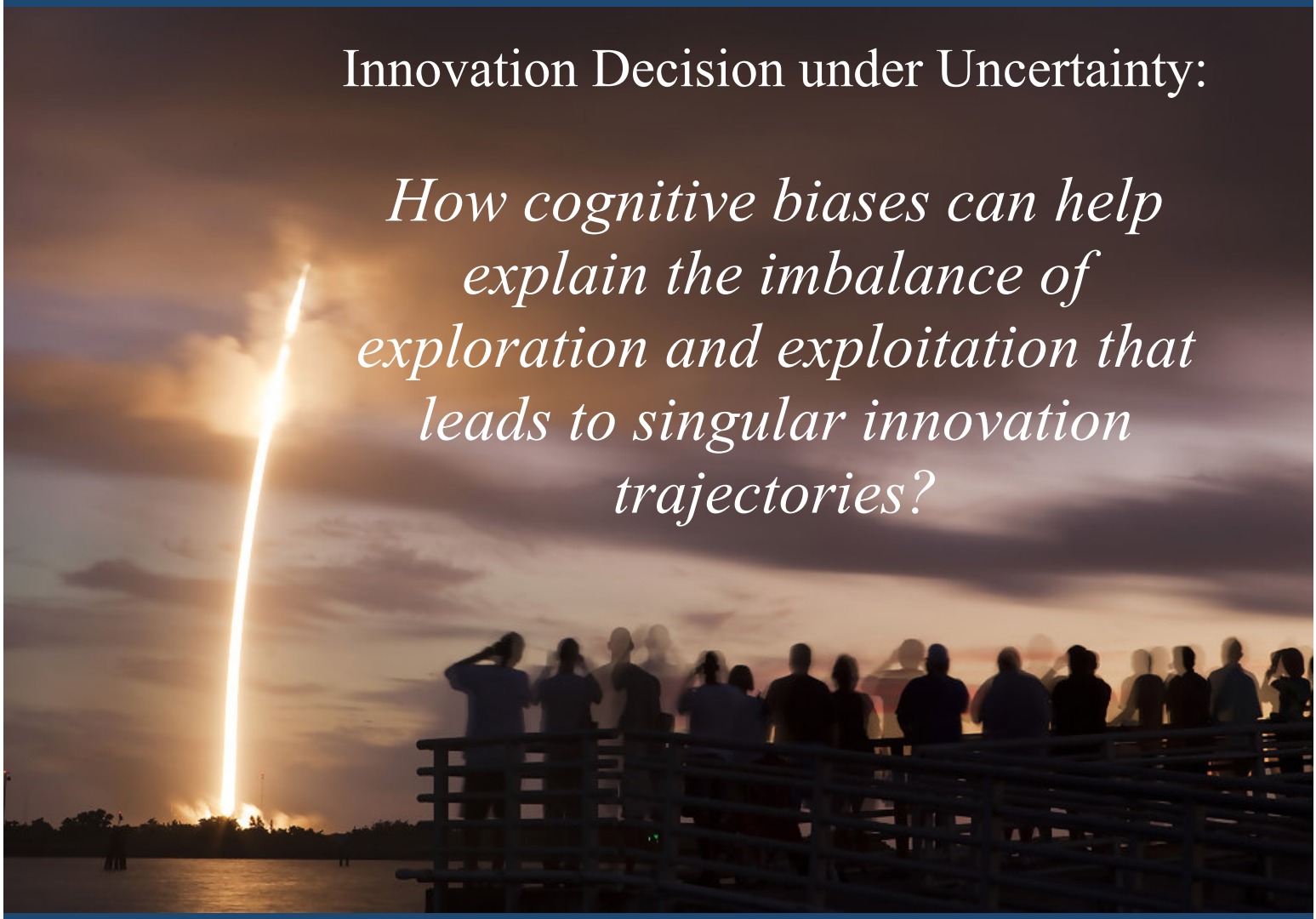
Innovation Decision under Uncertainty:

How cognitive biases can help explain the imbalance of exploration and exploitation that leads to singular innovation trajectories?



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Abstract

Research in innovation has long studied the balance and imbalance of exploration and exploitation with the consensus that a balance of both is necessary for the long-term survival of a business entity, a business of any size. The specialization of exploration or exploitation leads a business entity into a state of failure, success, or competence trap (a result of a singular innovation trajectory) that can render a business entity vulnerable to changes in the market. Innovation scholars have studied this phenomenon largely at an organizational level, therefore, an inadequacy exists in explaining the balancing mechanism in relations to the actual innovation decisions that balance or dis-balance the business entity. In decision making, one is bounded by limited information, time, and cognitive constraints. This research fills the gap by investigating the cognitive constrains known as cognitive biases—mental filters and short cuts that can mis-guide the assessment and decision process—at an individual level. This thesis links known behaviors found in singular innovation trajectories (trajectories with only exploration or exploitation) to culpable cognitive biases. In doing so, this thesis finds that overconfidence in one's ability and over-optimism in the odds of favorable outcomes can cause errors in estimating the relative importance of cues and information processed during decision making. Therefore, the root cause of the imbalance is the cognitive biases that affect the accuracy of estimation and lead to such overconfidence and over-optimism. Moreover, this research also investigates cognitive biases' role in the persistence of singular innovation trajectories. By understanding the role of cognitive biases in innovation decision making, this thesis is able to purpose a balancing mechanism based on managing the undesired effects of cognitive biases, thus, re-balancing the decisions on exploration and exploitation.

Keywords: balance, innovation, exploration, exploitation, success trap, failure trap, competence trap, trajectory, inertia, organizational ambidexterity, punctured equilibrium, cognitive biases, decision making

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1.0 Introduction

The future always encompasses a high degree of uncertainty. At any given time, a business entity, a business of any size, uses limited information to make assessments and decisions that are deemed beneficial to that entity at a later time (Simon, 1955). In addition, decision makers are bounded by time constraints and their cognitive limitations (ibid). This is the foundation of *bounded rationality*, that people's decisions are bounded by these constraints. This thesis investigates the third set of boundaries, namely, cognitive limitations, in the form of cognitive biases[i]. It surveys how cognitive biases distort cues and information that lead the innovation decision makers toward a state of vulnerability known as *success trap*, *failure trap*, or *competency trap* from the pursuit of only exploitation or exploration (Levinthal and March, 1993). Based on robust empirical observations on the effects of success, failure, and competency traps, there exists an academic consensus that a balance between exploration and exploitation is necessary for the long-term survival of a business entity of any size (March, 1991; Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006).

In innovation studies, singular courses of action that results in success, failure, and competency traps are observed in both incumbents and new entrants. Many new entrants fail during the commercialization of a product or service; the odds for success, according to Stevens and Burley (1997), is on average 3,000 raw ideas[ii] for 1 commercial success. In the 1990s, following the success of Internet warehouse giant, Amazon.com, many new entrants attempted to emulate its logistics and wide-selection, two of its most important success factors, by offering other products online. Pet.com, a subsidiary of Amazon.com, was one such new entrant who failed in 2000, after two years of operation with a loss of $200 million (Van Pelt, 2008; Wolverton, 2000). During the two years, Pet.com persisted in exploring on developing a larger range of products and improving its logistics. However, it overestimated the customer preference for a wider selection of pet food and underestimated the cost of shipping, which led to its bankruptcy (ibid). Another example is the Dvorak Simplified Keyboard, which failed in competition with the QWERTY keyboard. The modern QWERTY keyboard was designed to scatter common letters in order to slow down typists and resolve the initial jamming problem, thus, it is not an efficient keyboard system. In 1914, forty years after the QWERTY keyboard had been commercialized, August Dvorak realized the inefficiency and set out to create an ergonomic and speedy keyboard with his brother-in-law. After two decades of exploration and R&D, the invention was launched in 1932, but it never gathered

enough customer-base to become successful. Dvorak died in 1975 a bitter man, and reportedly said, "I'm tired of trying to do something worthwhile for the human race. They simply don't want to change!" (Diamond, 1997). In this case, Dvorak overestimated the value for an improved keyboard to customers and underestimated the unwillingness for people to relearn a new routine. The cases of Pet.com and the Dvorak Simplified Keyboard[iii] are illustrated examples of failure traps, in which a new entrant has encountered numerous failures in its exploration process yet determined to explore further (Levinthal and March, 1993). They disregarded the need for *exploitation*—deliberate activities including 'refinement, choice, production, efficiency, selection, implementation, execution (March, 1991)' that focus on harvesting the innovation's value to the market in exchange for financial gain, the key being objective to market cues and information.

For incumbents, it is expected that some will fail in the future. 24/7 Wall Street[iv], a division of the Wall Street Journal, publishes an annual list of ten well-known brands that it predicts to disappear in a decade. In the cult classic, Blade Runner, director Ridley Scott showcased thirty-one[v] incumbent brands in 1982 that were expected to remain successful in the capitalist-dominant future of 2019 (Sammon, 1996). However, a few large corporations including Atari, Bell, Polaroid, RCA, TDK, and TWA had encountered significant market loss and/or bankruptcy within the decade after their product placements in Blade Runner. The coincidental string of corporate misfortunes led to the popular superstition of a Blade Runner Curse (IMDB.com), which illustrates two points: *first*, incumbents can succumb to failure as do new entrants if they misinterpret market cues or information; s*econd*, people have the tendency to string unrelated events together into a coherent story that in reality has no correlation or causality to each other (Kahneman, 2011, p. 75-6). To elaborate the first point, Polaroid was an iconic company known for its instant camera technology. Its founder, Edwin Land, was a visionary leader and an avid inventor[vi] that led the company into great success in the magnitude comparable to Apple today (Dayal, 2012). Polaroid experienced dramatic setbacks after Land retired in 1982 and during the wave of digital cameras in the 1990s (Dayal, 2012; Bonanos, 2012). Although Polaroid explored in digital technology in the 1980s, it was also reluctant about cannibalizing its successful chemical film business (ibid). Instead of recognizing the future of digital camera, Polaroid concentrated on building new coating machinery to stay competitive in the old technology (ibid). It filed for bankruptcy in 2001. In the case of Polaroid, it underestimated the potential for digital camera and overestimated the future revenue from its existing innovations. After the retirement of Land, Polaroid reduced its effort on

exploration—activities including 'search, variation, risk taking, experimentation, play, flexibility, discovery, innovation (March, 1991)' that focus on creating new market-ready innovation with commercial value. Relying on known competences, Polaroid continued to focus on exploitation, which led it to a success trap.

Both in the case of new entrants falling into a failure trap or in the case of incumbents engulfed by a success trap, the innovation decision makers assessed market information inaccurately, which can be a reflection of mis-estimation caused by cognitive biases. In both cases, the inaccurate assessment of cues and information led to overestimation or underestimation of future events. Consequently, the mis-estimations that led to singular innovation trajectories were very costly for the business entities. The balance between exploration and exploitation enables a business entity to pursue new business ideas while earning financial returns on the existing business ideas. Therefore, balancing exploration and exploitation is agreeably the optimal state for a business entity (March, 1991; Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006). There are two schools of thought on the balancing mechanism: *organizational ambidexterity* and *punctured equilibrium*—the former is a cross-sectional view of achieving both exploration and exploitation simultaneously, while the latter is a longitudinal view of shifting the intensity of exploration or exploitation over time (Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006). Organizational ambidexterity advocates for an organizational design that separates existing exploiting businesses and emerging exploring businesses. In doing so, an organization can bypass the seemingly contradictory objectives. Punctured equilibrium observes the natural shifts between exploration and exploitation and advocates for managerial vigilance towards the shift. Comparatively, it is less normative than organization ambidexterity.

The study of exploration and exploitation in innovation management as well as the balancing mechanism are often researched on an organizational level (March, 1991; Katila and Ahuja, 2002; Corso and Pellegrini, 2007; Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006). While other innovation studies center the units of analysis on leadership (Smith and Tushman, 2005), team composition (Beckman et al., 2007), personal traits (Zhao and Seibert, 2006), organizational design (Tushman and O'Reilly, 1996), strategy (Afuah and Utterback, 1997), sources of innovation (Poetz and Schreier, 2012), venture capital (Shepherd, 1999), etc., often the level of analysis continues to focus on an organization or a team. The continuing focus on an

organization or a team as the unit or level of analysis neglects the individual as the common denominator of any innovation activity. Furthermore, any innovation decision made by an individual is processed cognitively, therefore, it is reasonable to use cognitive activities as an objective and generalizable unit of analysis within innovation studies. Current research focusing on cognitive behaviors and innovation is rare and often superficial (Morrison and Potts, 2008; Potts, 2010; Van Pelt, 2008). Since cognitive biases are universal denominators to all individuals, which extend to decision makers of innovative activities, it is important to incorporate cognitive biases into innovation studies, especially their roles in singular innovation trajectories.

Since success, failure, and competency traps can happen to any business entity and there exists a lack of comprehensive linkage between cognitive biases and the imbalance of exploration and exploitation, this paper aims to investigate the linkage between the three. In doing so, this research sets out to investigate *how can cognitive biases help to explain the imbalance of exploration and exploitation that leads to singular innovation trajectories?* The research employs cognitive biases as the unit of analysis and the individuals as the level of analysis. The thesis adopts the dual process theory (System 1 and System 2) in recognizing there are two systems in cognition: the intuitive and biased System 1 and the deliberate and detailed System 2 (Evans and Frankish, 2009; Kahneman, 2011). System 1 is the fast thinking that connects information to create coherence; it is also the source of cognitive biases. On the other hand, System 2 is the slow thinking that conducts computations and comparative thinking; it is also the controller of System 1. By understanding how cognitive biases contribute to singular innovation behaviors, innovation decision makers can become aware of such behaviors and their implications. In countering the negative effects of cognitive biases in decision making, a small branch of cognitive research called *debiasing* offers some descriptive solutions to re-frame our biases and enable our System 2 to counter-balance the biases (Larrick, 2004). Although it is not easy to modify behaviors, if the opportunity cost is high enough, it might become necessary (Kahneman, 2011). In theoretical contribution, this research can help to create a stronger and more comprehensive link between behavioral science and innovation management via cognitive biases. Alternatively, the linkage of cognitive biases to innovation can be further development as a focus in the study of personality traits. For instance, instead of researching on finding personality traits in entrepreneurs or incumbents leaders (Zhao and Seibert, 2006), the study can investigate if successful leaders have a higher capability to utilize System 2 to assess

market cues more accurately. Ultimately, this paper is a pebble in creating a comprehensive link between cognitive psychology and innovation management.

