Making Decisions When Outcomes are Irreducible: Shackle's Imagination and Virtual Reality

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Abstract

This paper addresses the challenge of navigating irreducible outcomes, where predicting future patterns proves futile despite understanding the underlying rules. It advocates for G.L.S. Shackle's imagination-focused decision approach as a partial solution. Integrating the concept of the extended mind, I argue that modern technological advances such as Virtual Reality (VR) further enhance Shackle's approach, rather than compromising its subjective nature. In light of the challenges in applying reductivist tools to the outcomes of VR, I propose Shackle's framework as promising for integrating such outcomes into decision-making processes to capitalize on large gains and hedge against large losses when facing irreducibility.

Keywords: Decision Theory; Computational Irreducibility; Shackle; Extended Mind; Virtual Reality.

JEL Classifications: A12; C63; D01

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1. Introduction

The theory of decision-making developed by G.L.S. Shackle (1903-1992) is classically recognized by its author's contemporaries as a pioneering framework that explicitly excludes probabilistic reasoning when describing behavior under uncertainty (Arrow, 1951; Loasby, 2011). A central feature of this theory is that the decision-makers in an increasingly complex and unpredictable environment do not rely on probability distributions when describing uncertain domains (Shackle, 1949b, 1949a). Instead, these decision-makers prioritize attention-grabbing gains and losses that are imagined but deemed possible (Shackle, 1961). Shackle's emphasis on subjective behavior, distrust of probabilistic reasoning, and explicit recognition of the role played by human imagination made his theory less epistemically appealing than the probability-based paradigms of its day (Earl & Littleboy, 2014). However, the gradual shift away from the Bayesian dogma has revived interest in Shackle's view. Basili and Zappia (2008) explicitly link Shackle's contribution to developments in non-additive probability theory (Gilboa & Schmeidler, 1994).

My first goal in this paper is to underscore the significance of Shackle's approach to decision-making when facing a specific class of problems: those with irreducible outcomes. As defined by Gorard (2018, p. 117), irreducibility implies that it is impossible to predict a system's behavior with fewer steps than the system itself takes to evolve. In this context, 'steps' refer to the individual stages or processes a system undergoes during its evolution. Irreducibility suggests that one must follow each of these stages sequentially for the outcome to be revealed, as no shortcut or simplified method exists to anticipate the final behavior. The development of the smartphone is a prime example of irreducibility, as it was impossible to predict its final form and impact even with a fine-grained understanding of the existing rules, technologies, and consumer habits at the time. Despite this knowledge, each step of the development process was necessary to uncover the smartphone's ultimate design and market success. The invention of the capacitive touchscreen, the iterative design of the user interface, and the creation of the App Store were all critical steps that couldn't be anticipated or bypassed. It was only by going through each step of the process that the smartphone's full potential emerged, illustrating the concept of irreducibility.

In more relatable terms for an academic economist, irreducibility means that at each stage of the decision-making process, the decision-maker – despite accessing a vast amount of information – encounters Knightian uncertainty (Knight, 1921) that is only resolved after taking action, allowing the process to advance to the next stage. This renders statistical and mathematical tools inadequate to provide ex-ante comprehensive insights into the system's future evolution (Wolfram, 2023) contributing to what Velupillai (2005, p.249) refers to as the "unreasonable ineffectiveness of mathematics in economics."

My central argument posits that, with the growing recognition that irreducible outcomes permeating the landscape of social sciences and decision-making, Shackle's imagination-focused decision-making framework (Shackle, 1949b, 1979) offers much-needed epistemic guidance for evaluating potential outcomes. Contrary to misconceptions of chaos and boundlessness, this imaginative process is guided by the decision-maker's prioritization of plausible imagined outcomes (Shackle, 1979). While irreducibility prevents Shackle's imagination from capturing every nuance of future outcomes before such outcomes unfold, decision-makers can still harness it by focusing attention on consequential outcomes rather than minor variations. I argue that coarse-grained representation facilitated by Shackle's imagination allows decision-makers to align their subjective preferences and select strategies that (a) capitalize on the potential gains from extreme positive outcomes and (b) mitigate the risks associated with extreme negative ones.

My second goal in this paper is to extend the notion of Shacklean imagination to encompass recent technological developments, with special emphasis on the role of Virtual Reality (VR), a process whereby a virtual environment is created to immerse users in a three-dimensional, artificial world using via head-mounted displays or goggles (Chalmers, 2022). I argue that this less restrictive definition of imagination does not compromise the subjective nature of Shackle's decision-framework. On the contrary, I posit that such a liberal definition expands the domain of subjective decision-making. I support my argument by appealing to the notion of the extended mind (Barr et al., 2015; Clark & Chalmers, 1998) which suggests that cognitive processes are not exclusively internal but can be distributed across external objects and systems.

