of the thing being observed" (Cranford, 2021: 2571). At the same time, other observers are in varying states of action and seeking to exploit the same opportunity. The reflexivity of agencies (observers and others) is both a cause and effect of indeterminacy, and the creative force of each creates uncertainty but "also animating agentic efforts in the face of the resulting uncertainty" (Alvarez & Porac, 2020, p. 742). "The quantum trajectories can be ascribed a degree of reality in terms of quantum measurement theory" (Wiseman, 1996: 205). The observation of opportunity itself, as a

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phenomenon, changes as it is observed. On registering and affirming the opportunity, the entrepreneur transits from the possible to the actual through entrepreneurial action. This explains widespread frustration among researchers that the entrepreneurship field is getting more questions and pieces of puzzles than answers, with no unifying picture emerging (Davidsson, 2003; Gartner, 1988; Koppl & Minniti, 2003).

Entrepreneurs are portrayed as economic agents equipped with skills to recognise opportunities that allow them to peer into an unknowable future (Ramoglou, 2021). Yet, the outcome of any discovery of opportunity is uncertain. It is a paradox "since nobody can know opportunities ex-ante" (Ramoglou, 2021: 2). At best, entrepreneurs have opportunity beliefs - not knowing when their ventures can succeed (Ramoglou, 2021). Knight (1921: 353) argued, "in the world as it is, where all human designs and acts are fraught with uncertainty".

Existing economic paradigms that are strongly influenced by Newtonian physics and its mechanistic approach (Koçaslan, 2014) with concepts featuring determinacy, predictability, divisibility, rationality, the notion of "either-or", order, reliability and validity, objectivity and impartiality, testability, consistency, independence, entitativity, causality, bivalency, atomism, linearity, proportionality, stability, classification/categorising and reductionism have limitations. They cannot deal with the knowledge problems of entrepreneurship. On the other hand, indeterminism, probability, nonlinearity, complexity, fuzziness, interdependence, inter-relatedness, duality (wave-particle [1]), intersubjectivity, nonlocal causes, uncertainty, complementarity, disproportionalities between cause and effect chain, sensitivity to initial conditions (chaos theory), potentiality, unknowability (or knowability in multiple quantum states) (Dulupçu & Okçu, 2000) provide greater interpretive and theoretic representations in entrepreneurship.

This paper introduces quantum referents to model interacting systems between multiple observers and the opportunity artefact. It further argues that the observation of opportunity changes as it is observed. The fundamental concepts introduced are wave/particle duality, the observer effect, and superposition[2]. Finally, the implications of theory and practice are discussed.

2 Literature Review

2.1 Epistemological Problems

Opportunity, as a phenomenon, should be expressed as an artefact, and this viewpoint challenges the existing definitions of how opportunity is formed (Leong, 2021). The dominant views of opportunity are the discovery and creation views. Shane & Venkataraman (2000) concocted a theory of entrepreneurship centring on Kirzner's (1973) assertion that entrepreneurial opportunities exist as discoverable phenomena (Kirzner, 1973, 1997, 1980). Kirzner's (1973) opportunity alertness became the predominant theme in entrepreneurial research. Short et al. (2010: 40) emphasised that opportunity is necessary for entrepreneurship and that "without an opportunity, there is no entrepreneurship". Put differently, without action, there is no entrepreneurship. Liubertė and Dimov (2021: 1) noted that the articulation of "opportunity is an essential part of the denotation and actualisation of the opportunity" by drawing a framework differentiating "between words as content of speech ("opportunity") and world as its object (opportunity), connected via illocutionary force (e.g. assertion, promise, intention) and used for perlocutionary effect (e.g. persuading, convincing)" (Liubertė & Dimov, 2021: 2).

"Entrepreneurship is a practice of identifying and creating from what is relatively unknown, new or emerging" (Neck et al., 2014: 3). Although the discovery approach has been influential in the extant literature, competing ontological approaches such as creation (Alvarez & Barney, 2005, 2007, 2019) and actualisation (Ramoglou & Tsang, 2015, 2017a, 2017b) are gaining traction to offer alternative views on opportunities. The semantics and linguistic juggernauts are problematic (Dimov, 2020; Ramoglou & McMullen, 2022) as the varied interpretations enormously complicate the definition. Ramoglou (2021) argued that any entrepreneurial foreknowledge is paradoxical and posed the question: how a knowable opportunity can be situated in an unknowable future? The discovery approach presupposes entrepreneurial foreknowledge and assumes that opportunity can be known ex-ante. Ramoglou argued that opportunity cannot be known ex-ante and asserted that the semantics, expressions and language of opportunity discovery are like a distorting mirror "trapped in illusions of infallible perception" (Ramoglou, 2021: 2).

The other dominant view is the creation approach relying on an iterative, incremental and inductive process for resource utilisation. By using available socio-material

[1] Wave-particle duality is a quantum mechanics concept where every quantum entity may be described as either particle or wave. Couder and Fort (2012: 1) revealed from their experiments that "forms of wave-particle duality exists in classical system with emergence of quantum-like behaviours"

[2] Superposition describes a quantum system in multiple states at the same time until it is measured. It describes a fuzzy boundary between the classical and quantum worlds where no certainty exists yet (Monroe et al., 1996).

resources on hand, entrepreneurs work on the available means and resources to create new opportunistic ends incrementally and experimentally (Alvarez & Barney, 2007; Foss & Klein, 2020; Shepherd et al., 2021). Effectuation is closely associated with the creation approach. "Core to effectuation is the idea that rather than discover and exploit opportunities that pre-exist in the world, the effectual entrepreneur is one who 'fabricates' opportunities from the mundane realities" (Sarasvathy, 2009: xiii), and effectuation lies in the logic of control (Sarasvathy, 2001).

Although some researchers argue that the subjective or socially constructed nature of opportunity makes it impossible to separate opportunity from the individual, others contend that opportunity is an objective construct visible to or created by the knowledgeable or attuned entrepreneur. Either way, a set of weakly held assumptions about the nature and sources of opportunity appear to dominate much of the discussion in the literature (McMullen et al., 2007: 237).