The research is divided into seven chapters: introduction, literature review, dual process system, method, analysis and discussion, conclusion, and implications. In chapter 2, innovation literature is reviewed to examine the common behaviors and the reasons for the persistence in singular innovation trajectories. In Chapter 3, a general introduction of the dual process system is presented. In Chapter 4, a method in establishing ontology, epistemology, research design, unit and level of analysis, assumptions, and limitations, is presented to clarify the research foundation. Chapter 5 presents the cognitive biases associating with mis-estimation and the persistence of singular behaviors. Additionally, it analyzes the applicability of these cognitive biases in initiating singular innovation trajectories and their persistence. In Chapter 6, the conclusion recapitulates the findings and answers the research question. In Chapter 7, implications and future research are presented to highlight the theoretical implications and learning applicable for business entity as well as the possibilities for addition research.

2.0 Theory Review

The research question *How can cognitive biases help explain the imbalance of exploration and exploitation that leads to singular innovation trajectories?* amalgamates three research areas—cognitive biases, the balance of exploration and exploitation, and singular innovation trajectories, which the latter includes the pathways to success, failure, and competence traps. This section reviews the theoretical bases and critiques for the last two research areas according to innovation literature. There are three aims for this review 1) to survey for the common behaviors exhibited in innovation decision makers on the way to success, failure, and competence traps, 2) to investigate the reason for the persistence of singular innovation trajectories, 3) to examine the current literature on the mechanism for balancing exploration and exploitation.

2.1 Failure, Success, and Competency Trap

The terms, failure trap and success trap, illustrate a state of vulnerability resulted from the specialization of exploration or exploitation; whereas competency trap depicts a state of vulnerability resulted from specialization of competences (Levinthal and March, 1993). Over time, the persisting specialization diminishes the long-term viability of a business entity by reducing the

business entity's abilities to survive in conditions that warrant variations, perhaps with a mixture of exploration and exploitation or with different competences (ibid). As the study of failure, success, and competency traps originates from organizational learning, self-evidently, it adopts the organization as the level of analysis.

2.1.1 Failure Trap and Competency Trap

In the short-run, Levinthal and March (1993) reasons that 'Sometimes exploration drives out exploitation…Failure [in exploration] leads to search and change which leads to failure which leads to more search, and so on (p.105-6)'. The illustration expresses that failure trap is only associated with persistent exploration. As exploration concerns with 'search, variation, risk taking, experimentation, play, flexibility, discovery, innovation (March, 1991, p. 71)' that partake on creating a new market-ready innovation with commercial value, it implies a higher level of risk and uncertainty in remuneration. Therefore, a commitment to exploration exhibits a willingness to commit large quantity of resources to projects in which the return can be uncertain (Miller and Friesen, 1978). During exploration, resources such as cash reserve are being depleted, if the business entity continues with a high aspiration for future exploratory success despite current failures, it is made vulnerable by its own persistence (Levinthal and March, 1993, p. 106).

Being trapped by exploration is often associated with new entrants who are in the process of perfecting an invention for commercialization (Gimeno, J. et al., 1997). However, intensity and persistence in exploration can also be observed in incumbents whose past success in exploration drives it towards more exploration, even when current exploratory projects are unsuccessful (Liu, 2006). Persistent failure entices the business entity to further its search and be optimistic that success is forthcoming; in other words, adjusting aspiration and optimism downward according to negative feedback occurs slowly (Lant, 1992, reciting from Levinthal and March, 1993), Therefore, overestimation of the coming success or any favorable occurrences can skew innovation decisions.

Despite failures, repetition in exploration increases learning and competences. Therefore, it is complementary to study another state of vulnerability, known as *competency trap*, which 'involve[s] short-term positive feedback on either exploration or exploitation and thus upset a balanced attention to both' (Levinthal and March, 1993, p.105). For example, a business entity's experience in exploration will increase its competences towards exploration, which can limit organizational deviation towards exploitation (Liu, 2006). Therefore, competence in exploration can

develop in incumbents or new entrants during exploration despite persistent failures. Therefore, all business entities are subjected to competence trap from failure in exploration as competences in exploration accumulate.

When failure is persistent, the continuation of exploration delineates a behavior with higher risk-preference. Levinthal and March (1993) reasons that when individuals are operating below their aspiration level, an expected target, they tend to increase risk taking activities; however, this so called, risk-seeking behavior only increase until they approach a survival point. Levinthal and March (1993) argue that persistent failures can heighten risk-seeking behavior because of a mixture of insufficient adjustment in aspirations and desperation. Risk is a cognitive perception that will be further discussed in Section 5.3.3 and insufficient adjustment is examined under anchoring in Section 5.1.2.

To recapitulate, failure trap is the state of vulnerability brought on by a singular and persistent pursuit of exploration even after repeated failures in exploration. It is associated with overestimating the odds of the any coming favorable event as a result of insufficient adjustment in aspiration, therefore, the business entity has a tendency to behavior in a risk-seeking manner. During failures in exploration, business entities can learn and develop competences around the area in which they are exploring, therefore, the increasing competences can also develop into a trajectory and limit the possible deviations.

2.1.2 Success Trap and Competency Trap

On the other hand, success trap is the short-term positive feedback from exploitation that 'drives out exploration (Levinthal and March, 1993, p. 106)'. During exploitation, a business entity remunerates the investment made during exploration. As a business entity refines an innovation, an invention with a proven commercial value, the positive reception of the innovation mobilizes the business entity to further refine and improve the innovation. In addition, the business entity begins to tailor its capabilities[vii] such as production, logistics, distribution, etc., to complement the successful innovation.

During this process, specific and local competences develop. As competences and experience accumulate locally, fewer failures occur and thus, the likelihood of success increases (Levinthal and March, 1993; Liu, 2006). The repeated success also implies that learning is localized as the

opportunity cost increases for doing business in areas that deviate from current learning and competences. This way, success trap is closely related to competency trap, in which a business entity specializes in competences that has brought previous success. The series of successes prompts the business entity to continue exploitation. In a longitudinal study on chemical patents, Ahuja and Lambert (2001) discover that large corporations have high preference towards projects that are familiar, mature, or using existing solutions. In other words, even in their R&D effort, large corporations prefer exploiting current technologies. Consequently, this preference has a tendency to make business entities myopic toward long-term needs (Levinthal and March, 1993, p. 101). The negligence toward exploration and deviation of competences exposes a business entity to vulnerability in changes that necessitate learning, competences, and resources outside its specialization.

During a series of successes, individuals become biased in their perception of risk and causality. They attribute success more often to themselves and underestimate risk in future events (Levinthal and March, 1993, p. 105). They become more confident about their abilities and optimistic about the odds of success or any favorable occurrences. The business entity develops risk aversion as modest success progresses (Levinthal and March, 1993, p. 108) because exploration becomes comparatively more costly. Therefore, the business entity begins to overestimate the risk in exploration; consequently, they also underestimate risk in regards to their specializations.

The study of success and failure trap is highly subjected to *hindsight bias*, when mistakes appear obvious because the effect has been observed and examined (Kahneman, 2011, p. 203). The states of vulnerability remain potential until an occurrence overwhelms the business entity. By extension, if the overwhelming event does not occur, business entities that have persistent success in exploitation or local competences are likely to be praised for their core focus. Similarly, without the occurrence of an overwhelming event, those with persistent failure in exploration can arguably reach a break-through point. At that point, the past persistent failure is seen in better light. Empirical research into success, failure, and competence trap are largely conducted by case studies (Burgelman, 2001; McNamara and Baden-Fuller, 1999) or industrial-level studies (Benner and Tushman, 2002; Ahuja and Lambert, 2001) albeit case studies can be laced with hindsight bias.

To summarize, success trap is a state of vulnerability brought on by a singular and persistent pursuit of exploitation during persistent success in exploitation. It is associated with overconfidence in one's abilities and overestimation in the odds of favorable outcome. With increase success, learning, competences, and resources begin to localized, thus, increasing the opportunity cost towards exploration and the likelihood for risk aversion. It should be noted that studying success, failure, or competency trap through cases is prone to hindsight bias.

2.2 Initiating Innovation Trajectories

After reviewing various innovation trajectories (failure, success, and competency trap), there is a consensus in the literature that it is difficult to deviate from an innovation trajectory after specialization. With the accumulation of specialized competence, learning, and resources, the business entity also experiences less failure. As opportunity cost for variation increases, and the business entity continues to specialize, three behaviors emerge: 1) increase of confidence on the current trajectory, 2) increase of confidence on analogous domains, and 3) mis-estimation of risk, that can initiate an singular innovation trajectory in the form of exploration or exploitation.

First, as learning is tested, verified, and specialized, mistakes and failures are reduced, therefore, it increases the business entity's confidence in its own abilities (Murmann and Tushman, 1997). However, the confidence is likely to become excessive in instances, when previous record is a poor predictor of future success (Levinthal and March, 1993, p.104-5); thus, overconfidence on the business entity's abilities can encourage over-optimism in the continuity of success.

Second, and in extension to the first, the confidence in the business entity's own abilities can lead it to become overconfident in the generalizability of its learning and success in other *analogous domains*, business fields that the business entity may find its success and abilities applicable. In doing so, it is likely to exaggerate the probability of success (Levinthal and March, 1993, p.104); thus overconfidence on the business entity's abilities can lead to overconfidence in the general application of its abilities.

Lastly, risk perception can be compromised due to the overconfidence of its abilities and over-optimism of its future. It can in turn affect the accuracy in the estimation of risk. Levinthal and March (1993) reasons that 'Any inclination to over attribute outcomes to luck will be associated with overestimating risk, thus with decreasing risk taking. Similarly, any inclination to over-

attribute outcomes to ability will be associated with underestimating risk, thus with increasing risk taking. As a result, persistent failure leads to a tendency to overestimate the risks of actions, and persistent success leads to a tendency to underestimate those risks. (p.105)'.

It is shown that success can condition a business entity into becoming overconfident of its own faculty, thus, underestimate risk; however, persistent failure do not necessarily leads to a tendency to overestimate risk. In the same article, Levinthal and March (1993) posit that when individuals are operating below their aspiration levels, they tend to increase risk-taking activities. A contradiction exists if a persistently failing business entity is to overestimate risk yet continues to act in a risk-seeking way. Although Levinthal and March (1993) mention that an ignorance to risk can induce risk taking, it was meant as a strategy to increase exploration by altering risk perception (p. 108-9) and not a reconciliation to the contradiction. In order to placate the contradiction, it is reasonable to assume that when a persistently failing business entity is acting in a risk-seeking way, its risk perception is compromised, therefore, it becomes insensitive to risk and its risk assessment is wildly inaccurate during persistent failure. The theory on mis-estimating risk in relations to persistent failure is further discussed under Prospect Theory in Section 5.3.3.

To summarize, the three singular innovation trajectories examined in the last section have shown that it is difficult to deviate from specialization due to the increasing opportunity cost. Meanwhile, business entities can become overconfident in its abilities and over-optimistic in the odds of favorable outcomes. The overconfidence and over-optimism can contribute to an overall mis-estimation in innovation assessment, such that it distorts the opportunity cost assessment, therefore, increasing the business entity's proclivity to specialize.

Insight 1: Therefore, the examination of the literature on innovation trajectories identifies that mis-estimation stemmed from overconfidence and over-optimism is the initiator to singular innovation trajectory.

Although overconfidence can appear disadvantageous, especially in hindsight when the business entity does not benefit from it, overconfidence in its abilities and odds of success are sometimes necessary for the renewal of innovation. In facing the odds of 3,000 raw ideas in 1 commercial success (Stevens and Burley, 1997), it is rational that most business entities, overconfident or not, will fail. On the other hand, only the overconfident will ever be heroes (Levinthal and March, 1993;

Goel and Thakor, 2000), and have the mental strength to preserve. Therefore, for innovation to happen, a degree of overconfidence is necessary, but this thesis argues that overconfidence and having a sense of objective assessment are not in conflict.

2.3 Path Dependency, Capability-Rigidity Paradox, Coevolutionary Lock-In, and Organizational Inertia—the increasing opportunity cost to deviate

Path dependency is the tendency to persist with a specific pathway as a result of past decisions and their momentum (Cohen and Levinthal, 1989; Collier and Collier, 1991). It relates to the opportunity cost of deviation once a trajectory is set. Path dependency illuminates the preference toward depending on existing competences due to convenience, profitability, and reliability. Moreover, past success reinforces behaviors that associated with the success (McNamara and Baden-Fuller, 1999) such as overconfidence in one's abilities and over-optimism in the odds of favorable outcome. In the short run, specialization in local competences can be a source of competitive advantage; however, without renewal, the same competences can become a source of organizational rigidity when the market changes; the concept is known as *the capability-rigidity paradox* (Leonard-Barton, 1992). As capabilities, the ability to utilize competences, become localized, the opportunity cost to acquire other non-local capabilities also increases. Meanwhile, the organization's value and norms are integrated into the capability trajectory, which raise the opportunity cost for deviation. This creates an inertia[viii] toward capabilities specialization. The capability-rigidity paradox is an extension of *competency trap*, positive short-term feedback from competences developed (Levinthal and March, 1993).