This perspective broadens our understanding of cognition by emphasizing the active role of the environment in shaping mental processes. For example, individuals often rely on external resources such as notebooks, smartphones, and computers to store information, solve problems, and enhance memory. These external tools become integrated into cognitive processes like imagination by effectively extending the reach and capabilities of the mind (Clark& Chalmers, 1998). In their more modern incarnations, these include VR, in addition to the array of rich and complex computational models. Capitalizing on the findings that imagination shares common mechanisms with other cognitive phenomena (Schacter et al., 2008), I suggest that integrating technological advancements like VR into Shackle's imagination framework, as part of the extended mind approach, offers a new way to utilize their outcomes in decision-making.

This becomes especially important considering the recently expressed frustrations about the failure of conventional statistical tools to explain the multifaceted features of the VR experience. I posit that such inconsistencies may be due to how researchers traditionally approached the technology. Often, VR has been used to enforce existing theories and produce predictable outcomes. This approach may overlook VR's unique potential as a platform for imaginative scenario planning. VR excels in situations where decision-makers face novel, complex tasks requiring creative thinking and exploration beyond conventional norms. By immersing users in vivid scenarios, VR encourages experimentation, adaptation, and broader exploration of possibilities – all considered as features of the Shacklian approach to decision-making.

I discuss several studies that highlight VR's effectiveness in these contexts. For example, VR has been shown to reduce judgment errors in valuing non-market environmental goods and improve consistency in outcomes (Bateman et al., 2009; Meyer, 2020). VR also proves valuable in police training, offering a flexible, cost-effective alternative to live-action scenarios while enhancing training results (Lavoie et al., 2023). Additionally, VR simulations for construction hazards assessment demonstrate its effectiveness in improving safety through scenario-based decision-making (Isleyen & Duzgun, 2019). I argue that these successes can be attributed to Shacklian principles, where VR helps focus on significant scenarios and competencies, emphasizing strong outcomes without requiring exhaustive evaluations of every detail.

On a final note, I expand the Derbyshire (2017) emphasis on the link between Shackle’s decision framework and Taleb’s emphasis view of decision-making under uncertainty. In particular, I highlight the usefulness of technologically enhanced Shacklean imagination in not only fostering resilience, but also enhancing antifragility (Taleb, 2013), which posits that systems can thrive and grow stronger in the face of volatility, uncertainty, and disorder. This proactive approach enables them to not only identify areas of vulnerability but also uncover hidden opportunities for innovation and growth. Rather than succumbing to paralysis in the face of uncertainty, decision-makers harness the power of imagination to adapt swiftly, innovate boldly, and capitalize on unexpected events. By capitalizing on VR as a tool for identifying Shacklean focal points, investors and regulators focus on addressing significant risks and opportunities instead of minor fluctuations that fit statistical patterns. In doing so, decision-makers leverage technological advancements to better identify, hedge against, and capitalize on consequential outcomes that are considered plausible.

In summary, this paper makes significant contributions to the literature on decision-making under irreducibility and the use of technological and computational advances in decision-making. By elucidating the efficacy of Shackle's framework in navigating irreducible uncertainties and advocating for embracing this framework to analyze VR environments, the findings offer valuable insights for researchers, practitioners, and policymakers seeking to harness the potential of emerging technologies in decision-making contexts. Moreover, by advancing our understanding of how decision-makers can effectively navigate complex and uncertain environments, the research contributes to the broader discourse on decision-making theory and practice, ultimately paving the way for more informed and strategic decision-making processes in an increasingly complex world.

This paper is structured as follows: Section 2 addresses the issue of irreducibility in decision-making and explores different approaches for decision-makers to navigate uncertainties caused by irreducibility. Section 3 presents Shackle's imagination-focused and possibility-driven decision-making framework. In Section 4, we introduce the concept of the extended mind, with a specific focus on advancements in VR. Section 5 emphasizes the advantages of considering these technological advancements as tools to enhance imagination within Shackle's subjective framework. Finally, Section 6 provides a conclusion.

2. Irreducibility and Autonomy in Decision-Making

In the context of the computational paradigm, the observation that complex and unpredictable patterns can emerge from running computational rules can be traced back to the pioneering work of Conway (1970) and Wolfram (1984). This observation is placed in a more detailed framework in the Wolfram (2002) principle of computational irreducibility: rule-following behavior can generate unpredictable patterns that can only be observed by running the rule. This irreducibility limits the effectiveness of mathematics and probability-based epistemic tools available to guide the decision-maker's behavior to form ex-ante expectations.