The epistemological tension with this opportunity theorisation raises two provocative questions: (a) why do entrepreneurial opportunities exist and (b) why do some people and not others discover and exploit these opportunities" (Leong, 2021: 2150021-3). The intervening years generated new research streams and dialogues on the nature of the opportunity, particularly the middle-ground definitions (Davidsson, 2015; Foss & Klein, 2020; Ramoglou & Tsang, 2017). Yet, at the core of the recognition and pursuit of opportunity, uncertainty grips entrepreneurs in most instances (Leong, 2021). Knowing that opportunity is the necessary anchor for the actualisation process, the entrepreneurs need an imagined future state while immersed in differing degrees of uncertainty, defined by the opportunity belief (Ramoglou, 2017, 2017, 2021). The force of external circumstances acting on the entrepreneurs is never-ending (Davidsson, 2021) and forms one part of Ramoglou's "knowable opportunity-ingredients whose knowability varies across contexts" (Ramoglou, 2021: 1). Ramoglou (2021: 2) translated the problem of "opportunity unknowability" to manageable and reducible "epistemological problem of knowable and unknowable Opportunity-Ingredients (OIs)… explain the fact that particular ingredients may be knowable does not make opportunities knowable because the entirety of Opportunity-Ingredients can never be knowable".

We argue that opportunity is an artefact with perceived potentialities expanding on Ramoglou and Tsang's (2016: 416) notion of propensity where opportunity exists "akin to the unactualised propensity of seeds". Here, we argue that the opportunity has many seeds' propensities or possibilities. Entrepreneurial opportunity straddles many possibilities, and according to Ramoglou and Tsang (2016: 430), entrepreneurship "stands on the thin line between possibility and actuality and therefore faces unique conceptual difficulties unknown to disciplines studying actualised phenomena with more discernible patterns of causality".

This paper finally discusses these potentialities as probability waves[3].

2.2 Resolving the definitional clumsiness

Davidsson (2021) suggested ditching Shanian's discovery and Alvarez-Barnean creation views since these views constrain future entrepreneurial research. Foss and Klein (2020) called for the abandonment of the opportunity construct since current standpoints and attributes of the opportunity construct obscure its intended meaning. "Opportunities can at best be manifested ex-post, when entrepreneurial outcomes are successful. What entrepreneurship scholars mean by "opportunity" is simply a business idea, plan, or belief, which may or may not turn out as the entrepreneur imagines" (Foss & Klein, 2020: 367). Conceptualising opportunity as an artefact-centred design provides an alternative conceptualisation of opportunity in entrepreneurship research constrained by their current definitions (as discovered and created). Whether the opportunity is discovered as pre-existing causes or created through the ultimate consequences of entrepreneurial action, entrepreneurship scholars generally agree that the basic definition of opportunities is about lucrative market imperfections (Berglund et al., 2020) situated in uncertainty and disequilibrium. Whether opportunities are objective, subjective, or social construction makes it impossible to separate opportunity from the observer. Either way, a set of weakly held assumptions about the nature and sources of opportunity appear to dominate much of the discussion in the literature" (McMullen et al., 2007: 237).

The weakly held assumptions about the properties and nature of the opportunity, including the sources from which it arises, need a reformulated construct. If the opportunity is a visible objective construct recognisable by some and not others, "uncertainty plays no role because they are known as soon as they are discovered" (Ramoglou, 2021: 4). Such linear assumptions are an oversimplification of the opportunity's construct. Here, we argue

[3] Probability wave of a quantum system is characterized by a wave propagating through space in which the square of the magnitude of the wave at any given point in time corresponds to the probability of finding the particle at that point. Researchers debate on the best way to think about quantum mechanics with many competing schools of thought (including the Copenhagen School) and the views are referred to as "interpretations" of quantum theory. All these interpretations rely on the idea of probability in a fundamental way.

that opportunity's state is not situated in one fixed causal relationship with a determined outcome but is presented with possibilities depending on the contexts (and Ramoglou's opportunity ingredients). The interactions between the different known opportunity ingredients concoct other possibilities.

Opportunity's indeterminacy needs addressing since opportunity's subjective or socially constructed nature is contingent on the observer. Short et al. (2010: 40) asserted that "opportunities are one of the key concepts that define the boundary and exchange conditions". The entrepreneur, as the observer, is situated at the boundary and exchange conditions; any exchange or exploitation is based on the interpretation and evaluation of the opportunity. Nonetheless, the fundamental issues of the opportunity construct and its properties remain elusive (Davidsson, 2017; Dimov, 2011; Leong, 2021). Burt (2004) used the imagery of the structural holes[4] to represent opportunities, with alert entrepreneurs able to broadly see the information discrepancies/dissonance and arbitraging this information to their advantage. Burt stressed that entrepreneurs exploit structural holes that lie between constrained positions (Walker et al., 1997).

Opportunities can only be manifested ex-post when the venture proves successful and is contingent on a true-positive outcome (Foss & Klein, 2020). Therefore, the intervening period from recognition to entrepreneurial action that results in either success or failure must be a belief. This opportunity belief is subject to change at the interface/boundary between the entrepreneur and the environment. Therefore, entrepreneurs constantly scan for lucrative market imperfections to form opportunity beliefs. These beliefs are continually changing and updated when new information is revealed. This information includes competitive counter-actions, imitations, and interactions among heterogeneous stakeholders. Presenting opportunity as an artefact with many possibilities provides interpretative flexibility. "Rarely new ideas or concepts evolve full-blown and are totally ready for use, unless it's a hole-in-one eureka moment, as it requires time and expenditure of efforts to shape the idea to fruition and the process is almost never linear. There are false starts and dead ends, ups and downs and "backing and forthing" as the entrepreneurial pathway unfolds" (Leong, 2021: 23)

The entrepreneur, as an observer, processes the information, or lack of it, in that space and time and has to decide whether to act under uncertainty since any action arising shifts the trajectory from possible to actual. The observation disturbs the possibility as the observer may become another competitor to pursue that opportunity (Figure 3). Such competitive acts impact the other agents locking in to observe the same opportunity. Other agents' actions affect the possibility state of the opportunity. Thus, we argue that such observations by any agents, including the entrepreneur, influence the opportunity and its various possibility states. The re-contextualisation of opportunity as an artefact provides convenient and interpretive flexibility.

2.3 Re-contextualising opportunity as artefact and possibility object

The role of opportunity in entrepreneurship must be understood in its proper context. This paper suggests re-contextualising opportunity as an artefact and a possibility object. Ramoglou and McMullen (2022) argued that opportunity is a possibility concept situated in the future. The opportunity artefact, when unobserved, is represented by a wave with different potentialities and possibilities. These states are mixed states (or superimpositions). When observation is made, the mixed states collapse into a pure state[5] (or actual state). In a way, an opportunity is probabilistically framed. Here, this paper asserts that every observation generates a probability distribution with different possibilities rather than defined by a single possibility. With Ramoglou's (2021) knowable opportunity ingredients, entrepreneurs abstract information from all possible sources to understand to form the belief to inform entrepreneurial action. This understanding impacts the degree of believability and motivates action on the opportunity belief.