Burgleman (2002) presents another concept on path dependency called *coevolutionary lock-in*, 'a positive feedback process that increasingly ties the previous success of a company's strategy to that of its existing product-market environment, thereby making it difficult to change strategic direction (p. 326)'. Co-evolutionary lock-in is also an extension of *competency trap*. It differs with capability-rigidity paradox by recognizing that the inertia is not only a result from competences specialization, but also the internal and external dynamics that drive the trajectory forward. It stipulates that the initial success of the innovation sets a forward trajectory for the business entity, forming an internal strategy to specialize, a *vector*; simultaneously, if the innovation is well received by the external market, an external expectation can also gather and encourage the business entity to localized R&D, production, and other resources. In obliging to the internal and external expectations, the business entity continues to form competences locally and it becomes increasingly

difficult to deviate from the strategic trajectory. In the case study of Intel's success on microprocessor, its CEO at the time, Andy Grove, said "There is a hidden danger of Intel becoming very good at this [microprocessor]. It is that we become good at one thing only (Burgleman, 2002, p. 342)". It reflects the shortcoming of specialization because it limits the business entity's scope in learning, competences, and resources. Co-evolutionary lock-in is a more comprehensive concept of innovation trajectory; it recognizes that the inertia is not only a result of increasing opportunity cost from competences deviation; in addition, the inertia comes from the opportunity cost of strategic deviation.

Another kind of path dependencies studied in organizational ecology is *structural inertia* (Hannan and Freeman, 1984). In alignment with coevolutionary lock-in, structural inertia recognizes the investment made towards a strategic trajectories as well as any external expectation. However, it concentrates on the structural rigidities of an organization once developed. Building an organizations structure requires scarce resources that are non-recoverable. Once developed, they grow into bureaucracies that value reliability[ix], accountability[x], and reproducibility[xi], therefore, change in organizational structure incurs very high opportunity cost.

Literature on organizational inertia consents that as business entities progress with a trajectory, many factors contribute to its inertia and persistence. The increasing opportunity cost of deviating from current capabilities, strategy, and organizational investments reinforces the trajectory; thus, the business entity persists with the trajectory.

Insight 2: Therefore, increasing opportunity cost for deviation enables the persistence of the imbalance of exploration and exploitation that leads to success, failure, and competency traps.

The three kinds of organizational inertia are conceived at an organizational level, therefore, the investigation on an individual level, which can yield a different conclusion, has been largely omitted; this will be remedied in Section 5. Moreover, literature on organizational inertia tends to over-emphasize an organization's inability to deviate from innovation trajectories. Original literature on capability-rigidity paradox, coevolutionary lock-in, and structural inertia focuses on the persistence and not the exit. The former advocates that for an organization to exit the trajectory, it has to discredit the value and norm system (Hannan and Freeman, 1984). The last two[xii] takes an

ecological perspective and suggest that a natural rebalancing of exploration will occur if the organization is to survive. According to *resource-based view* under strategic management, an organization has the tendency to follow a strategic trajectory as a result of its optimization in resources and competences. In building competition advantage around its resources, it submits to an organizational trajectory and inertia; however, resource-based view emphasizes that the trajectory may not be linear because organizational competences and resources are dynamic and capable of alteration as learning is updated, whether the change is intentional or not (Barney, 1991).

In the study of organizational learning, variation in knowledge is necessary in anticipating changes in the market. Cohen and Levinthal (1990) uses the term *absorptive capacity* to denote a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends (Cohen and Levinthal, 1990, p. 128). For an organization, it can be gained as a by-product of R&D, marketing, etc. In studying long-run knowledge stock, March (1991) posits that a mixture of slow learners and fast learners as well employee turnovers can help organization attain higher knowledge level in the long-run according to simulations. Therefore, a mixture of employees with skills conforming to the organization and some with diverging skills is beneficial to the firm's long-term survivability and short-term balance in exploration and exploitation. In essence, high degree of conformity within a business entity will limit the growth and knowledge stock in the long-run.

To summarize, within the research on innovation inertia, including capability-rigidity paradox, coevolutionary lock-in, and structural inertia, scholars have focused on opportunity cost as the overall reason for the persistence of innovation trajectory. Although organizational inertia does not stipulate the mechanism to which business entity can exit the inertia, dispersing the old value and norms appears to be an important factor to change. Resource-based view assures that business entities can exit the trajectory by updating their competences and resources, rather it is intentional or not. Furthermore, a mixture of employees with both localized learning and non-localized learning can enhance a business entity's ability to balance exploration and exploitation, and exit a particular trajectory through new learning.

2.4 Balancing Exploration and Exploitation

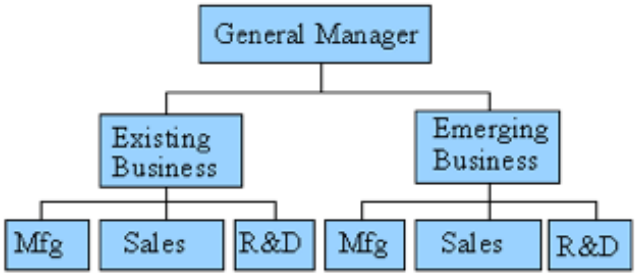
Innovation management has studied exploration and exploitation extensively (Gupta and Smith, 2006;Tushman and O'Reilly, 1996; Burgelman, 2002) since James March (1991) loosely defined the terms[xiii] within the innovation context. Although a consensus on the definitions of exploration

and exploitation has not been reached (Gupta and Smith, 2006), there exists a consensus on the need to balance exploration and exploitation (March, 1991; Levinthal and March, 1993; Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006). The balance is to 'engage in sufficient exploitation to ensure its current viability and, at the same time, to devote enough energy to exploration to ensure its future viability. Survival requires a balance, and the precise mix of exploitation and exploration that is optimal is hard to specify (Levinthal and March, 1993, p. 105)'. Essentially, the mechanism(s) of which this balance confers to is still debatable. There are two main schools of thoughts on the balancing mechanism: *ambidexterity* and *punctured equilibrium*—the former is a cross-sectional view of achieving both exploration and exploitation simultaneously, while the latter is a longitudinal view of shifting the intensity of exploration or exploitation over time (Tushman and O'Reilly, 1996; Burgelman, 2002; Gupta and Smith, 2006). Both schools of thought employ an organization as the level of analysis.

2.4.1 Organizational Ambidexterity

With the core perspective of simultaneously attaining exploration and exploitation for short-term and long-term survival, organizational ambidexterity takes a cross-sectional view at a point in time. It stipulates that an organization can accommodate the seemingly contradictory objectives of exploration and exploitation, by separating and empowering both via organizational structuring. Tushman and O'Reilly (1996) propose that an organization can become ambidextrous, being dexterous to both exploration and exploitation, by separating the existing businesses and emerging businesses; meanwhile, both kinds of businesses can receive separate supports in daily operations and remains competitive in their own agendas (ibid). This way, each business can concentrate on exploration or exploitation and the company culture can deviate within the respective units (O'Reilly and Tushman, 2004). In studying companies who are considered successful in balancing exploration and exploitation, O'Reilly and Tushman (2004) found two important attributes: *first*, they separate their new, exploratory units from their traditional, exploitative ones; *second*, they maintain tight links across units at the senior executive level. With the loosely integrated units, this organizational design encourages cross-fertilization and discourages cross-contamination.

Figure 1: Ambidextrous organization chart



The success in separating traditional businesses with emerging businesses is empirically possible and theoretically sounded, yet it is not so easy for all businesses to emulate. *First* of all, some business entities can have overtly complicated organizational structure as a result of un-designed growth, including value and norms system, which can limit its organizational flexibility to rearrange itself (Hannan and Freeman, 1984). *Secondly*, a business entity can have tacit knowledge, knowledge that is difficult to express explicitly, that limits the success of such reorganization due to the time and resources required for tacit knowledge transfer (Arora et. al., 2001). *Third*, the necessary and durable commitment of senior managers to all traditional and emerging business can be difficult to maintain over time when some business units fair better than others (Daellenbach et al., 1999). *Fourth*, since each business unit is to remain competitive, it can be difficult to encourage cross-fertilization of ideas. Consequently, it is reasonable to suppose that ambidexterity by restructuring may be easier to execute in younger incumbents or new entrants but at the same time, they may not have the resources necessary for a large restructuring.

Although Tushman and O'Reilly (1996) posit that organizational ambidexterity is achieved through organizational restructuring, there are independent cases of companies innovating ways to accommodate both exploration and exploitation in other manners. One of which is Google's 20/80 time rule, in legitimizing and enabling all employees to use 20% of work hours to work on secondary projects that may contribute to innovation within Google[xiv] (Kotter, 2013). Another method is crowd sourcing[xv] innovative ideas through social intranets like ThinkPlace that is used at IBM (Majchrzak, et al., 2009).

2.4.2 Punctured Equilibrium

The second mechanism for balancing exploration and exploitation is punctured equilibrium. It takes a longitudinal view to how a business entity can maintain exploration and exploitation by shifting the emphasis on one or the other over time (Burgelman, 2002). It has a theoretical base from evolutionary biology in the observation that species can endure a long time with no evolving change but can suddenly develop mutations. In an innovation context, instead of balancing exploration and exploitation at the same time, punctured equilibrium observes that a business entity can have sequential shift in the allocation of attention on one or the other (Levinthal and March, 1993). Burgelman (2002) reasons that punctured equilibrium is more likely a solution in balancing exploration and exploitation because it describes a nature progression. His conclusion draws on his

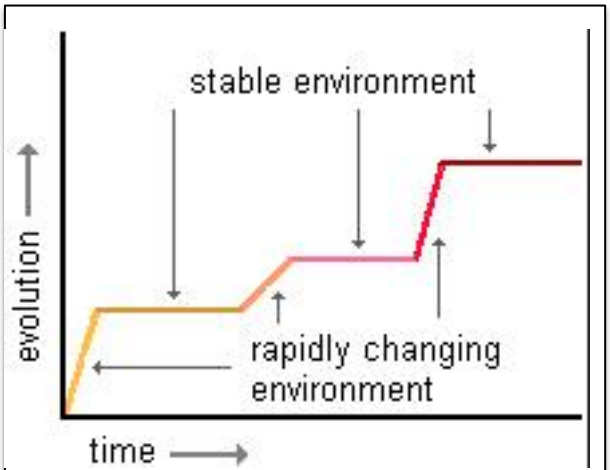


Figure 2: Punctured equilibrium illustration

longitudinal study of Intel, in which he observes that even with the vast resources and intention to balance the duo simultaneously, Intel still follows a pattern of punctured equilibrium; it exploited one innovation, memory drive or microprocessor, before shifting towards exploration to find the next core product line (Burgelman, 2002; Burgelman and Grove, 1996). Under the assumption that a balancing mechanism is necessary, the adaptation between exploration and exploitation over time exhibits a more natural and ecological rhythm while at the same time, it remains passive and less normative in comparison to creating an ambidextrous organization via restructuring. Burgelman (2002) postulates that middle management needs to become better at recognizing autonomous exploratory efforts and projects through strategic context determination process, although prescriptive details of this process is absent. Essentially, managers need to learn to recognize promising projects that can renew the organization before the organization exhausts the remuneration and capabilities gained through exploitation.

2.5 Balancing Exploration and Exploitation is Difficult

Although balancing exploration and exploitation is regarded as a necessity for long-term survival for a business entity (Levinthal and March, 1993; March, 1991; Grupta and Smith, 2006), it is nevertheless a difficult endeavor without clear academic consensus on a normative mechanism (ibid). Furthermore, balancing exploration and exploitation has, so far, been shown empirically difficult due to business entities' preference towards specialization and the subsequent inertia developed toward that orientation.

In examining the success trap, failure, and competency trap as well as the three forms of organizational inertia, innovation research suggests that trajectories naturally form in business entities because of the tendency to specialize. Thus, making the effort toward balancing the duo difficult. *First*, learning tends to specialize. If a business entity has persisted in exploration or exploitation, it tends to develop learning locally because of the increasing opportunity cost to learn non-locally. Therefore, this inertia compels the business entity towards either exploration or

exploitation. To alter the trajectory is, in a way, counter intuitive to cost and benefit analysis unless the business entity is considering long-term viability. *Second*, a business entity develops competences and resources around its learning, therefore, these specialized competences and resources are used more frequently (Levinthal and March, 1993), thus, they also tend to specialize and form a trajectory. *Third*, internal and external expectations, including strategy, value, norm, and any investment, will develop around the specialized competences and innovation trajectory; therefore, it is also difficult for the business entity to adjust direction. *Fourth*, overconfidence in abilities and over-optimism in the odds of favorable outcomes serve as initiators toward a singular trajectory of exploration or exploitation because they favor existing trajectory and overestimate the risk to change. As it progresses, the increasing opportunity cost serves to maintain the persistence. *Lastly*, innovation research presents two main mechanisms, *organizational ambidexterity* and *punctured equilibrium*, for balancing exploration and exploitation. However, ambidexterity requires resources for restructuring that not all business entity can provide, thus, reducing its universal application to all business entities. On the other hand, punctured equilibrium offers theoretical generalizability, also on an individual level, but there is little detail on normative actions. To conclude, this literature review establishes mis-estimation as the initiator of innovation trajectory while the increasing opportunity cost to deviate serves to reinforce the persistence. In essence, there are many difficulties in balancing cognitive biases on an organization level.

Insight 3: Therefore, the balancing literature can benefit from a perspective on an individual level that can explain the individual decisions leading to singular innovation trajectory.

Decision making is a process that includes information processing—cognition. During cognition, the brain evaluates the relative importance and relationship regarding cues and information received. Meanwhile, cognition can favor certain assessment outcomes because of cognitive biases. By understanding the relationship between cognitive biases and the imbalance of exploration and exploitation, innovation studies can assist business entities in overcoming biased behaviors and preventing singular innovation trajectory from forming and/or persisting. However, the literature on the linkage is currently rare within innovation research[xvi].

2.5 Current Literature on Cognitive Biases and Innovation Management

In searching for academic journal articles with regards to cognitive biases and innovation management, this study locates only three and they are published between 2008 and 2010. It appears that academic research into the linkage of cognitive biases and innovation management is still in its infancy.