Beyond the emphasis on the technicalities of computer simulations, there is a growing recognition that irreducible outcomes are omnipresent in both social and natural sciences, challenging the notion that analytical solutions suffice to unravel their complexities. Human behavior, deeply nuanced and influenced by myriad internal and external factors, often eludes precise prediction or analysis (Gigerenzer & Selten, 2002). Emergent phenomena, arising from intricate interactions within social systems, defy reduction to simple causal relationships (Holland, 2000). These emergent properties, manifesting at collective levels, blur the boundaries of predictability and resist analytical dissection (Axelrod, 1997).

Moreover, the dynamic and adaptive nature of social systems adds layers of uncertainty to predictive endeavors (Arthur, 2009). Social phenomena, shaped by historical, cultural, and environmental contexts, exhibit contextual specificity that defies generalization (Swidler, 1986). Traditional modeling techniques often fall short of capturing the complexity of social dynamics, overlooking nonlinearities and feedback loops crucial to understanding emergent behavior (Epstein, 2012).

The emphasis on irreducible outcomes is not alien to classical economic thought. Wolfram's concept of computational irreducibility resonates strongly with F.A. Hayek's ideas, highlighting the inherent complexity of rule-following behavior. While Hayek may not have articulated the term "irreducibility," his insights foreshadow the growing understanding of irreducible outcomes in complex systems that emerged in later literature. In his *Individualism and Economic Order*, Hayek (1948, p.8) writes that "true" individualism "is a product of an acute consciousness of the limitations of the individual mind which induces an attitude of humility toward the impersonal and anonymous social processes by which individuals help to create things greater than they know".

Hayek's emphasis on the decentralized nature of decision-making and the adaptive capacity of free individuals echoes the notion that certain emergent phenomena cannot be simplified or reduced to the intentions of any single actor or plan. In his *Law, Legislation and Liberty*, Hayek (1976, p.187) describes the challenges of entrepreneurial decision-making:

"Much of the knowledge of the individuals which can be so useful in bringing about particular adaptations is not ready knowledge which they could possibly list and file in advance for the use of a central planning authority when the occasion arose; they will have

little knowledge beforehand of what advantage they could derive from the fact that, say, magnesium has become much cheaper than aluminum, or nylon than hemp, or one kind of plastic than another; what they possess is a capacity of finding out what is required by a given situation, often an acquaintance with particular circumstances which beforehand they have no idea might become useful".

Such concerns related to irreducible phenomena fuelled Hayek's scepticism of central planning. Just as no single mind can encompass the vast array of knowledge dispersed throughout society, no centralized plan can anticipate or replicate the intricate interactions and innovations that arise from spontaneous collaboration.

The focus on the unpredictability of the individual's environment does not mean that the decision-maker is left undefended against irreducibility. According to Ismael (2016), the decision-maker's tendency to control her environment is both enabled and constrained by physical laws. The emergent self-governance structure emerging from such laws "creates the psychological platform for the emergence of an inner point of view" Ismael (2016, p.102) via which the decision-maker evaluates her reaction to external factors. This also allows for a decoupling of behavior from stimulus, leaving substantial room for self-modeling, internal deliberation, and choice in decision-making that exerts partial conscious influence on one's surroundings.

These themes are echoed in recent cognitive science studies that evaluate the structure of self-regulating brains (Lewis & Todd, 2007; Navi et al., 2022; Thibault et al., 2016). Similarly, Clark (2007, p.101) suggests that "soft selves" can exercise a significant degree of ecological control. Recent elaborations by Mitchell (2018, 2023) indicate that both evolutionary forces and neuroscience leave considerable room for exercising free will with a "real causal power in decision-making" (Mitchell, 2018, p.1). When examined from a computational standpoint, the above discussion can be reframed as follows: the decision-maker embedded in a computational structure is endowed with a computational budget. The bigger the size of this budget, the bigger this decision-maker's ability to exert partial control on the choice of the rules influencing her environment. However, the choice of epistemic tools that guide this choice remains to be examined.

How can a decision-maker maintain a degree of stability in her environment when the fundamental phenomena that influence such an environment are irreducible? What epistemic tools can be used to model this behavior? A relatively recent framework for modeling self-organizing entities' attempts to enhance their environment's predictability is Karl Friston's Free Energy Principle (FEP) (Friston, 2010; Kirchhoff et al., 2018; Parr et al., 2022). Through this framework, agents minimize variational free energy, defined as the upper bound on surprise. Such minimization occurs by rebalancing actions, perceptions, and learning (Friston, 2010). This surprise minimization behavior happens when agents reposition themselves in their environment by either (a) engaging in action to alter sensory perceptions or (b) updating their internal state to make it more compatible with the environment.