Opportunity-as-artefact changes over time as information is discovered and entrepreneurs gain experience and knowledge/information—the strength of the initial opportunity formation changes with new and emerging knowledge (Leong, 2021). Eckhardt and Shane (2003: 340) discussed entrepreneurial opportunities manifesting themselves in multiple ways – "by the locus of the changes that generate the opportunity; by the source of the opportunities themselves; and by the initiator of the change". Dimov (2011: 62-63) added:

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,

[4] Burt's theory suggests that individuals have various advantages from their location in social structures and neighbourhoods. A structural hole represents a gap between individuals who have complementary sources to information that involves "information breadth, timing and arbitrage advantages of network brokers" (Burt, 2021: 384).

[5] Mixed and pure states refer to a quantum system. A pure state refers to a quantum state with exact information about the quantum system; whereas the mixed state is the combination of probabilities of the information about the quantum system (Zhang et al., 2007).

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.

The entrepreneurs' worldviews influence the way opportunity beliefs are formed. Still, the clarity of the opportunity-as-artefact depends on the observer's interpretation and the observer's interaction with the environment under conditions of uncertainty. It provides interpretative flexibility where prevailing theories on opportunities (Dimov, 2011; Eckhardt & Shane, 2003; Sarason et al., 2006) present theoretically problematic definitions with limited practical use. For example, Berglund et al. (2020: 40) suggested making "opportunities real by treating them as artificial" (Berglund et al., 2020: 40).

2.4 Observer effect

The observer effect is predominantly featured in physics, where observation and uncertainty undergird the fundamental aspects of quantum physics (Baclawski, 2018). The observer effect generally describes circumstances in which the observed entity is affected by the curious observer. For example, Jeraj (2014: 201) noted the interrelationship between curiosity and optimism influencing entrepreneurial action, particularly when entrepreneurs "hold positive expectancies for their future". Jeraj (2014) argued that curious observers with optimism have a higher level of self-efficacy and therefore are likelier to act. In physics, the term describes circumstances in which the mere act of observation changes the observed phenomenon (Thompson, 2016).

Quantum mechanics states that particles can behave like waves, which can become particles depending on the situation. For example, when an observer is watching, the wave collapses to become a particle, and when it is left unobserved, the particle becomes a wave (Figure 1). "In the ambit of the creation-discovery view, it is usually stated that quantum measurements are not just observations, as they can provoke a real change of the state of the measured entity" (Sassoli de Bianchi, 2013: 1). As new information surfaces and becomes available from the environment, the probability distributions also can evolve (Baclawski, 2018). Peljko et al.'s (2016: 172) study noted the interrelationship between entrepreneurial curiosity and innovation, motivating "entrepreneurs to gather information about their business and innovativeness".

Observation can also be either invasive or non-invasive. That "it is always possible to observe the countless entities populating our reality without disturbing them, i.e., without influencing their state and evolution" (Sassoli de Bianchi, 2013: 2) in a non-invasive and non-intrusive way. "The observation of living entities, like when a hunter hides to observe a prey from afar, can possibly involve some very subtle levels of inevitable disturbance that could influence the behaviour of the living entity being observed" (Sassoli de Bianchi, 2013: 20) and in an invasive way that influences their state. In quantum theory terms, any independently existing physical system is situated in a definite state at every moment. "Intuitively, the state of the system is the totality of its observable properties, but the relation of this totality to individual observables is peculiar to quantum mechanics" (Shimony, 1963: 756).

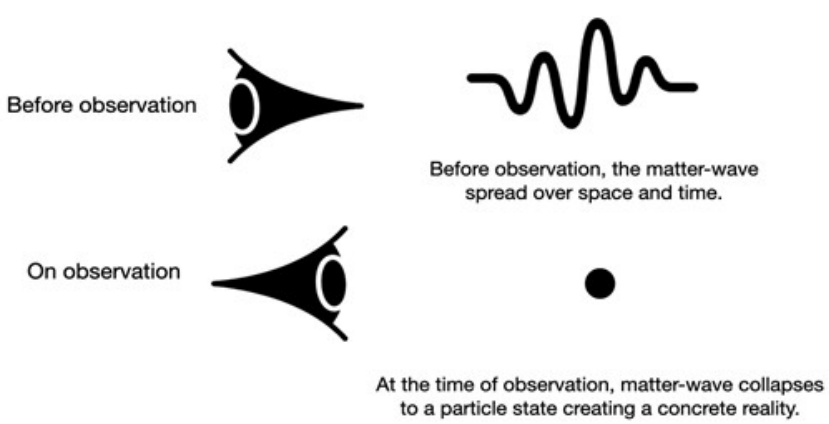


Figure 1: Illustrates the observer effect and the wave-particle duality

Even worse, the uncertainties in the system exist prior to and independent of any measurement, and the uncertainty principle is, therefore, more fundamental than the observer effect. So not only did you change the system being measured/observed, you can't even tell how you changed the system being measured/observed, and you can't avoid it! You can only accept the fact that you changed it (Cranford, 2021: 2571).

We must consider the possible effects and changes the observation may produce when an opportunity is observed. With wave functions, re-conceptualising opportunities as artefacts open new dialogues and orientate future research.

2.5 Understanding uncertainty

"Entrepreneurship is fundamentally action under uncertainty" (Foss & Klein, 2020: 369). Purposeful behaviour under uncertainty is the fundamental assumption undergirding theories of entrepreneurial actions. Simply put, "entrepreneurs operate in uncertain environment" (Townsend et al., 2018: 659). Uncertainty is a persistent struggle for entrepreneurs, and sensemaking is crucial for their venture's ongoing concern. Knight (1921) differentiated risk and uncertainty. Keynes (1921) discussed risks probabilistically. Knight and Keynes both drew the line between risks and uncertainty. Knight's account of how an agent's beliefs and confidence in uncertain events influence their choices (Westgren & Holmes, 2021). According to Knight, the risk is quantifiable uncertainty (Holton, 2004). Westgren and Holmes (2021) examined subjective probabilities and indeterminism to understand degrees of uncertainty. Uncertainties, in a nonequilibrium environment, provide the contexts for opportunities to arise. Alert entrepreneurs perceive, act and profit from purposeful actions. Khalil (1997: 27) drew the distinction:

Two kinds of indeterminism, one arising from the knower's limited skill of computation and the other from the phenomenon's inherent uncertainty. The former kind of indeterminism, characterising market equilibrium dynamics, is heuristically captured by chaos theory and, in economics, by Frank Knight's notion of risk. The latter kind of indeterminism, expressing innovativeness, is analogous to the laws of quantum mechanics and, in economics, Knight's notion of uncertainty.