Current research focusing on cognitive behaviors and innovation is rare and often superficial. Morrison and Potts (2008) research on a paradigm called innovation under novelty. They posit that novelty is different than uncertainty because the former does not operate in a world of bounded rationality but in an unknowable world where there is no precedence and information for objective assessments. They outline ten reasons[xvii] for failure to occur in such condition with a behavioral perspective, however, it is insufficient in linking cognitive biases to innovation mishaps. For example, regarding *awareness of novelty is hard*, they reason it was hard because human brain routinely filters novelty. It is true that the brain can underestimate novelty and reduces its importance in cognition; nevertheless, the article made no attempt to explain the mechanism or the reason.

Potts (2010) attempts to rectify the inadequacy with another publication on three cognitive biases—status quo bias, risk and loss aversion, and myopia bias—based on the ten reasons for innovation failures under novelty. The article is closely based on the collaborative article in 2008, although he includes the use of a standard heuristics and biases framework of behavioral economics[xviii], which contains ten common heuristics and biases. He reasons that status quo bias, risk and loss aversion, and myopia bias are most relevant to innovation under novelty, although the correlation between the three cognitive biases and innovation management is insufficiently presented in less than one page.

Van Pelt (2008) investigates cognitive biases in innovation teams. He concentrates on a few themes: the allure of winning big, planning fallacy, the pit fall of analogy, anchoring, and confirmation bias. Although it is the first true attempt to link cognitive biases and innovation management, it is still incomprehensive since he offers no information on the origin of the cognitive biases. It is essentially an article on innovation challenges attaching to terms of cognitive biases.

These research attempt to bring awareness to the subjectivity of human behaviors regarding innovation; however, they are superficial and unstructured with no formal reference to theories from cognitive and social psychology. Since cognitive biases are universal denominators to all individual, we all have and think through these filters, it is important to incorporate cognitive biases into innovation studies. Additionally, their roles in the imbalance of exploration and exploitation are pivotal. Hereafter, this thesis will investigate the cognitive environment and systemic errors that can bias decisions, including ones relating to mis-estimating the risk and the need for new learning.

3.0 Cognition under Cognitive and Social Psychology

Because difficulties in balancing exploration and exploitation are ubiquitous to incumbents and new entrants, they have a significant impact to innovation studies; thus, it is essential for innovation researchers to understand the obstacles involved. However, knowing that there are multiple forces working to entice business entities into a singular trajectory of exploration and exploitation is not enough to mitigate them (Burgelman, 2002); consequently, the underlining causes needed to be investigated.

The investigation into the underlining causes of the initiation and persistence of singular innovation trajectories begins with understanding the general working during cognition. This chapter focuses on investigating the cognition process to establish some general conditions that can be applied to innovation decision-making. This thesis adopts the perspective of dual process theory that cognition and decision making occur under two theoretical systems, System 1 and System 2 (Kahneman, 2011; Evans and Frankish, 2009). The two systems in cognition, information processing, are examined separately to clarify their characteristics, then collectively to highlight their strengths and weaknesses when working in harmony and in conflict. Within the examination of the two systems, this research will introduce the systematic errors, or cognitive biases in System 1, that readily and repeatedly alter the objective assessment of information and produce biased judgment.

3.1 System 1 and System 2—general relationship

System 1[xix] represents the quick and intuitive thinking; its decision mechanism is filtered by cognitive biases, and they cannot be turned off. On occasions when intuitive thinking fails, cognitive process switch to a slower, more deliberate and effortful form of thinking performed by

System 2 (Kahanman, 2011, p. 13). Essentially, System 2 is in charged with monitoring the assessments from System 1.

Individuals usually identify themselves as rational and deliberate, characteristics of System 2; however, the rational and slow thinking performed by System 2 is often compromised by the quick and biased thinking performed by System 1. Although the slower System 2 is solely capable of organizing thoughts in an orderly manner, System 1 can generate substantially more complex idea automatically (Kahneman, 2011, p. 21). Therefore, each is designated to perform different tasks and it is necessarily to examine the working of System 1 and System 2 separately before investigating the compromised interaction.

3.1.1 System 1—intuition, associative memory, systemic errors

> *System 1 provides the impressions that often turn into your beliefs, and is the source of the impulses that often become your choices and your actions. It offers a tacit interpretation of what happens to you and around you, linking the present with the recent past and with expectations about the near future. It contains the model of the world that instantly evaluates events as normal or surprising. It is the source of your rapid and often precise intuitive judgments…the origin of many of the systematic errors in your intuitions.* (Kahneman, 2011, p. 58)

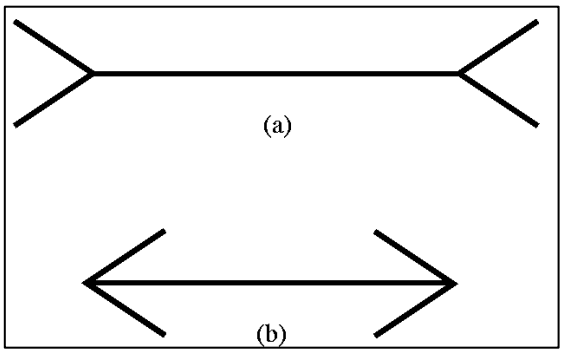
System 1 relates to tacit knowledge such as instincts and automatized responses from prolonged practices (Kahneman, 2011, p. 21). In a simple sense, System 1 governs the quick and instinctive part of the cognitive process. Herbert Simon writes, "intuition is nothing more and nothing less than recognition (cited from Kahneman, 2011, p. 11). By extension, System 1 is responsible for generating intuition responses that are extrapolated form experience. Valid intuition occurs when one learned to recognize familiar elements in a new situation and act in a manner appropriate to it (Kahneman, 2011, p. 12). In such way, non-valid intuition can be observed in instances when overconfidence in one's abilities affects the judgment to apply current learning to analogous domains inappropriately as exhibited in success trap and competency trap. Intuition is further studied in Section 5.3.2 in analyzing its role in the persistence of singular innovation trajectories.

The core of System 1 is *associative memory*, the ability to create coherence by linking cues and information that may or may not be related to each other into a story (Kahneman, 2011, p. 13). The process is known as *associative activation*, in which sensual or mental cue(s) can activate memory

that System 1 finds appropriate to create cohesion. For instance, the two words—banana vomit—will undoubtedly invoke mental imageries and past memory that invoke an instant facial and/or physical response. Similarly, the two words—Apple Success—will also activate personal memory that associates with the words, the same way—GE Failure —will. The cohesion occurs quickly by linking words into a causal story and it becomes a representation of reality (Kahneman, 2011, p 51); therefore, the mis-assessment of information and cues can lead to false anticipation of the future.

Another mental process within System 1 is executed through mental shortcuts, known as *heuristic*. It is an experienced-based mental procedure that helps the mind find adequate but, often imperfect, answers to complex questions (Kahneman, 2011, p. 98). Heuristic is helpful in dealing with complexity, however, it often oversimplifies cues and information to fit past experience and learning. Because heuristics are foundational to the working of System 1, it will be analyzed carefully in Section 5.1.1 in relations to mis-estimation that leads to singular innovation trajectories. The systematic errors, or cognitive biases, arise from associative memory within System 1 are generally introduced next.

Figure 3: The Müler-Lyer illusion



Some systematic errors during cognition cannot be turned off. A prominent example is the *Müler-Lyer illusion*, which shows two lines of equal length with different directional tails. Although one can intellectually accept the reality after measuring and verifying that the two lines are of the same length, the cognitive illusion continues to be prevalent. One cannot decide to see the lines as equals but one can learn to mistrust her own impressions and assessment (Kahneman, 2011, 27). Another display of systemic errors in System 1 is illustrated by the question—How many animals of each kind did Moses take into the ark? (Kahneman, 2011, p. 73). This is known as the *Moses Illusion* since Noah is the one who built the ark and rescued the animals. Because the animal and the ark set up a known biblical scene and Moses is also an importance biblical character, the appearance of Moses to the scene of animals and ark is not surprising. System 1 forms a plausible cohesion and focuses on recalling the quantity of animal; meanwhile, the error of Moses is

undetected. It is an illustration of *norm theory*, which if the scenario seems normal, the error detection (System 2) is not alerted. Lastly, Kahneman (2011) writes that some years ago, he and his wife, who lives in the United States, were vacationing in a small 40 rooms resort in the Great Barrier Reef. They were very *surprised* to meet Jon, a psychologist acquaintance, at the resort. Two weeks later, they were in London waiting for the start of an opera when the light dims and Jon sat down next to them. On the second occasion, the surprise of seeing Jon is subsequently less and they began to anticipate meeting Jon. Even though both incidences were statistically unlikely event, System 1 became accustomed to the chance meetings and began to create cohesion in the brain that meeting Jon around the globe is a likely event. Ultimately, System 1 has biases and it cannot be turned off; meanwhile, some biases are receptive to control if detected but often System 1 is running on autopilot (Kahneman, 2011, p. 25).

The complexity in associative memory can make the network susceptible also to external influence, which can also modify objective connections and assessments. The psychological technique known as *priming* is one such external modifier. It describes the technique to expose someone to a specific stimulus that will influence that person to behave in a specific manner. For example, people who are asked to nod while answering a yes/no question are statistically more likely to give an affirmative answer. Another effect that external stimulus can have on System 1 is *anchoring*, in which a seemingly unimportant piece of information becomes extremely important in the decision-making process because the mind is drawn to that piece of information, sometimes unconsciously. Due to the intensive effect of anchoring on decision-making, it will be analyzed separately under in Section 5.1.2 in relations to mis-estimation.

While System 1 can succumb to undesirable cognitive biases, it is also responsible for generating novel ideas. Psychologists believe that ideas are nodes within the associative memory network, where they are linked and interconnected (Kahneman, 2011, p. 52). Within this network, connection are linked by cause and effect, property-association, and category-association; everything has a connection to another thing, yet the connecting processes occur simultaneously and only a few is registered on the conscious mind (ibid). Both System 1 and System 2 can access memory, however, extensive and deliberate searching is a characteristic of System 2 and creating cohesion is a characteristic of System 1 (Kahneman, 2011, p. 46). Therefore, the same cognitive process that produces biased assessment is also the system that can make new and sometimes random

connections between ideas, thereby, producing novelty and innovation. Accordingly, Sarnoff Mednic suggests that 'creativity is associative memory that works exceptionally well (Kahneman, 2011, p. 67).

Since System 1 operates automatically, cognitive errors cannot be willingly switched off. Sometimes, System 2 may not know of the existence of the errors if the associative cohesion appears normal and plausible. Consequently, errors can only be prevented when the monitoring by System 2 is enhanced.

3.1.2 System 2—rational and lazy

When intuitive thinking fails, one switches to a slower, more deliberate and effortful form of thinking known as System 2 (Kahneman, 2011, p. 13). System 2 has two general tasks—to monitor System 1 and to perform deliberate and effortful cognitive assessments. Essentially, the first task is about self-control and System 2 has the overriding power over System 1 (Kahneman, 2011, p. 25). Additionally, System 2 is the only system capable of following rules, comparing attributes between objects and making choices between options (Kahneman, 2011, p. 36), and understanding statistics (Kahneman, 2011, p. 13).

Because following rules require the understanding of a reality other than the one constructed by heuristics and associative memory, therefore, it is reasonable that System 1 may not have the ability to navigate outside of its reality without System 2. More so, comparing attributes and choosing between options may not be possible by System 1 since it tends to quickly submit to heuristics and anchoring effect. However, Kahneman's reasoning for System 1's inadequacy for statistics is that 'statistics requires thinking about many things at once, which is something that System 1 is not designed to do (Kahneman, 2011, p. 13). It can be reasoned that the necessity for heuristics and associative memory in System 1 is in easing the burden from complexity, complexity from thinking about many things at once; therefore, System 1 is capable of thinking many things at once. Furthermore, it can be argued that the magnitude of information that System 1 is able to access simultaneously is greater than System 2. Meanwhile, it is conceivable that System 1 is inadequate to understand statistics because it requires the comparison of attributes and the understanding of their correlations, if there is any, without jumping into conclusion.

Adamantly, operations by System 2 require attention and effort that are in limited supply. Cognitive efforts are tasks requiring attention such as mathematical computation. A simple example is Add-1, in which a random 4 digits number is given, for instance: 3629, then, while keeping a rhythm of one computation per second, one must add one to each digit; thus, the next number is 4730 and 5841 after. When System 2 is engaged, known as *cognitive busyness*, there are two consequences. *First*, when System 2 is engaging in an effort-based task, the reserve capacity on attention is diminished, therefore, System 2 becomes less capable to take on other effortful tasks. For example, it is impossible for someone performing Add-1 to parallel park. *Second*, during cognitive busyness, System 2 is less capable in monitoring and controlling System 1. Moreover, physical wellbeing also affects the full function of System 2. Fatigue, hunger, and sickness have drastic *depletion effect* on judgment from System 2. A study on eight parole judges in Israel found that although the default decision is parole denial with an average granting rate of 35%, immediately before food breaks, the approval rate spiked to 65% (Kahneman, 2011, p. 43-44). The depletion effect is statistically significant although it is unclear why approval rates spiked as supposed to falling since rejecting a request can also speed up processing time in order to reach food breaks quicker. Additionally, it is a demonstration that people in positions that are considered impartial experts are still culpable of biased judgments even though cognitive bias is not necessarily the culprit in this case. On that account, System 2 is easy to disrupt since it depends on attention capacity immensely.

System 2 is designed to handle the allocation of attention according to the urgency of the tasks in real time (Kahneman, 2011, p. 35). It protests the most important activity, then allocate the spare capacity to other tasks continuously. The selection is based on evolutionary history, thus, System 2 allocates most attention for survival needs; otherwise, the Law of Least Effort applies. It asserts that if there exists many paths in achieving the same goal, people will eventually gravitate towards the less demanding path. In a cognitive sense, least effort can be reasoned as the task and execution method with the least attention required. The Law of Least Effort, therefore, supports the general consensus from innovation literature on path dependency. When people repeat a task, the mental effort required for completing the task diminishes, then a preference is developed toward that task since it requires less effort than before and in relation to others. However, Kahneman (2011) also references that talented and intelligent people require less effort than others in solving the same problem. Consequently, it is conceivable that people who are talented in other subjects than their

current learning or generally intelligent people can avoid the learning path dependency by engaging in multiple subjects that are effortless to them.