Nonetheless, an essential feature of the FEP is that the boundary between the decision-maker and her environment is statistical and primarily dependent on Bayesian tools (Kirchhoff et al., 2018). This renders free energy minimization epistemically contingent on the agent's ability to identify a complete list of possible outcomes and assign apriori probabilities to them (Parr et al., 2022). With the limited effectiveness of Bayesian tools in the presence of computational irreducibility, the decision-maker is expected to resort to alternative decision paradigms that help her calibrate exposure to irreducible outcomes. In the following section, I highlight the merits of Shackle's decision-making approach in achieving this objective.

3. Shackleian Imagination as a Tool for Navigating Irreducibility

G.L.S. Shackle, among other noted economists who preceded him (Keynes, 1921; Knight, 1921), recognized the deficiencies of the probability-based paradigm in tackling the challenges imposed by radical uncertainty in the decision-maker's environment. Keynes (1937, p.114) explicitly states that "there is no scientific basis on which to form any calculable probability. We simply do not know". Earlier on, Knight (1921) famously argued that the relation between changes in the firm's environment and its profit are always indirect and largely vulnerable to uncertainties that are impossible to quantify. In attempting to design a decision-making scheme that is immune to the deficiencies of probability theory, Shackle capitalizes on imagination as the fundamental device for dealing with the "ineluctably unforeknowable" (Shackle, 1979, p.145) and forming the critical link between the present and the future (Cantillo, 2010).

Cantillo (2014, 2023) highlights how this focus on imagined outcomes allows individuals to explore a range of possibilities, not confined by historical data or probabilistic constraints. The emphasis on "focus gains" and "focus losses" means that people give more attention to certain outcomes based on their subjective importance, which in turn influences their choices. This approach enhances the decision-making experience by making it more reflective of human psychology, where expectations and fears play a crucial role. It suggests that the richness of the imagined future—shaped by personal hopes and anxieties—can guide decisions in ways that purely predictive models cannot, offering a more nuanced and human-centric understanding of how people navigate uncertainty.

To impose a form of discipline on imagination, the Shackleian approach appeals to a possibility-focused framework and prioritizes its focus on the imagined but deemed possible (Earl & Littleboy, 2014; Shackle, 1983). Having developed an assessment of the dynamics that shape her environment – what Shackle (1979, p2) labels as the "geometry" of the field – the decision-maker assigns a degree of disbelief, i.e., potential surprise, to the imagined gains and losses of each potential course of action relative to the initial state.

Shackle's theory of decision-making highlights non-additivity by rejecting the idea that the probabilities of all possible outcomes can be summed up to determine the best choice. In traditional decision theory, outcomes are evaluated by adding their probabilities to form a complete, additive picture. However, Shackle argued that decisions under uncertainty do not follow this additive logic. Instead, he suggested that individuals consider outcomes independently, without assuming they combine neatly into a total expected value (Shackle, 1949a). This non-additive approach reflects the complexity and subjectivity of real-world decision-making, where people prioritize certain possibilities without aggregating them mathematically. This ensures that two mutually exclusive outcomes can be assigned the same level of potential surprises without logical contradiction (Basili and Zappia, 2008). Equally important, the non-additivity feature enables the decision-maker to expand the list of possible outcomes over time without explicitly linking the new possibilities to existing ones (Earl & Littleboy, 2014; Shackle, 1949a, 1952).

Another critical feature of Shackle's decision framework is his focus on consequential possible outcomes when assessing potential actions. Recognizing the limitations of cognitive resources, Shackle suggests that the decision-maker should focus on attention-grabbing positive and negative outcomes instead of producing a fine-grained statistical representation of all scenarios. Shackle (1983, p.32) writes: "When we divide all hypotheses into possible and not-possible, it is only the valuation-extremes of the 'possible' set which count". That is, Shackle's focal gains/loss points represent the interaction between the action's potential payoffs and their plausibility. Indeed, Shackle's focus on a limited set of possible outcomes, in addition to his recognition that the act of deciding is in itself a contributor to the uncertainty that shape the overall outcome become increasingly relevant when considered alongside recent philosophical contributions such Paul' (2014) work on transformative experiences. Shackle argued that decision-making often involves uncertainty, where individuals consider only a few plausible outcomes. Paul (2014) builds on a similar line of reasoning by discussing transformative experiences—life-changing events that are unpredictable and reshape preferences and values. Paul's work suggests that the outcomes of such experiences are inherently unpredictable and profoundly alter one's identity, making it impossible to fully anticipate or evaluate their impact beforehand. This challenges traditional decision-making frameworks, as the value and preferences post-experience can drastically differ from pre-experience, complicating any attempt to make rational choices about them. Together, they highlight the limitations of conventional decision theory, stressing the need for a more nuanced understanding of choice under uncertainty.