"Heisenberg's uncertainty principle is a milestone of the twentieth-century physics" (Atkinson & Peijnenburg, 2022), borne of the Copenhagen school[6], lies on an epistemological interpretation where the uncertainty is attributable to the conjoined interactions between the subject and observer. The conjoined interactions generate a certain indeterminism, formulated as Heisenberg's uncertainty principle[7] (Busch et al., 2007). The uncertainty principle states that "it is impossible to specify a particle's location and momentum simultaneously. As soon as the experimenter finds out the particle's location, the experimenter's tool unpredictably influences the particle's momentum, and vice versa" (Khalil, 1997: 29). "Heisenberg's uncertainty principle is usually taken to express a limitation of operational possibilities imposed by quantum mechanics" (Busch et al., 2007: 1). According to Soros (2013: 316), "Heisenberg's uncertainty principle in quantum mechanics is subject to the laws of probability and statistics, the deep Knightian uncertainties of human affairs associated with the human uncertainty principle are not". "Heisenberg's uncertainty principle showed that the act of observation impact a quantum system" (Soros, 2013: 318). Khalil (1997: 29) explained the Schrödinger's cat example:

Erwin Schrödinger summarises quantum uncertainty with the famous metaphor of a cat placed in a box with a radioactive substance which can trigger at any moment the release of a lethal poison. In a Newtonian indeterministic world, one can state with certainty the chance (i.e., risk distribution) of whether the cat can be found dead upon opening the box in two hours. That is, in two hours, the cat can be either alive or dead with a certain probability distribution. In a quantum indeterministic world, however, the cat can be in the potential state of being alive and dead. Thus, the uncertain state can be determined only through experience, one of which is the act of opening the box. This finding has led to the subjectivist Copenhagen interpretation that the act of opening the box affect in an uncontrollable manner whether the cat will be found alive or dead view.

Quantum phenomena are not intuitive and do not obey the notion of locality familiar to everyday experiential perception. However, opportunity-as-artefact can be flexibly posited in a locality formed as an entrepreneur's imagination with possibilities. This is consistent with Ramoglou and Gartner's (2022: 7) view that "venture success is ultimately a matter of entrepreneurial imagination and effort". McMullen (2022) proposed that entrepreneurial innovation can be an endogenous imagination act where the mental models interact in a process that generates an output. Metaphorically, an opportunity artefact is repre-

[6] The Copenhagen interpretation is a set of views about quantum mechanics, principally attributed to Niels Bohr and Werner Heisenberg. The earliest interpretations of quantum mechanics during the period of 1925–1927 (Paty, 1995).

[7] Heisenberg uncertainty principle also known as the indeterminacy/ uncertainty principle states that the position and the velocity of an object cannot be simultaneously measure with any precision. The uncertainty principle asserts a fundamental limit on the accuracy with which an object's physical quantity such as position and momentum can be predicted from initial conditions (Busch et al., 2007).

sented as a quantum particle, and if "a quantum particle is taken to exist independently of the observer, it must be conceived as existing as a coherent potential which occupies a locality in an uncertain way" (Khalil, 1997: 29). According to Ramoglou (2021), there is no visual interaction of opportunity with the physical aspects of the world, and when "entrepreneurs talk about discovery or perception of opportunities, they are engaged in a language game of imagination" (Ramoglou, 2021: 8). The locality of the opportunity, a socially constructed artefact, can be situated in the observer's mind. Alvarez and Porac (2020: 739) claimed that "complexity is a function of the mind and not the world". McMullen (2022) asserted that entrepreneurs create knowledge[8] that helps realise profit potential, but they do not create the profit potential itself. What is realistically observable is the abstracted information, such as the market trend, consumers' habits, and technological development. Courtney et al. (2017) examined the signals and endorsements obtained from multiple information sources to mitigate information asymmetry[9]. "The multiple signalling factors and endorsements[10] interact to influence a project's likelihood (of success)" (Courtney et al., 2017: 284, emphasis added). The assemblages of information from multiple sources form opportunity beliefs. Soros (2013: 314) further clarified:

Risk is when there are multiple possible future states and the probabilities of those different future states occurring are known. Risk is well described by the laws of probability and statistics. Knightian uncertainty occurs when the probabilities of future states, or even the nature of possible future states is not known.

When Mark Zuckerberg spoke of his vision of the metaverse and transformed his business to pivot into the metaverse, he imagined that the metaverse contains possibilities for alternative interactions between people (Newton, 2021). He peered into the unknowable future with his ability to recognise and identifies:

1. the metaverse will be the successor to the mobile internet;
2. the spatial distance between people is compressed in the metaverse, and this spurs interaction;
3. the interactions are immersive and can unlock new experiences;
4. the immersive reality will change the way people interact and intermingle.

"Technology that's built around people and how we actually experience the world and interact with each other. That's what the metaverse is all about" (Zuckerberg, 2021). Despite the unknowable and uncertainty in today's context, Mark Zuckerberg persists with his vision to transform social interaction through his platform and innovation.

Opportunity-as-artefact is only meaningful when it stirs entrepreneurial actions. The action occurs in time, inherently making it uncertain (Mises, 1949). "Thus, it seems that one cannot have opportunity without uncertainty, but because the human condition is characterised by the passage of time, there will always be uncertainty, and therefore, some form of opportunity" (McMullen et al., 2007: 15). Under "uncertainty-based theories entrepreneurs do not so much discover profit opportunities as create them, often through their organising efforts" (Alvarez & Barney, 2005: 788). According to Foss and Klein, "uncertainty is central to entrepreneurship and innovation yet absent from opportunity-based approaches" (Foss & Klein, 2020: 366). Opportunity-based approaches (Alvarez et al., 2013; Mole & Mole, 2010; Venkataraman et al., 2012) feature discovery and creation, but what does an entrepreneur discover or create? We argue that entrepreneurs discover information under uncertain conditions, strengthening their opportunity artefact[11]. The opportunity artefact potentially motivates them to a specific action. Whether it is "price differentials

[8] Knowledge and information are distinctively different. Knowledge refers to relevant and objective information gained through experience and learning. Knowledge is accrued from combining information and helps draw inferences to develop insights. Information refer to processed data that has been ascribed meaning through relational connections. Information informs and provides answers to problems.