Reflexively, the Law of Least Effort also implies that System 2 is efficient but lazy. Kahneman (2011) reiterates throughout the book the laziness in System 2, almost as a warning. Its preferential state is to minimize attention consumption; therefore, although one of its roles is to monitor and control System 1, often it fails in its duty. If the assessments made by System1 seem reasonable and System 2 does not detect any error in progress, the latter often endorses the former's suggestions and intuitive responses without modification (Kahneman, 2011, p. 64). Although cognitive biases affect System 1 the most since biases are linked with heuristics and associative memory, this paper proposes that the inherent laziness in System 2 can also be viewed as a bias, given that a bias is a particular preferential tendency. Since System 2 will always prefer least effort, there exists a tendency for it to endorse decisions that will reduce overall attention requirement; consequently, a bias exists. Therefore, System 2's laziness has an amplifying effect on the cognitive biases from System 1 by not intervening when it should. Stanovich, one of the original proposal of the two systems, lends support to this view by expressing that there are two parts to System 2—slow thinking and rationality—and laziness is a failure in rationality (Kahneman, 2011, p. 49). Kahneman (2011) suggests that some decision-errors can be prevented with a small investment of effort from System 2 (p. 44), therefore, overcoming the lazy bias of System 2 is advisable when the opportunity cost of mistake is high. Additionally, System 2 is sparsely capable of modifying the way System 1 works by imposing guidelines to the latter (Kahneman, 2011, p. 23).

The introduction of System 1 and System 2 has preluded how cognitive biases are prevalent in individual decision-making and thus affect innovation behavior. It illustrates that cognitive biases contributes to the skewing of estimation because of heuristics used by System 1. Meanwhile, System 1's attempt to create cohesion can also lead to novel ideas. Moreover, the Law of Least Effort employed by System 2 offers a preliminary explanation to innovation research's findings regarding the tendency towards specialization.

3.2 A Limited Budget of Attention—when system 2 gives in to system 1

The last section introduces System 2's intensive attention need and clarifies that the supply of attention for cognitive functions are limited. This section examines the consequences of decision-

making when attention is undersupplied and how the insufficiency contributes to System 2's monitoring on System1 and to the normal function of System 1.

System 2 is in charged with overcoming the impulses of System 1; in other words, it is in charge of self-control (Kahneman, 2011, p. 26). Both self-control and cognitive effort are forms of mental work (Kahneman, 2011, p. 41). There are three scenarios in which *cognitive busyness*, as mentioned in the last section, can affect System 2 and impinge upon System 1. *First*, cognitive busyness occurs when System 2 is engaging in one or more task(s) that requires a degree of effort. This commitment reduces the spare capacity on attention to perform other tasks, such as monitoring and controlling System 1. When System 2 is busy, System 1 has more influence on behavior, which can involve yielding to temptation and biases (Kahneman, 2011, 41). Daniel Gilbert, professor of psychology at Harvard University, reasons that when cues and information are presented to the mind, System 1's automatic response is to believe the cues and information to be true and to create coherence. The operation to un-believe[xx] involves only System 2, therefore, when System 2 is engaged in other operations, individual will believe almost anything (Kahneman, 2011, p. 81). Essentially, it alters the importance of cues and information if the mind will believe almost anything.

Secondly, even if the task that System 2 is performing is less effortful such as exerting self-control over System 1, a condition known as *ego depletion* can occur over time causing System 2 to relinquish control. Similar to the depletion effect from fatigue, hunger, and sickness, *ego depletion* is the impoverishment of control over System 1 because preceding effort has already been made to exert self-control. Namely, forcing oneself to do something cognitively, emotionally, or physically undesirable at this point will diminish System 2's ability to exert self-control shortly after. When System 2 loses control over System 1, it enables cognitive biases to misinterpret cues and information.

Lastly, when System 2 is engaged in cognitive busyness, it can negate the effect of stimulus over System 1. This condition is known as *change blindness* and it is most illustrated by Christopher Chabris' and Daniel Simons' experiment, *the invisible gorilla*. The test subjects are asked to watch a video clip of two basketball teams and count the number of basketball passes made by the team dressed in white uniform; this elicits attention from System 2. During the video, a person in a gorilla suit, an anomaly and a stimulus, walked across the court for 9 seconds, but almost half test

subjects do not see the gorilla. One of System 1's functions is to respond to stimulus, which during cognitive busyness, it fails to perform. Therefore, cognitive busyness can lead to System 1's omission of cues and information.

3.3 The Friendenermy—System 1 and System 2

The interplay between the automatic and intuitive reaction from System 1 and the deliberate and effortful thinking from System 2 is a mundane occurrence. Interestingly, in synergy, System 1 exercises heuristics and associative memory in dealing with complexity quickly while System 2 is tasked with monitoring this act and then slowly comparing, organizing, and selecting the surfaced thoughts with its own additional calculation. In conflict, System 1 is biased in the treatment of cues and information with heuristics and associative memory and System 2 is lazy to monitor and enforce over System 1.

Two contradistinctions exist within System 1 and within System 2. *First*, System 1 is inherently capable of associating vast quantity of cues and information and arriving at new conclusion and correlation, albeit not always accurate. Simultaneously, it is also subjected to cognitive biases such as anchoring and norm theory that limit the scope of its creativity. *Second*, System 2 is inherently competent in objective and comparative thinking, yet its laziness limits its rationality. Because System 1 operates automatically and involuntarily, cognitive errors from biases can be difficult to prevent when System 2 is ignorant of the errors' existence. Some cognitive errors can be prevented with minor intervention from System 2 by enhancing the monitoring effort from System 2. Nevertheless, continuous vigilance is impractical and contrary to the principal of System 2 in minimizing effort and attention use. Therefore, it is more constructive for System 2 to learn to recognize situations in which mistakes likely occurs (Kahneman, 2011, p. 28). In the end, System 2 has the last words.

Because cognitive biases can affect the objective evaluation of cues and information and System 2 has a preference to least effort, the dual process system also faces challenges to balance each other as exploration and exploitation do. With the two systems working in synergy, cues and information can be more objectively evaluation. It can be reasoned as a source of balancing exploration and exploitation.

Insight 4: This thesis purposes that a mechanism for balancing exploration and exploitation exists in enabling System 1 and System 2 to work in synergy.

To elaborate, the optimal state is for System 1 and System 2 to work in synergy, in which System 2's laziness is overcame by teaching System 2 to recognize situations requiring intervention; this can be executed by highlighting the cognitive biases likely to surface in success, failure, and competency traps. In doing so, System 2 can better able to monitor and control the cognitive biases within System 1. Meanwhile, System 1 can take advantage of certain cognitive biases such as associative cohesion in establishing novel connections. Ideally, a synergy can be formed in which System 2 monitors and enables System 1.

4.0 Research Approach and Method

This research is a library-based exploratory study in tracing the pathology of success, failure, and competency traps, which are states of vulnerability as a result from singular persistent innovation trajectories, either in exploration or exploitation (or their respective competences). It is an inductive research (Babbie, 2010) to establish linkage between cognitive biases and innovation behaviors known to occur in business entities that were trapped by singular innovation trajectories.

4.1 Ontology and Epistemology

The research approach is based on the ontology of *objectivism* in recognizing that 'social entities exist in reality external to social actors (Saunders, Lewis, and Thornhill, 2009, p. 110)'. This research posits that the ability to balance exploration and exploitation exists whether or not an individual exercise it. Essentially, objective reasoning exists independently from the decisions to explore and/or exploit and the subsequent behaviors associated with the decisions. The normative actions exist independently from the actual actions of the innovators and the statistical likelihood of an event occurring is independent from the perceived likelihood of its occurrence.

This thesis adopts the epistemology of *realism* in consenting that 'what the senses show us as reality is the truth (Saunders, Lewis, and Thornhill, 2009, p. 114). In alignment with the book, *Thinking, fast and slow*, by Daniel Kahneman (the main source of reference for this thesis regarding cognitive biases), this thesis adopts the research philosophy of *critical realism* in recognition that 'what we experience are sensations…not the things directly (Saunders, Lewis, and Thornhill, 2009, p. 115)' and that ours senses often deceive us. While innovation decision makers can feel the

success ‘around the corner’, this thesis holds the perspective that personal optimism does not equal reality. Although the reality is too complex and individuals have too little information or capability to grasp the full extent, one can aspire to manage one’s senses into a closer alignment to the collective reality when the decision is critically dependent on other’s perception. The focus of this research is not to highlight that decision makers should be objective, but that they should behave less subjectively when opportunity cost, the forgone value of the next best alternative, is high.

4.2 Unit and Level of Analysis

The unit of analysis is ‘the what or whom being studied (Babbi, 2010, p. 98) and the level of analysis is ‘the context within which (or the level of which) we examine the topic (Yurdusev, 1993, p. 78)’. Innovation research have heavily adopted the organization as the unit or level of analysis (Grupta and Smith, 2006), such as organizational learning, organizational inertia, organizational ambidexterity, and punctured equilibrium, which are used in Chapter 2. Meanwhile, arguably, the individuals are the decision makers both in an organization and in any business entity from the size of an entrepreneur to a corporation; therefore, it seems insufficient that studies have heavily focused on the organization instead of the individuals. Moreover, depending on the unit or level of analysis, the research findings may not be applicable to all business entities.

In the rhetoric on success, failure, and competency traps, the imbalance between exploration and exploitation initiates the singular innovation trajectory that leads business entities to vulnerable states. Because the complexity, competences, and resources present to each business entity can be different, the applicability of balancing strategy can also differs (Grupta and Smith, 2006); for example, arguably, it is easier for a larger organization to achieve ambidexterity in assigning separate units for exploration or exploitation than for an individual. In essence, the circumstances at which research findings can be reapplied differ depending on the unit or level of analysis. Adopting the organization as the unit or level of analysis does not invalidate the research finding but it can reduce the generalizability of the conclusion to other sizes of business entities. Therefore, to increase generalizability, this research traces the pathology of success, failure, and competency traps to the level of the individual. By using cognitive biases as the unit of analysis and the individual innovation decision makers as the level of analysis, this research aims to highlight the fundamental and generalizable linkage between the cognitive biases and the imbalance of exploration and exploitation.

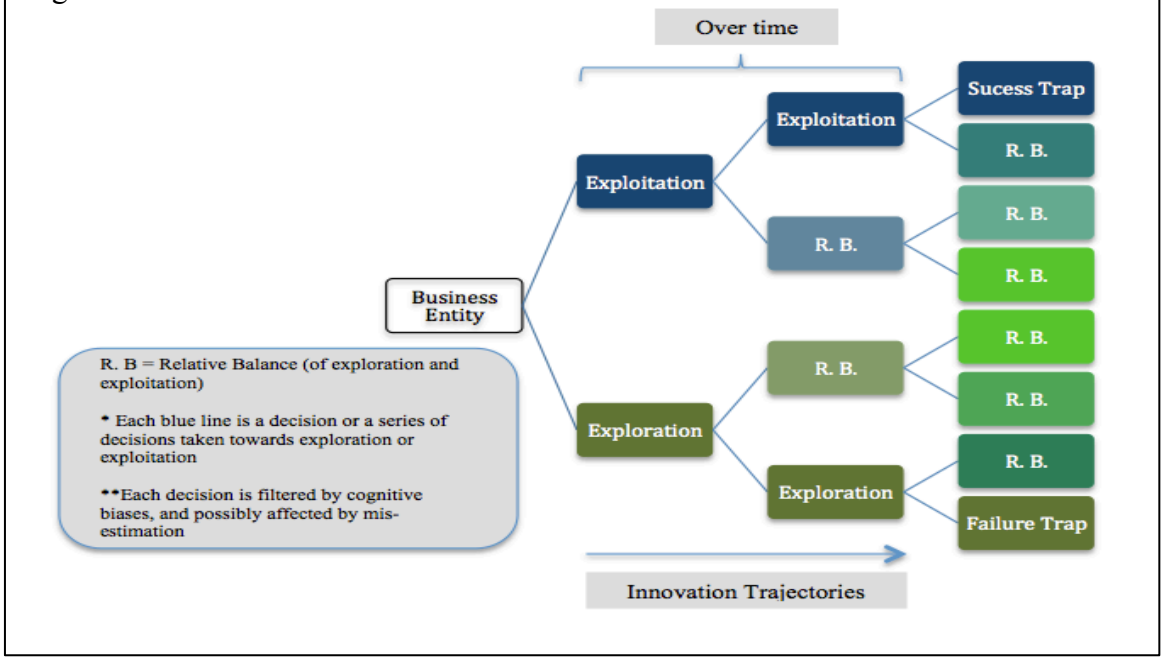
4.3 Methodology

This thesis traces the pathology of success, failure, and competency traps to the imbalance of exploration and exploitation, the persistent engagement of exclusive exploitative activities or the persistent engagement of exclusive exploratory activities (Levinthal and March, 1993). It aims to connect cognitive biases to innovation behaviors know to occur in singular innovation trajectories. Moreover, it also investigates the persistence of singular innovation trajectories with the lens of cognitive biases and illustrates the effect of these cognitive biases through three cases: Pet.com and Amazon.com, the Dvorak Simplified Keyboard, and Polaroid Corporation. Ultimately, the intent is to answer the research question *How cognitive biases can help explain the imbalance of exploration and exploitation that leads singular innovation trajectories*?

4.3.1 Research Model

The model in which this study views the relationship between cognitive biases, the imbalance of exploration and exploitation, and success and failure trap, is illustrated by Figure 4. Excessive exploitation or exploration can respectively lead to success trap or failure trap. During the progression, biased decisions based on biased estimations guide the innovation trajectory into a singular focus. At the same time, competences can form and lead the business entity towards a singular innovation trajectory. The lack of variation and the negligence to the market make the business entity vulnerable to the external shocks such as changes in customer preferences.

Figure 4: Research Model



4.3.2 Research Objectives

The first research objective is *to investigate the linkage between cognitive biases and the imbalance of exploration and exploitation that leads to singular innovation trajectories*.