Shackle adopts a Cartesian approach, creating challenges in understanding how the mental and physical realms intersect. However, as argued by Lewis (2017), Hayek's "The Sensory Order" (Hayek, 1952) offers solutions to these challenges. Hayek aims to explain why our subjective perception of the world differs from the objective reality discovered through natural sciences. This perspective clarifies the relationship between the mental and physical worlds through the concept of emergence, wherein higher-level mental properties, such as consciousness and intentionality, arise from lower-level neurophysiological processes. While retaining material causality, higher-level emergent causal powers are irreducible to their lower-level counterparts, emphasizing the active interpretation of the world by subjective beings, consistent with Shackle's perspective.

Shackle acknowledges the limitations of this viewpoint by recognizing that choices are influenced by past events and present circumstances. Individuals and organizations cannot create any desired future without being constrained by historical factors and current realities. Shackle refers to this process as creating "history-to-come," wherein individuals shape the future within the constraints of existing conditions (Shackle, 1979 p.21). Despite emphasizing the role of subjectivity and choice in decision-making, Shackle acknowledges that future possibilities are not limitless; decision-makers must contend with fatal flaws that limit the range of feasible outcomes (Shackle, 1983). Additionally, Shackle emphasizes the importance of "constant elements," which are prevailing trends that influence decision-making within a specific context (Shackle, 1979 p.2).

Contributions such as Earl and Littleboy (2014) and Derbyshire (2017) offer the equivalent of executive summaries for Shackle's view as follows:

1. The decision-maker imagines the outcomes of each of the available rival strategies.
2. The possibility of each outcome is presented on a scale ranging between the unsurprising, i.e., perfectly possible, and the maximum level of surprise.
3. The gains and losses for each outcome are then imagined.
4. For each strategy, the decision-maker focuses on the most attention-arresting outcomes. This attention-arresting feature arises from the combination of possibility (Point 2) and gains (Point 3). This creates two focus outcomes: the largest possible gains and the largest possible losses for each strategy.

5. Having assigned pairs of focal gains/losses points to each strategy, the decision-maker chooses the strategy that best suits her preferences and attitude towards uncertainty.

In this context, Shacklean imagination, rather than offering a meticulously detailed portrayal of future events in a way that defies irreducibility, often provides a broader, coarse-grained perspective. Despite its lack of granularity, this expansive view can be invaluable for decision-makers, particularly in identifying extreme outcomes. By transcending the constraints of precise data and delving into imaginative scenarios, decision-makers gain the ability to foresee and prepare for outlier events that may have significant ramifications.

By providing glimpses of these consequential outcomes, imagination prompts decision-makers to consider a wider range of possibilities and potential consequences. This heightened awareness can lead to more robust decision-making processes, as decision-makers are better equipped to anticipate and prepare for unforeseen circumstances. In essence, while imagination may not capture every nuance of future experiences, its ability to highlight extreme outcomes based on prior knowledge is invaluable in guiding decision-making towards more informed and proactive strategies.

There's a growing recognition in mainstream economics that personal experiences and imagination significantly influence decision-making especially when facing novel circumstances. In a recent study, Bordalo et al. (2022) developed a model highlighting the role of imagination in decision-making. According to this model, when individuals recall events, they draw from various experiences, both general and specific to certain areas. However, some experiences, particularly those related to a specific domain, might be overlooked. These recalled experiences serve as the foundation for envisioning the future, with their similarity to it being crucial. The model proposes a hierarchy of experience effects based on similarity, alongside potential interference from unrelated experiences when utilizing domain-specific information. They suggest that this imagination-based framework explained the attitude towards novel risks during the COVID period.

It's important to highlight that imagination, whether viewed through the lens of Shackle's theories or more contemporary interpretations, is typically considered a purely mental process. However, in the following lines, I contend that embracing broader definitions of imagination, which include recent technological innovations such as virtual reality (VR), can lead to a deeper comprehension of the decision-making process. Furthermore, I propose that Shackle's approach, which emphasizes imagination in decision-making, provides a solid framework for integrating technology into decision-making processes.

4. Imagination, the Extended Mind, and Virtual Reality

Clark and Chalmers (1998) challenge the legitimacy of the skin/skull as a boundary between the mind and the external world. This framework challenges the traditional dichotomy between internal mental states and external physical objects. Rather than viewing cognition as a purely internal phenomenon, this perspective recognizes the continuous interaction between the mind and the environment. As a result, cognitive boundaries become fluid and dynamic, reflecting the ongoing exchange of information and resources between individuals and their surroundings. The authors provide multiple examples of how decision-makers "lean heavily on environmental support" (p.7) by delegating various parts of their cognitive efforts to external media (notebooks, calculators, as a basic example).