[9] Information asymmetry refers to imbalance of knowledge of relevant factors and details between negotiating parties (Bergh et al., 2019) where one party has more or better information than another.

[10] Endorsements refer to third party's expressed views and according to Courtney et al. (2017), third-party endorsements alleviate information gap as prior research has shown that these endorsements through interorganisational relationships serve as signal of quality.

[11] Opportunity artefact, opportunity-as-artefact and opportunity belief are used interchangeably in this paper. Artefact refers to an object of interest that can be represented: an aspect of thing, a state of affairs, knowledge stock, information feed or material resource, something observable in the environment that is of concern to the observer. Opportunity artefact, technically, is composed of Ramoglou's (2021)opportunity ingredient which is the knowable part in the opportunity construct (market demand, competitive reactions, prevailing interest rate, etc.). Ramoglou (2021) explained that particular knowable ingredients do not make opportunities knowable because "the entirety of opportunity ingredients can never be knowable" (p. 2). Opportunity belief refers to the aggregated information abstracted from various sources. The aggregated information motivates and sustains actions. Opportunity belief is grounded with degrees of intentions that guide skilled actions. Fridland (2021) described intentions "as hierarchically organized, where intentions at higher or more abstract levels of description causally influence, structure, and organize intentions lower down in the intentional hierarchy. This kind of top-down causal influence would allow, and in some cases even require, the simultaneity of intentions at different levels of action specification" (p. 489).

(spatially or temporally)" (Foss & Klein, 2020: 368) or Burt's (2004) structural holes, entrepreneurs interpret the information within the opportunity artefacts to create arbitrage-able opportunities (Foss & Klein, 2020). The alert entrepreneurs scan and recognise these structural holes where the disequilibrium brings arbitrage opportunities. The entrepreneurs seize these opportunities before other actors who may be observers of the same opportunities. Observing the phenomenon impacts the phenomenon itself and necessarily changes it (Baclawski, 2018). This disequilibrium does not last long as all knowledge is effectively parameterised in multi-actor observations. The opportunities arising from the disequilibrium are discovered and exploited. The entrepreneurial discovery, in a way, causes markets to equilibrate.

Alert entrepreneurs explore the prevailing social relationships and material resources in combinatorial ways to generate values and profits under genuine uncertainty (Foss & Klein, 2020). The disequilibrium, visibly observed in the chaotic environment, is constantly changing, with resources, opportunities and relationships dissolving and reforming. The "real world entrepreneurship consists primarily of choosing among combinations of heterogeneous capital assets" (Foss & Klein, 2020: 370) to create possibilities from each combination. The creation involves combination and recombination, dissolving and reforming resources. "When emergence happens, something new and unexpected arises, with outcomes that cannot be predicted even knowing everything about the parts of the system" (Lichtenstein, 2014:1). McMullen (2022) argued that the world determines emergence[12] in an indeterminate way though resources are at entrepreneurs' disposal. "The origin of emergence is a potentiality" (Lichtenstein, 2014:5). Lichtenstein (2014) viewed the opportunity as emergent with potentiality and possibility.

According to the discovery approach, opportunities are an outcome resulting from conditions and constraints in technology, markets and entrepreneurs. According to the creation approach, opportunities are an emergent process; a viable opportunity is one that becomes increasingly visible through entrepreneurial organising and enactment. An emergence perspective provides a unique integration by viewing opportunities as emergent that are and can be, enacted (Lichtenstein, 2014:7).

Implicit in the emergence perspective is the emergence of potentialities and possibilities instead of an actual fixed state. Opportunity is more of becoming instead of being.

3 Discussion

The act of discovering, creating and evaluating opportunities requires information. "Many entrepreneurship scholars see risk, ambiguity, and uncertainty as different, though relatedly, informational contexts" (Alvarez & Barney, 2019: 12). On quantum terms, the "quantum wave function has a pure information nature" (Haven & Khrennikov, 2017: v).

The act of observation of the opportunity artefact is complex. It invokes cognitive decision-making and call-for-action—any action arising impacts the interdependence of events and stakeholders at multiple social levels. Entrepreneurs operate in a highly interdependent environment where they form organised structures in which the parts and wholes are dynamically interdependent with bewildering entangled complexities (Lawless, 2017). The interdependence of the interwoven parts cannot possibly be understood in its totality[13]. Opportunity artefact represents all these interwoven and interlaced relationships and information encapsulated in the artefact.

The Schrödinger's cat thought experiment queries the counterintuitive quantum superposition of macroscopic objects. Here, each cat represents an opportunity artefact (quasi-classical object) which in turn is represented by a wave function. As a natural extension, several cats (opportunity artefacts) "can be prepared into coherent quantum superposition states, which is known as multipartite cat states demonstrating quantum entanglement among macroscopically distinct objects" (Wang et al., 2022: 1). This superposition state (or mixed state), is where the opportunity artefact simultaneously occupies several possible states. "In Schrödinger's thought experiment, a cat would be in a peculiar mixture of being dead and alive" (Wang et al., 2022: 1). Thus, the "wave function incorporates everything there is to know about a particle, summing up its range of all possible positions and movements" (Yam, 1997: 124). Metaphorically, the wave function represents all the possibilities in the artefact. The act of observation necessarily changes the state to reveal the reality – either dead or alive. The action causes the wave function to collapse on observation where only one reality persists. Figure 2 clarifies this point – the revelation of the cat's state of being alive or dead occurs on observation. The wave function is presented like a three-dimensional Gaussian bell curve that maintains its shape in a mixed state of being

[12] Here, "the world" refers to the market with its unpredictability such as customers' demands and market trends. When entrepreneurs act in response to what they see of the world (their worldview), their entrepreneurial action is based on an opportunity belief and any emergence (such as successful or not) by turning out to be an actual opportunity for profit is uncertain. Hence, the emergence is a potentiality acting out.