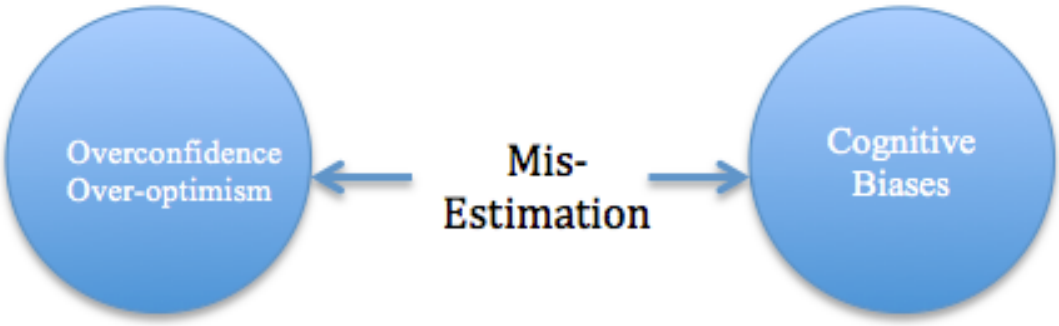


Figure 5: Linkage between innovation study and cognitive biases

Doing so will establish that cognitive biases are linked to success and failure traps. The linkage is established by reviewing literature on the imbalance of exploration and exploitation to identify behaviors that are known to initiate a singular innovation trajectory by favoring either exploration or exploitation. Another research objective is *to understand the persistence of singular innovation trajectories through cognitive and social psychology*. This will broaden the current innovation view that increasing opportunity cost is the main culprit to the persistence of singular innovation trajectories. These two objectives embody the two strategic points of a singular innovation trajectory—its initiation and its persistence. The third objective is *to suggest an alternative balancing mechanism between exploration and exploitation on an individual level*.

It is important to emphasize that the overall objective of this thesis is to enrich the current innovation research on the imbalance of exploration and exploitation with a psychological perspective. However, it is not a replacement to current innovation research.

4.3.3 Method

The literature review on innovation management offers three insights:

1) **Mis-estimation stemmed from overconfidence and over-optimism is the initiator to singular innovation trajectory.**
2) **Increasing opportunity cost for deviation enables the persistence of the imbalance of exploration and exploitation that leads to singular innovation trajectory.**
3) **The balancing literature can benefit from a perspective at an individual level that can explain the individual decisions that lead to singular innovation trajectory.**

The first two are used to investigate *How cognitive biases can help explain the imbalance of exploration and exploitation that leads to success and failure traps*?

The first insight is used to identify specific cognitive biases that can contribute to mis-estimation in one's abilities and the odds of favorable occurrences. It will include illustrations of psychology experiments to better explain the biases and the cognitive biases will be connected to innovation literature and empirical observations. This is the first part of the analysis (Section 5.1 and 5.2) and it consolidates the linkage between cognitive biases and the imbalance of exploration and exploitation.

The second insight establishes that there is a persistence to singular innovation trajectories. It provides a perspective from cognitive and social psychology to which innovation literature can build on. To do so, this research investigates three conditions that are reasoned to amplify cognitive biases. The first one is based on the scenario of a success trap in which positive feedback misguide the decision maker into relying more on his intuition because of experience and expertise established by previous successes. The second one is based on the scenario of a failure trap in which negative feedback misguide the exploring decision maker to exclude exploitation despite further exploration will result in higher loss. The last one studies the scenario within a success trap in which conformity within a business entity prevents deviation from the singular innovation trajectory, thus, contributing to the forward inertia. Each scenario is followed by an illustration from an innovation case to convey how cognitive biases contribute to the persistence of singular innovation trajectories.

4.3.4 Learning and Debiasing

One of the general conclusions by Kahneman (2011) is that System 1 has biases that cannot be turned off and System 2 is inherently lazy. Thereby, it may appear irrelevant to study cognitive biases and innovation management if they cannot be 'turned off'; however, they can be managed by awareness and debiasing techniques.

Learning creates a simplified world (Levinthal and March, 1993, p. 101). The concepts of learning and development are often studied together (Valsíner and Voss, 1996). Development signals a high degree of irreversibility while learning is characterized with a high degree of reversibility (Plotkin

and Odling-Smee, 1981). In this sense, learning can be renewed and it is not subjected to a trajectory unless System 2 lacks the self-control over cognitive biases in System 1.

In psychology, conditioning is the principle of learning (Pavlov, 1932), meaning that repeated exposure is the key to learning as well as correcting behaviors. This can be one way to counter undesirable behaviors resulting from cognitive biases. In a large[xxi] study on the differences between entrepreneurs and mangers regarding heuristics and biases in decision making, Lowell Busenitz. and Jay Barney (1997) found that entrepreneurs use significantly more heuristics in their decision making than managers. This is an illustration that System 1 can be systematically managed by guidelines and external accountability to decision made. More specifically, there is a small branch of research, in psychology called *debiasing* that specializes in examining theories and prescriptions in modifying cognitive biases (Lilienfeld et al., 2009). Although debiasing is still a new area of studies, which explains its lack of comprehensiveness and empirical consistency comparing to a tested research branch, there are promising advances (ibid). The concept refers to techniques that assist in shifting thinking from System 1 to System 2, so that System 2 has more 'overriding' control (Stanovich and West, 2000, p. 660). Essentially, debiasing is about equipping individuals with tools for re-biasing System 1, enabling System 2, or modifying the decision environment (Larrick, 2004). First, re-biasing is executed by introducing another heuristic such as a rule of thumb[xxii], so System 1 has a more reliable shortcut to refer to (ibid). Second, System 2 can be enabled by increasing its accountability to other people (Lerner and Tetlock, 1999). Additionally, System 2 can perform better if it starts to question System 1's assessment (Kahneman, 2011) and systematically considers the alternative assessment to ensure the objectivity of the initial assessment (Soll and Klayman, 2004). The latter has been shown to have a significant counter effect on confirmation bias (ibid). Third, modifying the decision environment can be executed through priming, in which System 2 is pre-exposed to an unfamiliar concept that may induce negative response (Larrick, 2004). It is not the intention for this thesis to review the literature of debiasing but to provide research evidence that it is possible to modifying cognitive biases relating to re-balancing exploration and exploitation through learning and debiasing.

4.3.5 Data Collection

Since this research is library-based, the main sources of data are books, journals, and newspapers in both print and digital formats. The literature focuses largely on innovation management and cognitive psychology. In collecting data in innovation management, particularly attention was paid

to success, failure, and competency traps, the reason for the need to balance exploration and exploitation, the mechanisms to balance exploration and exploitation, and the current research on the linkage between cognitive biases and innovation management. These literatures were found in the curriculum of MSc. Management of Innovation and Business Development 2010-2011 and online academic journals. In assembling data relating to cognitive biases, this research began with the book *Thinking, Fast and Slow*, by Daniel Kahneman, Nobel price winner for economics in 2002 for his seminal work on Prospect Theory. The book is also an academic introduction to cognitive and social psychology with references to experiments that verified the causality of specific cognitive bias to specific behaviors. Regarding cognitive biases that related to this thesis, original publications of the experiments and relating articles were searched on Academic Search Elite, JSTOR, and Business Source Complete under the Copenhagen Business School access. Other online sources, such as Google Search, Google Books, and Google Scholar were also used. For the three cases that relate to success and failure traps, articles from the course work of MSc. Management of Innovation and Business Development 2010-2011 were consulted such as the case of the Dvorak Simplified Keyboard. Additional case information was found on the book *Instant: The story of Polaroid* by Christopher Bonanos and via Factiva and Google Search, with regards that they are from respectable sources such as BBC News. The reference to Blade Runner's product placement was first introduced to the author by Jesper Vej, an associate professor at Copenhagen Business School, during a lecture in July, 2013, then researched online. The duration of data collection was approximately 12 months from September of 2012 to August 2013 with intermittent breaks.

4.4 Assumptions

There are eight assumptions this research employs to reduce the complexity of the research and to maintain focus on the research subjects of cognitive biases, the imbalance of exploration and exploitation, and success and failure traps. *First*, it is assumed that the research model, which establish the relationship between the three research subjects is simplified but true. *Second*, success and failure traps are vulnerable states that are contextual to external stimuli such as change in customer preference that can occur rapidly or gradually. The vulnerability is a result in the lack of variation in learning, competences, and resources for the business entity to overcome external challenges. In that sense, there is always hindsight bias in describing scenarios of success and failure traps. *Third*, for the sake of simplifying the complexity of this research, this thesis will not draw the difference between innovation under novelty and innovation under uncertainty. The first

stipulates that novelty has no precedence, therefore, one cannot rely on statistical prediction or experience to reduce the uncertainty (Morrison and Potts, 2008). In some way, Kahneman (2011) already recognizes the difference between uncertainty and novelty when he expresses that true experts understand the limit of their abilities (p. 239), so they understand when past learning does not apply to the new context. *Fourth*, System 1 has cognitive biases, which cannot be turned off, and System 2 is lazy. *Fifth*, by training System 2 to recognize signs of mis-estimation, it improves the reliability of the mental assessment. *Sixth*, improving System 2 can limit the instances of success when System 1 is 'lucky', but by bringing System 1 and System 2 into synergy, one can expect to minimize the business mortality rate from failure, success, and competency traps. *Seventh*, since the odds of success for innovation is relatively low (Stevens and Burley, 1997), it is sometimes necessary to be overconfidence and over-optimistic for innovation to preserve, however, being confident and optimistic is not in conflict with employing System 2. *Eighth*, this paper assumes that employing System 2 and being more atoned to one's rationality is desirable to all (at least those who read this study).

4.5 Limitations

Due to the complexity, time-constraint, and the novelty in researching the linkage between cognitive biases and innovation management, there are a few notable limitations. *First*, this thesis does not intend to resolve the debate between ambidexterity and punctured equilibrium but merely provide an alternative view that the balance can instead be managed cognitively if System 1 and System 2 are working in synergy. *Second*, this thesis does not attempt to settle the debate on how will increasing the recognition and vigilance of System 2 affect innovators' desire to preserve with innovation knowing objectively the odds of success. Instead, this thesis concentrates more on creating the linkage between cognitive psychology and innovation management. *Third*, this thesis' aim is to present cognitive biases relating to singular innovation trajectory, hence, it will not critique the research in cognitive biases. *Fourth*, this thesis does not presume to compare debiasing techniques but to suggest that debiasing strategy are present and monitoring by System 2 can be improved. *Lastly*, individuals are prone to overestimate how much they understand about the world (Kahneman, 2011, p. 14). This paper is after all, a qualitative analysis, so there is a degree of subjectivity in selecting which cognitive biases relate to singular innovation trajectories, even though a mediating filter—mis-estimation—is used. In addition, the cases presented to illustrate cognitive biases and the persistence of singular innovation trajectories can contain hindsight bias. In

the end, the author recognizes the possibility of overestimating her understanding of these research areas.

5.0 Analysis and Discussion—Cognitive Biases and Singular Innovation Trajectories

With the intention of making contributions to the management of biased innovation behaviors, this research investigates the cognitive reasons for such behaviors in connection to success, failure, and competency traps. After examination in the literature review, the initiation of the imbalance of exploration and exploitation is found to connect to behaviors of overconfidence in one's abilities and over-optimism in the odds of success. This research takes the perspective that mis-estimation, both in one's own abilities as well as in the business entity's future success, is critical to the result of success, failure, or competency trap. Mis-estimation is an overall bias in cognition that represents the results of many cognitive biases at work, therefore, cognitive biases are responsible for the initiation of singular innovation trajectories.

A quick search for a list of cognitive biases on Wikipedia reveals a count of ninety-four[xxiii] while Amos Tversky and Daniel Kahneman (1974) identified twenty biases in their research relating to intuitive thinking. It is apparent that there are many functioning cognitive biases during cognition and some are more relevant for specific behaviors than others. Consequently, this analysis begins by using the common denominator mis-estimation from cognitive biases—in connecting cognitive biases to biased innovation behaviors, overconfidence and over-optimism, that can lead to singular innovation trajectories. Using mis-estimation as the parameter, three themes on heuristic and associative memory, anchoring, and risk assessment are presented and then examined to identify their contributions to the initiation of innovation trajectories. In Section 5.3, the analysis examines specific cognitive biases and Prospect Theory to explain the persistence of singular innovation trajectories. Three innovation scenarios, two relating to success trap and one relating to failure trap, are used to illustrate three cognitive biases that can help explain the persistence of singular innovation trajectories in the perspective of cognitive and social psychology. This part contains literature on intuition and expertise, Prospect Theory, and conformity bias.

5.1 Cognitive Biases in Association with Mis-estimation

Cognitive biases are modifiers to the rational decision-making process. It can distort the representation that System 1 quickly generates, thereby, they affect the comparative evaluation that subsequently takes place within System 2.

5.1.1 Heuristics and Associative Memory

As mentioned, heuristics are the mental shortcut to intuitive thinking and they provide simplified protocols to access adequate information quickly within the vast associative memory network in order to answer difficult questions (Kahneman, 2011). Cognitive biases, such as availability heuristic and affect heuristic, can modify the relative importance and meaning of cues and information by triggering less relevant memories within the associative memory network. The representation of reality created by System 1 can be compromised and renders the subsequent estimation and evaluation unreliable.

5.1.1.1 Availability Heuristic and Conformation Bias

The *availability heuristic* or *ease of memory search* refers to the process of judging frequency by the ease with which instances come to mind (Kahneman, 2011, p. 129). When System 1 detects cues and information, it searches within associative memory via heuristic pathways in order to evaluate for the appropriate response. During the search, System 1 does not evaluate all memories simultaneously. Instead, the heuristic retrieves the memories most associated with the cues and information, and then System 1 presents an assessment for System 2's approval.