The emphasis on active externalism led to a growing body of research that examines the multiple dimensions through which cognitive processes can be delegated to the external environment. Barr et al. (2015) provide experimental evidence on the effectiveness of smartphones in supplanting thinking and reducing the problem-solving errors that arise from relying on heuristics. Smart (2012) highlights the potential of the patterns of interaction and information sharing on the web to create a web-extended mind. In discussing a version of the socially extended mind, Gallagher (2013)discusses the cognition-enhancing effectiveness of norms, practices, and institutional structures.

The concept of extended mind has profound implications for the design and use of technology. By acknowledging the symbiotic relationship between humans and tools, designers can create more effective and intuitive interfaces that seamlessly integrate with cognitive processes. For instance, wearable devices such as smartwatches and augmented reality glasses extend the reach of human cognition by providing real-time access to information and enhancing situational awareness (Hutchins, 2000). Moreover, online platforms, social media networks, and collaborative software enable individuals to share knowledge, coordinate activities, and solve problems collectively, leveraging the collective intelligence of interconnected minds (Hutchins, 2006).

Critics may argue that reliance on technological tools diminishes individual agency, overshadowing subjective decision-making, cornerstone of Shackle’s approach, with objective analysis. However, Shackle's framework accommodates the integration of technology within the imaginative process without diluting the subjective essence of choice. Rather than supplanting human agency, technology serves as a catalyst for imagination, empowering individuals to explore the vast landscape of possibilities inherent in subjectivist thought.

These tools sift through vast datasets, identifying patterns, and generating insights that may elude human perception alone. Through AI-driven analytics, individuals gain access to a wealth of information, prompting them to envision innovative solutions and anticipate future trends. Thus, technological tools serve as extensions of the human imagination, amplifying creative potential without compromising Shackle's emphasis on subjectivism. Moreover, collaborative platforms and digital networks foster collective imagination, transcending individual boundaries and fostering a culture of innovation. Crowdsourcing platforms, for example, enable diverse groups of individuals to contribute ideas, share perspectives, and co-create solutions to complex problems. In this collaborative ecosystem, imagination, rather than being compromised, is enriched by the diversity of viewpoints and the synergy of collective intelligence. In this context, VR offers a promising tool for this enrichment.

VR offers the most recent feature of the extended mind phenomenon: by immersing users in simulated environments, it offers a platform to visualize and interact with hypothetical scenarios (Chalmers, 2022). By donning a VR headset, individuals can step into alternative worlds, experiment with different courses of action, and evaluate potential outcomes—all of which stimulate the imaginative faculties. Emphasizing the vividness of the experiences offered by VR, Chalmers (2022) argues that "virtual reality is genuine reality. Or at least, virtual realities are genuine realities. Virtual worlds need not be second-class realities".

The applications of VR in decision-making span a wide range of industries and fields. In business, VR is envisioned as a tool for simulation-based training, market research, product prototyping, and customer experience enhancement (Slater & Wilbur, 1997). For instance, companies can use VR simulations to test new product designs, evaluate consumer reactions, and refine marketing strategies before launching them into the market. VR also plays a crucial role in risk assessment, allowing decision-makers to simulate various scenarios and anticipate potential outcomes in fields such as finance, engineering, and urban planning (Bowman & McMahan, 2007).[1]

It is important to note that VR is not the only tool for imagination and decision support. Individuals can also use numerical simulations, graphical representations, written scenarios in the form of vignettes, and even live training to enrich the input used in their decision-making. However, there are many factors that make VR stand out as a more effective and innovative feature of the extended mind. First, numerical and graphical simulations often face challenges related to the comprehension or "evaluability" (Hsee, 1996, p. 247) of the information they present. For information to be meaningful, individuals must be able to connect with and understand it on a deeper level. Even if someone can objectively recognize that one numerical value is larger than another, without evaluability, this information may lack significance. Psychological research suggests that in such cases, individuals may resort to decision heuristics or "rules of thumb" to construct their preferences (Kahneman et al., 1982), which makes evaluability crucial to avoid anomalies in stated preferences (Bateman et al., 2009).

Second, VR offers a distinct advantage over traditional tools by enhancing feelings of presence and perceived realism, which are often limited in written or purely numerical simulations. VR mitigates the cognitive challenges associated with imagining oneself in a hypothetical scenario by immersing users directly into a realistic environment. This

[1] In healthcare, virtual reality is employed for medical training, surgical simulation, patient therapy, and treatment planning (Rizzo & Kim, 2005). Surgeons can practice complex procedures in a risk-free virtual environment, enhancing their skills and confidence before performing operations on real patients. VR-based therapy applications help individuals overcome phobias, manage pain, and rehabilitate from injuries or disabilities. Moreover, virtual reality enables healthcare professionals to visualize patient data in three-dimensional space, facilitating better diagnosis and treatment decision-making.

approach addresses individual differences in the ability to visualize and engage with these scenarios, making the experience more universally accessible (Bowman & McMahan, 2007; Van Gelder et al., 2019).