[13] This description corresponds to Gell-Mann's idea of the entire fine-grained descriptions is not knowable because of observers' limited power of observation, cognitive abilities and computations. Ramoglou's (2021) view is consistent -that particular knowable ingredients do not make opportunities knowable because "the entirety of opportunity ingredients can never be knowable" (p. 2).

dead or alive until observation (or action) is made, where the wave function collapses to an emergent reality.

The experiment is not constructed on any quantum mechanical devices, but the thought experiment adequately demonstrates the variety of subjective interpretations against a backdrop of possibilities. The paradox is this- when the cat is in the sealed container with a radioactive substance (within an hour, the radioactive atom has an even chance of decaying), the decay will trigger a hammer that would smash the vial containing the cyanide. The cat is situated in a mixed state of being either alive or dead, half alive, or near death. The outcome is uncertain. When the box is sealed, it is in a mixed state with many possibilities. The act of opening the box immediately reveals the actual state – the earlier mixed state of possibilities instantly collapses into a pure state: alive or dead. The act of observation eliminates the notion of superpositions (other possibilities), and a particular state prevails to become a reality.

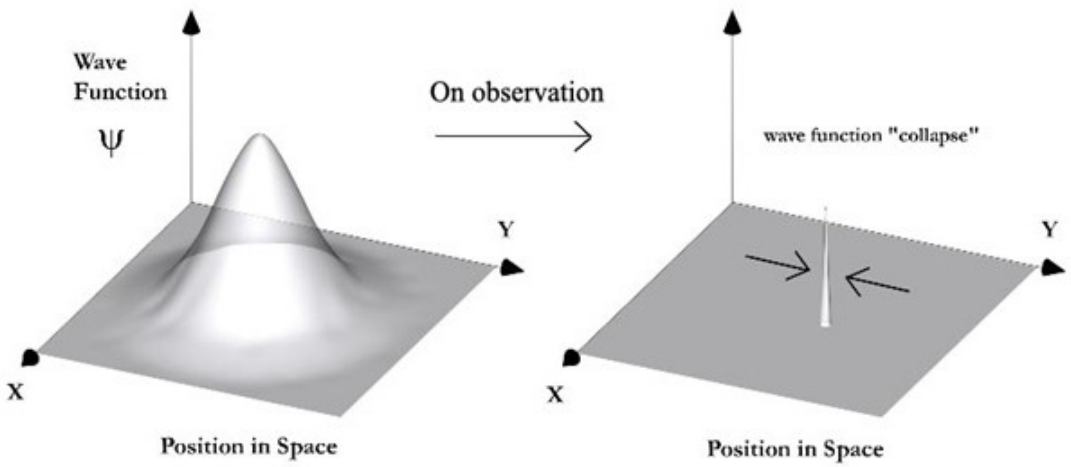


Figure 2: The collapse of wave function phenomenon.Illustration credit attribution to Andrew Friedman, http://afriedman.org/AndysWebPage/BSJ/CopenhagenManyWorlds.html

3.1 Rise and collapse of wave functions

The expression of uncertainty as potential states in a probability distribution is also known as Schrödinger's wave function (Khalil, 1997). The wave functions represent the range of possibilities in the opportunities, including the observer's interpretation and the interactions and entangled superposition at the observation point. Murphy summarises and draws the following conclusions (Murphy, 2021: 14):

- The social structure of the market is invisible and can be represented when considering all possible outcomes with its wave-like properties.

- Any interactions with 'the market' or any observation of market interaction, the market wave 'collapses' – just as would any photon being observed. Hence, when measuring with precise methodologies, there is no 'market' to see, as it is a social construct that includes buyer, seller, commodity, et cetera.

- Through the interactivities between markets (social structures) and the stakeholders (buyers, sellers, etc.), with the observer scanning for opportunities, market opportunities are constantly arising and collapsing because of the constant intra-activity of actors and structures.

- The market wave function interferes with other social wave functions, and the interaction effects may be constructive or destructive.

- The market and all the other social structures and the actors (all should be understood in terms of their social wave functions) can become entangled and conjoined one way or another. In such a case of entanglement, a significant change in the state of the market can have nonlocal effects on those actors with which it is entangled.

Using this quantum approach, this paper re-conceptualises opportunity as an artefact with possibilities expressed as a wave with a probability distribution. The entanglement and interference with other social structures like competitors, imitators, suppliers, distributors, and

investors contribute to the possible state actualising. The prevailed wave function is transformed into a certitude expressed in risk distribution (Khalil, 1997). The prevailed wave function is actualised into the observed reality from the earlier state of uncertainty. The rise and fall of the wave functions depend on the flow of abstracted information derived from relatively autonomous or independent sub-totalities or Ramoglou's opportunity ingredients. This more profound type of uncertainty can be mathematically represented by the tools of quantum probability theory. Such information can be modelled with quantum probability using superposition and entanglement of belief states (Haven & Khrennikov, 2017). The observable spike represents a highly likely actualisable opportunity. The rise-to-a-spike is a signal. "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: 2150021-12). The desire to actualise the end goal compels entrepreneurs to act to shift the trajectory from possible to actual over time.

3.2 Implications of an action framework framed as a wave function

With entrepreneurial action, the mixed state of possibilities collapses into a pure state (either of success or failure); the process of discovery/creation (pre-observation stage) and evaluation situates the entrepreneur in a mixed state of possibilities. Observing Schrödinger's cat (opportunity artefact), one state prevails among the mixed possibilities. The mixed state holds that the wave function describes all possibilities based on the entrepreneurs' knowledge/access to information and socio-material resources. The wave function becomes complex when encoded with much information (Yam, 1997). This wave function contains all the information of a system available to the entrepreneurs, leading to their asymmetric beliefs (Mises, 1949) and hence their choice of actions. Their actions are determined by their prior knowledge and motivation to act. Not all would act on the same knowledge with equal motivation and conviction. Those who act entrepreneurially are presupposed to possess a clearer vision of the future than those who have not acted. The objective reality "is thought to exist in which a market opportunity is there for the taking, but only for those who possess the qualities necessary to discover and exploit it. Thus, entrepreneurial action is seen as something all would engage in if they knew what to do, but, owing to epistemological differences, only some people (the entrepreneurs) "know" what to do" (McMullen & Shepherd, 2006: 137).