Under such memory retrieval protocol, the availability of associated memory can influence the evaluation due to the retrieval frequency and the retrieval speed. To illustrate, imagine being ask to list six instances in which one is innovative. The ease, both in frequency and speed, of memory retrieval will determine one's self-assessment on innovativeness. German psychologist, Norbert Schwarz conducted the same experiment on assertiveness, in which he asked two groups to list six and twelve instances that they were assertive, and a third group to list instances when they were not assertive (Kahneman, 2011, p. 132). Interestingly, the group members having to list twelve assertive instances had rated themselves less assertive than the members who only had to list six. This discrepancy is due to the difficulty in memory recall when more examples are required. Moreover, members in the third group who could not recall any instance in which they were not assertive, found themselves most assertive of all participants. The availability heuristic suggests that

individuals who can easily recall past success or failure can overestimate the likelihood of success or failure.

Furthermore, the ease in memory retrieval can also elevate one's assigned importance on that specific memory or cluster of memories in the overall assessment. For example, spousal disagreement on the relative contribution to the household often involves availability heuristic and the elevation of one's contribution over the other because it is easier for one to recall what he/she contributes than to recall what the other has. It implies that individuals who can recall more instances of contribution to success will also overestimate his/her own contribution in the success, thereby, become overconfidence in his/her abilities.

In addition, availability heuristic can aggregate with *confirmation bias*, the seeking of data that are likely to be compatible with the beliefs one currently holds (Kahneman, 2011, p. 81). It is the subconscious retrieval of memory and/or external search of information in order to confirm an assessment already made in System 1. Confirmation bias amplifies the initial assessment made through availability heuristic; consequently, System 1 is solely retrieving memories or information to confirm the initial assessment. It implies that individuals who have overestimate their own abilities and/or the likelihood of success, will henceforth only be searching in confirmation to the overestimation and it applies similarly to individuals who can recall failure with ease.

Linkage to the Balance of Exploration and Exploitation: In this way, the availability heuristic relates to innovation management through the mutual recognition of overconfidence when an individual can easily recall his/her learning, competences, resources, and successes (Hannan and Freeman, 1984; Levinthal and March, 1993; Burgleman; 2002). In a success trap, individuals can recall success with ease, thus, the availability heuristic also explains the over-optimism in the odds of future success. In addition, it can help to explain the desperation Levinthal and March (1993) described when an individual's performance falls significantly below the aspiration level. It can be reasoned that the desperation is a result of the ease in memory search for instances of failures; therefore, it magnifies the assessment of failure.

To summarize, the availability heuristic modifies the importance of parameters in estimations by elevating and decreasing the relative importance of them according to the ease of memory recall.

The easier the memory comes to mind, the higher the importance in the evaluation. Therefore, individuals with recent success are prone to feel confident about their ability as well as the odds of future success. Simultaneously, individuals with recent failure are prone to feel less confident. Additionally, the seemingly higher gap between their current state and their aspirations (Levinthal and March, 1993) due to the ease in recalling failures, can also influence further biased behaviors toward failure trap. This contribution to the persistence of trajectory is discussed under risk insensitivity in Section 5.3.3.

5.1.1.2 Resemblance, Coherence, and Causality

The availability heuristic deals with the internal access of memories. The concept of *resemblance* deals with processing internal and external cues and information. It links information and imageries together to create coherence. System 1 rationalizes a situation by connecting information into a causal story (Kahneman, 2011, p. 51). When information is limited, as in the case of bounded rationality, System 1 fills in the information gap and embellishes the story. Paradoxically, less information simplifies the construction of a story. If the story is coherent and enticing, it also appears more credible and likely adopted by System 2. According to Kahneman (2011), System 2 has unlimited ability to ignore our ignorance (p. 201). In the absence of a context for the information, System 1 generates one (Kahneman, 2011, p. 51). This statement can imply that System 1 updates its heuristic protocol. Suppose if System 1's heuristic in generating a context is constant, as System 2 improves its monitoring effort, it will find the representation that System 1 generates to be increasingly ridiculous. Since System 1 is built to create coherence, it is plausible that System 1's heuristics are updated even though the biases involved continue to preserver.

Resemblance can influence estimation because the story became so plausible that System 2 is not alerted, like the Moses Illusion. It evades System 2 because it displays a sense of normalcy, as illustrated by norm theory. To give a personal and innovation-related illustration of resemblance and norm theory at work: a post regarding the plan to launch a glass-bottom plane by Virgin Atlantic was circulating on Facebook earlier this year. When exposed to this information, my System 2 initially responded in disbelief, however, my System 1 recalled associated memory of Virgin Atlantic, Richard Branson, and Virgin Galactic. Conceivably, it seemed normal for Richard Branson, the founder of the Virgin group, who epitomizes innovation and entrepreneurship, to want to differentiate his airlines with innovative and trendy design. Therefore, it seemed a coherent and enticing story. Certainly, my System 2 did not account for the date, which was April's Fool, as well

as the possible thickness and weight of a glass bottom required to travel at 10,000 m above sea level. It is a demonstration that if System 2 is not sufficiently vigilant, we can believe anything. Moreover, it is also a demonstration that with a little investment of time and effort, System 2 can easily detect the error. This combination of resemblance and norm theory illustrate that accurate estimation can be compromised; for examples, in the case of a failing new entrants seeing signs of a breakthrough or a current incumbent seeing signs of continuing success for its core products. The mis-estimation can be attributed to a System 1 that sees pattern where there is none.

On the other hand, resemblance not only link information into pattern, but it can also induce individuals to see causality where there is none. In the cult classic, Blade Runner, director, Ridley Scott, showcased thirty-one[xxiv] incumbent brands in 1982 that are expected to remain successful in 2019 (Sammon, 1996). However, a few large incumbents including Atari, Bell, Polaroid, RCA, TDK, and TWA had encountered significant market loss and/or bankruptcy within the decade after their product placements in Blade Runner. The coincidental string of corporate misfortunes led to the popular superstition of a Blade Runner Curse (IMDB.com), which showcases the effect of resemblance on mis-estimation when System 1 takes random information and concocts it into a coherent story, and then assigned judgment and causality.

Linkage to the Balance of Exploration and Exploitation: Resemblance appears in innovation literature at the instances when individuals can see patterns of success or failure due to its repetition, like that in success and failure traps (Levinthal and March, 1993; Liu, 2006). Additionally, innovation decision makers can connect other cues and information into patterns as in applying learning directly from one domain to analogous domains because they resemble each other like the case of Amazon.com and Pet.com.

In sum, resemblance takes the cues and information and molds them into a coherent story while ignoring the need to evaluate the likelihood of the story to be proved true. Therefore, a coherent and enticing story can nullify any sense from System 2 to estimate the true implications of the information. Additional, resemblance can obstruct true estimation of events because it has already concocted a causal story with the cues and information. Individuals subjected to a coherent and enticing story without consciously engaging System 2 can mis-estimate the need for deviation, thus, are enticed into a singular innovation trajectory.

5.1.1.3 Cognitive Ease and Cognitive Strain

Heuristics help System 1 access large quantity of information within the associative memory network. Retrieved memory and the associated story can range from being pleasant to distressing, thus producing cognitive ease and cognitive strain. *Cognitive strain* is connected with the existence of a problem, in which effort is required to resolve it (Kahneman, 2011, p. 59). It develops even in simple task such as reading text with a small font (ibid). Mental effort associated with something straining, like learning something unfamiliar and thinking about the risk of failure, can lead individuals to avoid or adjust estimation and decision negatively in that direction, thus, can lead one into a singular innovation trajectory.

On the other hand, *cognitive ease* is a state and future projection associating with pleasantness and ease, which can simply be something that is familiar (Kahneman, 2011, p. 61). With specialization in competences and learning, a sense of familiarity can develop with exposures and thereby reducing mental effort needed on that subject. Cognitive ease elevates confidence subjectively in System 1 (Kahneman, 2011, p. 217); evidently, the confidence is not based on facts and estimation but on feelings. Consequently, cognitive ease induces individuals to select options that are familiar, thus, it endorses the formation of a singular innovation trajectory.

The sense of cognitive ease from something seemingly true or familiarity can be viewed as an extension of norm theory. Kahneman (2011) uses the examples “The moon revolves around the Earth” and “A chicken has four legs”. The former induces a sense of truth, therefore, a sense of ease, while the latter example conveys cognitive strain because System 2 is alerted (p. 61). Moreover, the second statement engenders less strain than a statement such as “A chicken has three legs” would because many animals have fours legs; therefore a chicken with four legs seems more familiar and true than a chicken with three legs (ibid). Evidently, cognitive ease can be associated with familiarity and truthfulness, however, both occasions can arguably cause cognitive strain in the cases of individuals seeking challenges or hearing the statement “The deadline is tomorrow”. In the former case, those individuals finding themselves in familiar repetitiveness can become distress and in the latter case, the truthfulness does not extinguish the strain.

On the one hand cognitive strain is constructive in raising vigilance and effort, however, it can also lead to behaviors that avoid cognitive strain. Such behaviors can lead individuals to submit to

confirmation bias by seeking familiarity and acquiesce to affect heuristic, judgment based on likings and disliking (next section), both of which can lead to singular innovation trajectory. Nevertheless, excessive cognitive strain can be overcome by inducing cognitive ease. For instance, in a situation of cognitive strain, one can delegate the task, ask for assistance, or temporarily delay the action. The last technique is observed by sales promotion in delaying the payment of goods at the time of purchase; it temporarily reduces the cognitive strain involved in making a large financial commitment. In innovation management, individuals can also schedule ahead tasks that are cognitively straining but necessary for the long-term survival of the business entity.

As cognitive strain reduces the effectiveness of System 2, System 1 can dominate by preferring decisions or actions that align with a state of cognitive ease, such are ones that are deemed familiar and/or true. Since System 1 is a natural believer, familiarity can be *primed* or deliberated induced (Section 3.1.1). For instance, pre-exposing individuals to words make them more familiar at secondary exposure. Even when the second instance is cognitively straining, the intensity is reduced. Moreover, smiling induces cognitive ease. Consequently, pre-exposing individuals to the coming of novel changes and innovations can induce better acceptance and adoption. In addition, cues and information relating to cognitive strain can be better accepted if the individual is in a state of cognitive ease during exposure.

Linkage to the Balance of Exploration and Exploitation: In innovation literature, cognitive strain is observed when business entities are engaging activities outside their competences and cognitive ease are observed in instances when business entities are engaging activities within their competences (Levinthal and March, 1993). Cognitive ease can be a strong motivator towards competency trap. On the other hand, cues and information that appears unfamiliar will induce cognitive strain, which tends to initiate actions of avoidance; this helps explain the negative reactions toward information of market change that seems threatening to incumbents in a success trap.

In sum, cognitive ease is associated with familiarity and cognitive strain is associated with mental effort that System 2 prefers to avoid. Specialization in learning and competences can inadvertently lead the individuals into a singular innovation trajectory either by preferring familiarity or avoiding the unfamiliar. However, both the sense of ease and strain can be primed by pre-exposure.

Therefore, it is possible to adjust the course of innovation trajectory when one becomes aware and willing to improve on the current trajectory.

5.1.1.4 Emotions and Affect Heuristic

System 1 generates a simpler and more coherent representation of the reality; it is one way System 1 is mitigating with the complexity of the world. One way to accelerate cognition and simplify assessment is to link judgment to emotion. *Affect heuristic* is the mental shortcut that concedes judgments and decisions to be affected by feelings of liking and disliking with minimal deliberation or reasoning (Kahneman, 2011, p. 12). According to Kahneman (2011), affect heuristic accounts for a substantial of occasions when people deviate from rationality especially under uncertainty (p. 8).

A subsidiary effect in basing judgments and decision on the liking and disliking of a person is known as *halo effect*, referring to a liked and saintly person can do no wrong. Recalling that System 1's default is to believe while System 2 must be mobilized to reject the belief (Section 3.1.1), therefore, once System 1 generates a sense of liking or disliking on a situation or a person, it requires the conscious effort of System 2 to make adjustment. Solomon Asch, a renowned pioneer researcher in modern psychology, conducted a telling experiment, which displays two imaginary people, Alan and Ben (Kahneman, 2011, p. 82). Their personalities are listed as:

> Alan: intelligent-industrious-impulsive-critical-stubborn-envious
> Ben: envious-stubborn-critical-impulsive-industrious-intelligent

One can observe that the list for Ben is exactly in reverse order to Alan, nonetheless, the list of personalities is exactly the same. Most people examining the list will develop a preference to Alan. Meanwhile, the arguably less desirable qualities in Alan are quickly justified as the flaws of an intelligent person. On the contrary, Ben is not as favorable since an envious person who is also intelligent can appear as a dangerous combination.

This experiment not only demonstrates that we let emotion governs our assessment and judgment, but also that System 1 creates coherence to justify the inconsistency and depress the significance of warning signs. Furthermore, the order of events exposed to System 1 matters, which will be examined further in the next section titled Anchoring. In the presence of emotion, biased conclusion can gain dominance over logic and arguments. Thus, an individual with a strong emotional

attachment to a person, product, concept, or situation, can become very unreliable in estimating and evaluating the future in relations to those attached concepts. Arguably, affect heuristic can naturally be mitigated as the emotion subsides. Additionally, Kahneman (2011) argues that 'Your beliefs, and even your emotional attitude, may change (at least a little) when you learn that the risk of an activity you disliked is smaller than you thought (p. 103)', this supports the argument mentioned that the heuristics in System 1, the one with the belief and emotion, can be updated, albeit only a little.

Linkage to the Balance of Exploration and Exploitation: The overconfidence and over-optimism observed in innovation literature are greatly influenced by affect heuristic since the vision of success and failure in innovation or financial gain can evoke strong emotion that motivates individuals to chose actions that are seeming logical in the short-run but irrational in the long-term survival of the business entity.

To recapitulate, affect heuristic links emotion to quick judgment in order to create a more coherent and simple reality, however, it affects an individual's ability to assess and estimate the true implications of the information presented. Emotional attachment distorts the true estimation of cues and information because liking elevates importance and depresses risk while disliking depresses importance and elevate risk. Furthermore, the order of information exposure matters because the first exposure often forms the judgment of like and dislike and can overshadow the entire assessment. Individuals can base innovation decisions on their likings, which can be what they think they are good at, thus, imposing an innovation trajectory to the business entity. However, through learning, it is possible to modify affect heuristic by updating the emotion linked to the judgment.