Third, as discussed by Lavoie et al. (2023), VR is a more cost-effective alternative to traditional scenario-based training. It uses pre-designed characters and settings, reducing the need for expensive resources like actors, physical locations, and set construction. The adaptability of VR environments allows for customization to reflect local settings or modify situational elements such as weather, traffic, or bystanders. Research consistently shows that VR enhances learning outcomes, increasing engagement, motivation, recall, and skills transfer, making it an invaluable tool for training across various fields.

5. VR and Decision-Making within Shackle's Framework

While VR can provide immersive experiences that help decision-makers navigate irreducible scenarios, the quest for statistical regularities in the VR domain has been a prominent but often futile pursuit. After surveying 61 articles that statistically analyze the outcome of VE settings, Lanier et al., (2019) point that, out of the total tests conducted, 54 (27.27%) were identified as "inconsistent" (p.74), indicating discrepancies between the test statistic, degrees of freedom, and p-value. Among these, four tests (2.02% of the total 198 tests; 7.41% of the inconsistent tests) were categorized as "grossly inconsistent" (p.74), meaning that the disparities crossed the threshold of statistical significance. Reflecting their results, Lanier et al. (2019, p.70) write:

"Given the impacts that VR technologies might have on users and society as a whole, scholars should take these developments into consideration when evaluating them through a social science lens. Otherwise, scholars could risk inadvertently misleading the general public when attempting to apply their research findings beyond the original laboratory setting."

A potential explanation is that the inconsistency and lack of robustness in studies examining the impact of VR on decision-making may stem from how researchers have traditionally approached the technology. Often, VR has been treated as a tool to establish behavioral regularities and enforce normative decision-making patterns aligned with existing theories. This perspective assumes that VR should produce outcomes consistent with established models of human behavior. However, such an approach may overlook the unique capabilities of VR, leading to mixed results in empirical studies.

This article suggests a different approach: rather than viewing VR as merely a tool for reinforcing pre-existing theories, it should be embraced as a platform for imagination-rich scenario planning. The true strength of VR emerges in contexts where decision-makers are not expected to conform to regularities or adhere strictly to theoretical norms but are instead required to navigate challenging and original tasks. In these situations, VR's value lies in its ability to generate vivid, imaginative scenarios that prompt users to think beyond the conventional and explore a wider range of possibilities. This creative engagement with complex scenarios allows decision-makers to experiment with different strategies, adapt to novel challenges, and gain further confidence in their decision-making skills.

A promising domain where VR makes significant headway is the challenging task of valuing non-market environmental goods like land use. Bateman et al. (2009) provide robust evidence that the enhanced evaluability provided by VR presentations reduces respondent judgment errors and lessens reliance on loss-aversion heuristics. Compared to conventional numerical methods describing potential changes in coastal land use, preferences elicited through VR treatments are more consistent and show a significant reduction in the asymmetry between willingness to pay (WTP) for gains and willingness to accept (WTA) for corresponding losses. Similarly, Mokas et al. (2021) conducted a split-sample experiment to evaluate the value of urban greenery, including trees and bioretention planters, through three different presentation formats: text, video, and VR. They found that VR outperformed other formats in assessing the value of urban greenery, significantly enhancing respondent certainty and influencing willingness-to-pay estimates. Meyer (2020) also emphasizes VR's effectiveness when environmental changes are complex or difficult for participants to evaluate.

In police training, VR has proven to be a highly effective scenario planning tool. Lavoie et al. (2023) demonstrate that VR-based training for de-escalating mental health situations is as effective as live-action scenario training. VR training offers additional advantages: it is less costly, involves less risk, and is more easily customized, making it a flexible and scalable option for dynamic and sensitive situations.

Another domain where VR has shown its efficacy is in the assessment and mitigation of underground roof fall hazards. Authors introduce VR simulations designed to improve the assessment of these hazards and implement necessary measures to mitigate related risks. The simulation includes decision-making tasks where participants create a safe working environment by identifying potential hazards, selecting and installing safety measures, and assessing the hazard before and after the support measures. The results highlight the benefits of VR in safety training and its effectiveness in enhancing the decision-making process to improve safety.

Although not explicitly stated, these scenario planning tools have strong underlying Shacklian components, particularly in how they handle focal gains/losses. In valuation scenarios, the novelty of assets and lack of prior experience lead participants to focus on attention-grabbing scenarios of value creation and destruction, helping them determine their bids and selling prices without a broad range of estimates. In police training, VR scenarios highlight strong competencies and noticeable weaknesses that need direct adjustments rather than requiring a detailed evaluation of every nuance. The same principle applies to roof fall hazard training, where participants enhance their skills by focusing on scenarios of robust strength and significant hazard instead of constructing a continuum of probabilities for less prominent scenarios.