Recognizing an opportunity is similar to looking at the box with Schrödinger's cat (opportunity-as-artefact). A hypothetical wave function emerges (Figure 2) with different possibilities. The act of observation changes the phenomenon being observed. The opportunity-as-artefact is hypothetically represented as a wave function containing all the possibilities. McMullen and Shepherd (2006: 137) qualify these bell curves as hypothetical "because in a natural context, only one point of an individual's response curve is observable". This one point of the response curve refers to the spike seen in Figure 2. Only the act of opening the box will reveal the actual state.

When opportunity-as-artefact is observed, the entrepreneurs rely on their prior knowledge to determine if the opportunity is exploitable. The lure of the opportunity will draw the entrepreneurs in the direction of the opportunity in a 'run-and-tumble' way without a firm strategy. The opportunity-as-artefact will change as new information becomes available and the environment changes. As they tumble along the venture pathway, they have to make sense of the uncertainty by understanding the "technological insights, latitude for strategic change, business model boundaries and local identity embeddedness" (Penttilä et al., 2020: 209). At this point, the entrepreneurs need to grapple with the local focal network including the broader surrounding environment" (Penttilä et al., 2020) and other heterogeneous stakeholders (competitors, imitators, upstream suppliers, downstream distributors, financiers, bankers, etc.) that may be entangled or may interfere with the entrepreneurial process. A critical point emerges at this stage. When evaluated, the opportunity presents sufficient stimulation for the entrepreneurs to act. If the answer is no, entrepreneurial action as an outcome is improbable because of the unwillingness of the entrepreneurs to bear uncertainty because of the amount of perceived uncertainty (McMullen & Shepherd, 2006).

"In the ambit of the creation-discovery view, it is usually stated that quantum measurements are not just observations, as they can provoke a real change of the state of the measured entity" (Sassoli de Bianchi, 2013: 1). The evaluation stage under action-specific uncertainty is a particular measurement by the entrepreneurs that relate to the "intrinsic (stable) properties of the observed entity, or about relational (ephemeral) properties between the observer and observed entities; also, they can be about intermediate properties, neither purely classical, nor purely quantum" (Sassoli de Bianchi, 2013: 1). The intrinsic properties of the observed entity (opportunity-as-artefact) refer to the amount of perceived uncertainty or asymmetric information embedded in it. The manifold interpretations of the opportunity-as-artefact are reflected in the information's intensity, strength, and clarity (Leong, 2021). Those "who do not have the necessary knowledge, information and motivation will not believe that the change represents an opportunity will no longer attend to it" (McMullen & Shepherd, 2006: 141).

"Opportunities? They are all around us … There is power lying latent everywhere waiting for the observant eye to discover it" (Marden, 2015: 276).

Leong (2021: 2150021-2) explains that "opportunities can be latent, where the information may not be interpreted to a point where it invokes response and action". Metaphorically, these are like Schrödinger's cat boxes all around us, each with its range of latent potentials. The key is to open these boxes. The observation, as an action, changes the phenomena leading to a quantum outcome. "The future offers many potentialities, which we define as alternative states and possible outcomes that could occur but have not yet occurred because to be actualised, they require the enactment of individual, social, and environmental events that are often serendipitous" (Lord et al., 2015: 264). By exploring and observing opportunity-as-artefact as a new physical imaginary, the quantum interpretation invites entrepreneurship scholars to re-conceptualise how tacit assumptions on entrepreneurial opportunities (Berglund & Korsgaard, 2017; Eckhardt & Shane, 2003; McKelvie et al., 2020; Sarason et al., 2006b; Shane, 2003; Shane & Venkataraman, 2000), entrepreneurial process (Dimov, 2011; Mcmullen & Dimov, 2013) limit our ability to understand the entrepreneurial practices and realities.

The observer effect concludes that an observer changes the object (opportunity as an artefact) as they observe (Figure 3). Furthermore, it suggests that the impact on the changing opportunity artefact (from other observers) changes its quantum state due to other heterogeneous agents' simultaneous observations. Our approach and methodology centre on this theory of evolving change in the opportunity-quantum artefact (its potentiality increasing or decreasing depending on the degree of exploitation by others), changing perceptions and subsequent interactions through the power of other external observations.

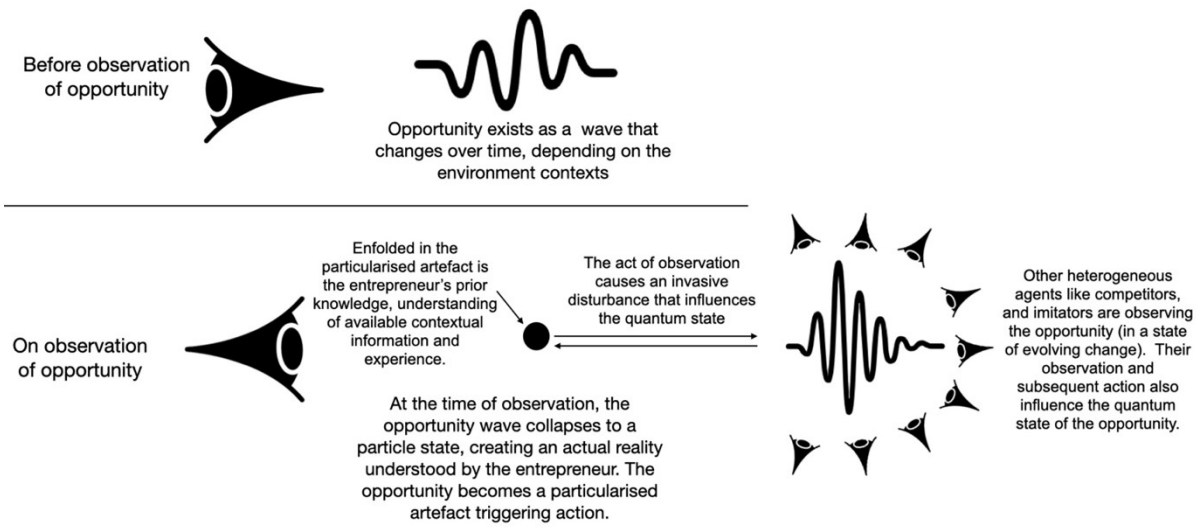


Figure 3: Shows opportunity-as-artefact being a wave-particle duality

3.3 Implications for theory and practice

Quantum physics states that nothing that is observed is unaffected by the observer (Sassoli de Bianchi, 2013). This statement holds an enormous and powerful insight into entrepreneurial practice. It means that subject to the interpretation of entrepreneurs, opportunity-as-artefacts can take many forms. The opportunity appears in varied forms because entrepreneurs create different futures from what they observe based on their understanding and weightage of uncertainty, risks and returns. This implies that individual agents see a different reality (based on prior knowledge and experience and their understanding of the contextual information). Each creates a different future using the resources and network at hand. When entrepreneurs observe an opportunity, the observer effect categorically states that observing the phenomenon necessarily changes it. The inspiration for the new idea in envisaging the opportunity is endogenous to the entrepreneurs. McMullen (2022: 49) argues that this "springs from the marriage of situational need and personal creativity such that a perceived ingenuity gap sparks ingenuity and the innovative reconfiguration of resources used in production". Innovation is possible when the knowledge is "created through experimentation relying on resources capable of being regenerated by natural capital" (McMullen, 2022: 49). Without knowledge and resources and, most critically, the will to act, nothing transpires, and possibilities are non-existent. With interactions