Another Shacklian feature, non-additivity, is evident in these experiments. For instance, identifying strong competencies in police training does not eliminate the need to address significant weaknesses, even within the same feature of the training. Similarly, in valuation and roof hazard assessments, recognizing strong performance does not negate the necessity to improve areas that require further development.[2]

In the context of financial investing, emphasizing optimal risk-return trade-offs through detailed financial metrics often leads investors away from their primary goal of accumulating wealth (Levy, 2017; Levy & Roll, 2016). Conventional risk models, both in markets and policymaking, frequently fall short in considering the tail risks linked to extreme events, resulting in investors underestimating the actual levels of volatility and uncertainty in the market (Taleb, 2007). This, in turn, fosters complacency in decision-making.

[2] Both Derbyshire (2017) and Loasby (2011) discuss an episode where Shackle and economists at Shell identified similarities between Shackle's Potential Surprise Theory (PST) and Shell's practice of scenario analysis. They recognized that both approaches emphasize exploring uncertain futures and avoiding reliance on additive probabilities, highlighting their shared focus on consequential outcomes. Derbyshire (2017, p.78) writes: *"PST and scenario planning share the same ontology, viewing the future as constructed by the imaginings of individuals, rather than existing objectively as a fully-specifiable choice set. As such, both PST and scenario planning place indeterminism stemming from free will and choice at the centre of consideration of the future; however, both also envisage this indeterminism as bounded, rendering anticipation of the future possible."*

Indeed, the similarities between Shackle's and Nassim Tabel's decision-approach, is emphasized by Derbyshire (2017). Both approaches emphasize the inherent unpredictability of the future, highlighting the limitations of traditional decision-making frameworks that prioritize statistical regularities and are excessively reliant on probabilistic models and historical data. Moreover, they both advocate for a more imaginative and intuitive approach to decision-making, acknowledging the need for adaptability and resilience in the face of uncertainty.

In a similar vein as Shackle's focus on focal gains/losses, Taleb's barbell strategy exemplifies this concept by advocating for extreme risk management: allocating resources in an extremely conservative manner on one end of the spectrum and aggressively on the other, while avoiding the vulnerable middle ground. This comprehensive approach to risk management not only enhances the resilience of investment portfolios but also enables investors to capitalize on opportunities that may arise in the wake of extreme events, achieving what Taleb labels as Antifragility. Antifragility stands in contrast to fragility, where systems are vulnerable to disruption and collapse under stress. The key idea is that antifragile systems benefit from disorder and uncertainty, as they use such events to adapt, evolve, and improve over time.

To gain a deeper understanding of the VR experience, it's more beneficial to integrate it into the Shackle/Taleb framework rather than focusing solely on statistical patterns. VR tools have the potential to help decision-makers identify critical focal points by highlighting extreme yet plausible outcomes. This approach enables decision-makers to develop a more nuanced comprehension of both risk and opportunity. By accepting the unpredictable nature of VR experiences and using them to stimulate imagination, decision-makers can adopt a more resilient mindset. This equips them with the ability to thrive amidst uncertainty and capitalize on unforeseen opportunities.

Such emphasis on focal points can guide the use of VR in training policymakers and investors by simulating real-world scenarios. Prioritizing extreme outcomes serves as a powerful antidote to complacency by challenging investors and regulators to confront the possibility of outlier events that lie beyond the realm of conventional expectations. By actively considering the full spectrum of potential outcomes, investors can cultivate a mindset of vigilance and open-mindedness, thereby reducing the likelihood of being blindsided by unforeseen developments. This proactive approach enables both investors and policymakers to anticipate and prepare for scenarios that may defy conventional wisdom, thereby increasing the robustness of their investment strategies and enhancing their resilience to unforeseen challenges.

6. Conclusion

This paper extends Shackle's framework to incorporate VR. By integrating insights from the extended mind hypothesis (Clark and Chalmers, 1998) and discussing the transformative potential of VR technology, I advocate expanding the understanding of Shacklean imagination to include new forms of cognitive augmentation. This interdisciplinary perspective bridges theoretical frameworks with practical applications, offering novel insights into decision-making in the digital age.

I argue that despite the inherent limitations of imagination in predicting every nuance of future outcomes, decision-makers can effectively leverage imaginative processes to evaluate potential scenarios and outcomes beyond the confines of probabilistic reasoning. This aligns with the broader discourse on the subjective nature of human experience and decision-making (Velupillai, 2005), emphasizing the importance of embracing uncertainty as an inherent aspect of decision-making processes.

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