and combinations, possibilities arise. With entrepreneurial action, the trajectory shifts from possible to probable and actual over time. The actuality is derived from a range of possibilities, but only one reality emerges where the rest collapse. "Opportunity should be viewed as an artefact with perceived potentialities" (Leong, 2021: 2150021-1).

By developing a new quantum perspective on opportunity, opportunistic outcomes are constantly collapsing, and only one actuality will emerge in reality. The re-conceptualisation of opportunity as a quantum wave function can provide a broad framework to understand opportunities and entrepreneurship.

The abstract wave functions are constantly rising and collapsing as entrepreneurs interact with the environment, abstracting, sensemaking and enacting to capitalise on the opportunities. Enactment with an entrepreneurial intensity, defined by Morris, refers to a high degree of strength, force or energy (Morris, 1998) of varying degrees and amounts that may not always end in successfully exploiting the opportunities. The observation effect on opportunity-as-artefact is integrally linked to the final act- entrepreneurial action. Without action, the outcome is suspended in an uncertain quantum state. In Schrödinger's cat example, the uncertain state can be determined by opening the box. This finding led to the subjectivist Copenhagen interpretation that opening the box affects the uncertainty of whether the cat will be found alive or dead. "Entrepreneurship requires action" (McMullen & Shepherd, 2006: 132). We argue that this quantum-like model provides a promising perspective to explain entrepreneurial phenomena. It can extend scholarly understanding from observation, recognition and evaluation of the opportunity to the final act- entrepreneurial action.

The emerging future comes from interacting artefacts and entities (opportunity, events, heterogeneous actors in the entrepreneurial ecosystem, etc.). The interactional effects – interfering and entangling generate possibilities. Entrepreneurs act on the indeterminate future based on their assessment of the probabilistic situations, relying on their experience and understanding of the contextual information derived from other sources, including the environment.

Lichtenstein's (2020) generative emergence describes how new entities are created and how new order comes from change and transformation. Lichtenstein's generative emergence explains the creation phenomenon at all interaction levels. Quantum science describes the complex interactions, entanglements and interferences of the wave functions under such uncertainties; from a different perspective presented by the classical interpretation. The embeddedness of potentiality and the many-possibilities scenarios at each junction, boundary or nexus of interactions, including the individual-opportunity nexus (Shane, 2003), hold great promise in entrepreneurship research. Adopting the metaphors and methods of the quantum theory has refreshingly new perspectives for entrepreneurial studies.

What matters for the entrepreneur is more than the active role as the observer; the action (taking a conscious bet on a future with many possibilities of other futures) spins off a new trajectory. According to quantum physics, the observer's relationship with the entrepreneurial event is quantised because of the subsequent action, compared to the classical observer (non-entrepreneur), who is merely a spectator.

4 Conclusion

Discussing entrepreneurship with references to quantum theory is new. Quantum theory is abstract, but it contributes to understanding entrepreneurial practices and entrepreneurs taking chances (playing with dice). It offers tangible suggestions that all things are implicated. An action by a heterogeneous agent, change in the context of material resources or change in technological solutions impact the shape of the wave function instantaneously, raising our awareness that a web of interdependent and interrelated connections constructs the universe around us. Quantum-like descriptions and metaphorical aspects can present an alternative representation of the opportunity construct and paradigm. Finally, re-conceptualising opportunity as an artefact with quantum potential is a new approach to overcoming the profound theoretical puzzle and definitional clumsiness of opportunity. By broadening the scope, opportunity straddles between possibilities due to contextual changes (environment, technology, market, etc.). The mere act of observation changes it. The other possible wave functions collapse to one reality the entrepreneur may pursue if it contains sufficient information (and potentialities) to excite and trigger entrepreneurial action. McMullen and Shepherd (2006) noted that the motivation to act with knowledge must be considered concomitantly when acting entrepreneurially. Without taking action, like opening the box to see the cat, the opportunity artefact remains in a suspended state. Ramoglou & McMullen (2022: 29) argued:

... what can happen is up to the world – the entrepreneur has no say. But whether what can happen will actually happen is up to the agent – the world has no say. Put differently: whether one can achieve A by doing B is determined by the world. But whether, when, or how such possibilities will actualize is entirely a matter of entrepreneurial choice and work.

Quantum mechanics phenomena are deeply mysterious. Its weirdness is hard to understand as it involves unseen forces with significant uncertainties and hidden potentialities. Whatever comes out of it depends on the action taken. Whatever comes out of it comes in response to the entrepreneur's observation. When we describe opportunity in whatever form, it should be probabilistically denoted

since complexly interacting factors determine emergent events, and probabilistic thinking help identify the most likely outcomes.

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David Leong, Ph.D., is an entrepreneurship theorist with more than two and a half decades of experience as an entrepreneur. He started his entrepreneurial ventures early, soon after graduating from the National University of Singapore in 1994 with a Bachelor of Business Administration degree. He has founded at least fifteen ventures spanning corporate finance, business and marketing consultancy, technology solutions, asset management to human resources (HR). He is widely regarded as an expert resource and a leader in the business field. In addition, local media, such as The Straits Times, Business Times, Lianhe Zaobao, and Channel News Asia, often seek his views on economics, politics and HR issues. He has a PhD from Charisma University. His research is in entrepreneurship. His other research interest is the Chinese Yijing (Book of Changes). He draws the relatedness of Yijing with modern science, particularly quantum physics. He is the author of several scientific and professional articles, as well as chapters in books. He also published a book "Uncertainty, Timing and Luck on Quantum Terms in Entrepreneurship". ORCID: 0000-0002-9440-3606.