5.1.2 Anchoring

In cognitive psychology, *anchoring* is an important concept that measurably alters the cognitive ability in estimation and assessment. It is the involuntary focus on the first piece of information given, thus, rendering judgment partial and biased. It can be executed deliberately through *priming* or activated involuntarily (Kahneman, 2011, p. 120). It is a cognitive bias that affects both System 1 and System 2, albeit in different manners.

For System 1, anchoring primes the associative activation by securing itself as an important piece of information and drawing memories that is in support to the prime, much like the nodding while answering a question example given in Section 3.1.1. Through associative coherence, System 1 attempts to construct a reality that reinforces that the anchor is true (Kahneman, 2011, p. 123). As discussed in affect heuristic, the order of information matters. When one has been primed with an attribute like intelligence, the subsequent attributes serves to reinforce the bond to the primed anchor. System 1 will experience the cognitive bias whether the prime was deliberate or random.

For System 2, anchoring fixates a scenario or a number to System 2's computation so strongly that the outcome is circumambient to the anchor; this is a condition known as *insufficient adjustment* (Kahneman, 2011, p. 121). Even though System 2 detects that the anchor is irrelevant, it cannot deviate far enough from it to become impartial. In addition, unlike System 1, System 2 is capable of doubt and perceiving uncertainty; therefore, this sense of doubt and uncertainty affect the magnitude of adjustment. A visual example can be found by taking a sheet of paper and asking someone to draw a line from the bottom to the middle, then on another sheet of paper, ask the same person to draw it from the top to the middle; the lines will most likely be closer to the origin than expected due to doubt and uncertainty. Another demonstration is found in adjusting down the speed when exiting the highway. System 2 always underestimates the magnitude required, albeit this insufficient adjustment is affected more by insensitivity than doubt. Insufficient adjustment also relates to risk assessment, which will be discussed in the next section.

Anchoring can occur deliberately by priming or randomly. In premeditated way, marketing strategy often primes customers to act favorably toward a product. *Arbitrary rationing* is a marketing tactic that arbitrarily set a limit to the quantity available, in total or to a person. This can be reasoned to activate cognitive biases in both System 1 and System 2. For System 1, the limit portrays a collective desirability, which anchors the product favorably. For System 2, the limit set a numerical anchor that it attempts to adjust from, even though the outcome is often insufficiently adjusted. Anchoring is proportionally more alarming since detection can be difficult without knowing when one is exposed to the anchor. Therefore, its implications on initiating innovation trajectory vary greatly as an individual might not be aware of the anchor. Theoretically, an inventor can be exposed to an anchor regarding the performance level for the invention in progress, and the performance level set may not be rational to the market desirability but merely a number he/she overheard in a

technology conference. This number that is irrelevant for the commercialization can drive the inventor to continue exploration.

In an interestingly and disquieting study conducted by Englich, Mussweiler, and Strack (2006), the researchers studied the effect of random anchor on judicial sentencing[xxv]. In the first three parts of the study, the participating judges and prosecutors were given a realistic case file and then exposed to sentencing recommendations from 1) a irrelevant source, 2) the defense and prosecutor but then were told the numbers are irrelevant, 3) a rolling dice to set upper and lower recommendation limits. In the second study, the participating judges were shown a recommendation of 3 months or 9 months but told to ignore the number. Surprisingly, the study found that when the recommendation is 9 months, the sentencing is averaged at 8 months; on the other hand, when the recommendation is 3 months, the sentencing is averaged at 5 months. Moreover, the study found that the random anchor (the dice) has the same effect on sentencing as the more deliberate anchor.

These studies illustrated a few implications: *first*, anchoring has a significant effect on judgment; *second*, even when instructed to ignore the anchor, one cannot adjust enough away from it; *third*, professionals and experts who are deemed impartial are equally susceptible to anchoring.

Linkage to the Balance of Exploration and Exploitation: Similarly, anchoring behaviors are also found in the success, failure, and competency traps in innovation management literature (Hannan and Freeman, 1984; Levinthal and March, 1993; Burgleman; 2002). It describes a persistence toward a vision with disregards to cues and information that are showing a different projection such as incumbents ignoring market changes. Although System 2 can attempt to compensate, it is often insufficient.

In sum, anchoring can have an extensive effect on individuals' estimation and judgments, sometimes without conscious knowledge of it, because the anchor is assimilated into the associative memory, which affects the relative importance of other parameters in estimations. Even when System 2 detects the anchor, the final assessment and estimation are still affected by the anchor. Therefore, an anchor can induce irrational innovation behaviors as a result of unreliable evaluations and can drive the individual to pursue a specific trajectory without sounded reasons.

5.1.3 Statistics and System 1

Individuals are subjected to fragmented information and the associative coherence constructed by System 1, therefore, can conclude on actions and strategies that are based on mis-estimation of available cues and information. People are inadequate statistician (Kahneman, 2011) in the evaluation of risk and uncertainty. Rather than relying on statistics, they often defer to heuristics such as resemblance and ease of memory search that are pervaded with cognitive biases. More often, they rely on intuitive thinking when the situations require statistical reasoning (Kahneman, 2011, p. 77).

While System 1 is incapable of contemplating statistic, System 2 can but it requires some training even for experts. For instance, the Gates Foundation spent $1.7 billion on reducing school size after commissioning a report on the characteristics of the best school in the United States (Kahneman, 2011, p. 117). One of the report's findings is that smaller schools are recommended because schools yielding higher results have conclusively less pupils. A causal story is formed to explain the finding that smaller schools give better education, which is intuitively true and resembles a sound finding. However, two statisticians, Howard Wainer and Harris Zwerling, reviewed the findings and found that the worst schools in the United States are also conclusively smaller. Therefore, we cannot rely on mathematical data if our System 2 is not trained to understand that correlation is not causal. This occurrence can be applied to other innovation assessments, such as the odds of success for an innovation in relations to market preferences and competitions. Individuals who are not trained to think statistically and comprehensively tend to rely on incomplete information even though the additional information can become available with a little effort.

System 1 is not designed to doubt its judgment; moreover, it is a pattern seeking that is built to believe in a coherent world, in which the occurrences of regularities are not by accidents but by causalities and intentions (Kahneman, 2011, p. 115). When assessing risk without statistically reasoning, two cognitive biases can be observed.

5.1.3.1 Base-Rate Neglect

The mitigations in creating coherence via associative memory neglect the statistical likelihood of such a scenario occurring, an ignorance of *base rate*. If a male individual is described as— shy and withdrawn with little interest of people or reality but has a need for order, structure, and detail[xxvi]— and asked if he is a librarian or a farmer? It is likely that people will register him as a librarian,

because of *resemblance*. However, it is statistically more likely for a male to be a farmer than a librarian; meanwhile, a farmer can also have the same characteristics described. System 1 does not estimate with objectivity but rather it assesses memory and associations via *ease of memory search*, meaning whichever memory associated with the cues or information surfaces first will become the de facto search pathway.

Another display of the neglect of base rate can be found with the Tom W Experiment[xxvii] (Kahneman, 2011, p. 146), in which the same fictional person, Tom W, is described twice in the experiment: *first*, with only information that he is a student at a major university and *second*, with more personality descriptions. The participants were asked to rank nine study majors in the order of the likelihood to Tom W's attendance. Participants encountered no obstacle in voluntarily referring to base rate at the first account. However, the second test proved to be cognitively challenging because System 1 automatically connected personality traits to stereotypical study fields they are associated with. According to Kahneman (2011), the *representativeness* or stereotypical descriptions confuses System 2 while System 1 took the lead in constructing a causal story (p. 149). When instructed to think like a statistician, participants referred more to base rate and statistical relationships, which led to System 2 regaining a degree of control. This experiment demonstrates that people are capable of understanding and employing statistical relations; however, in the events of being presented with less statistically relevant information that appeal to cognitive biases, the employment of base rate and objectivity diminishes. When estimating, individuals focus on cues and information that are statistically irrelevant, associative coherence and representativeness can easily overwhelm an undisciplined and untrained System 2.

Notably, clarification is needed on *resemblance* and *representativeness*. Resemblance is an established concept while representativeness is a similar concept conceived by Kahneman and Tversky. When comparing the two concepts under the examples of librarian/farmer (resemblance) and Tom W (representativeness), one cannot deduce the difference between the two concepts since both illustrate a phenomenon in which a few unrelated cues and information can be structured into patterns that do not exist. This comparison and lack of reconciliation is supportive of an observation that within the study of cognitive biases, there lacks a degree of comprehensiveness.

Linkage to the Balance of Exploration and Exploitation: The investigation into base rate neglect is not present in current innovation literature on balancing exploration and exploitation, although it makes references to over-estimation on the rate of success and under-estimation on the risk of failure for business entities that are in success, failure, and competency traps. The references have a more direct relation to probability neglect, which is addressed in the next section.

To summarize, individuals are capable of understanding statistical reasoning, but often, their cognitive biases skew ones' judgment by jumping into conclusions via heuristics. Therefore, a business entity can fall into an innovation trajectory by ignoring the based rate which actually reflect the likelihood to success.

5.1.3.2 Uncertainty and Probability Neglect

While doubt and uncertainty is not part of System 1, it is in System 2 (Kahneman, 2011, p. 80). As illustrated in anchoring (Section 5.1.2), uncertainty induces System 2 to adjust insufficiently. However, one can argue that System 1 is built to deal with uncertainty by creating coherence, thereby, leading people to make judgment according to affect heuristic, availability heuristic, cognitive ease, etc.

When cues and information are received as threatening, System 1 responds by elevating the perceived risk. Similarly, when cues and information are received favorably, System 1 responds by depressing the perceived risk. This response is also closely related to cognitive ease, cognitive strain, and affect heuristic. After the occurrence of a rare event such as the tsunami in 2011, System 1's risk perception is heightened. Cognitive strain is engaged and skewed the judgment to favor preventing another similarly distressing occurrence. Under such distress, base rate can be ignored even when provided. Immediately after the tsunami, there were heated debates regarding the safety of nuclear energy even though the base rate of an accident of that magnitude occurring has not change from one day to the next. Germany, influenced by the Fukushima accident, albeit after a long brewing rhetoric before the accident, decided to withdraw from nuclear power (BBC News, 2011). This incident portrays the elevation of perceived risk when worries take over and others, including politicians, can take advantage of the mis-estimation of risk. The willingness to predict rare events from weak evidence is a manifestation of System 1 (Kahneman, 2011, p. 194).

When the amount of concern is not proportional to the probability of harm (Kahneman, 2011, p. 316), and vice versa for affection and the probability of gain, a cognitive bias of *probability neglect* emerges. It can triggers cognitive ease or cognitive strain. Cognitively, it implies that the people tend to focus on the numerator of a probability and ignores the denominator (Kahneman, 2011, p. 144). The rationality within System 2 will try to see the probability as a whole while System 1 focuses on the what-if on the numerator. It skews the estimation of risk and any subsequent action based on the perceived risk. As psychologist, Jonathan Haidt, suggests "The emotional tail wags the rational dog (Kahneman, 2011, p. 140).

Linkage to the Balance of Exploration and Exploitation: The references to over-estimation on the rate of success and under-estimation on the risk of failure (probability neglect) for business entities are common statements in innovation studies. However, in innovation literature the terms are often used with a great hindsight bias, referring to situations when business entity have failed to notice certain cues and information while in cognitive psychology, it is a statistical gauge to the intensity of deviation cognitive biases can impose.

Table 1: Cognitive biases and overconfident/over-optimism

Cognitive Biases	Overconfidence (ability)	Over-optimism (odds)
Availability Heuristic	✔	✔
Confirmation Bias	✔	✔
Resemblance		✔
Cognitive Ease		✔
Cognitive Strain		✔
Affect Heuristic		✔
Anchoring		✔
Base Rate Neglect		✔
Probability Neglect		✔

To recapitulate, individuals can ignore the statistical probability of an occurrence, and defer to perceived probability based on heuristics. It can be triggered by cognitive ease or strain, thereby, focusing attention on certain actions over others. In doing so, the business entity can ignore the

probability of success or failure and continue on innovation pursuits, which can lead to decisional preferences that initiate a trajectory.

5.2 Mis-estimation and Innovation Trajectories

In the analysis of availability heuristic, resemblance, cognitive ease and cognitive strain, affect heuristic, anchoring, base rate-neglect, and probability neglect, research in cognitive psychology finds that they can considerably distort the accuracy of estimation and evaluation. In balancing exploration and exploitation, they can affect business entities in two ways: *first*, by distorting the estimation of one's abilities to overcome uncertainty, and *two*, by distorting the estimation in the odds of a favorable occurrence.

5.2.1 Overestimation of Ability

In the preceding examination of availability heuristic in Section 5.1.1.1, Kahneman (2011) indicates that the ease of memory search regarding both frequency and speed in associative memory retrieval can distort an individual's self-assessment. Individuals who were requested to list a lesser number of instances of assertiveness correlate with higher self-evaluation in that regard; moreover, when requested to name incidents in which the individuals do not display this quality and the participants cannot do so, it skewed their self perception extensively away from that personality. Both displays of self-assessment are illogical because individuals who can recall more instances have objectively higher aptitude in regards to that quality.

This misrepresentation and mis-evaluation of self can over-exaggerate one's ability in overcoming challenges in uncertainty. In the case of individuals who have experienced repeated successes, they can recall several successful instances with ease. Consequently, they are more confident about their own abilities in the contribution of the success while ignoring the contribution of luck (Kahneman, 2011, p. 13). Moreover, when individuals are asked to recall an incident of failure, and they cannot, it leads to a substantial increase of self-evaluation on the topic of being successful.

Confidence from specialized learning, repeated success, and confirmation search, can amalgamate and reinforce each other into a fallacy of expert intuition that are biased statistically, such as that found in the researchers for the initial Gates Foundation report. They were commissioned experts who mistook a correlation for a causality by not statistically eliminating if smaller school size has correlations to outcomes such as that found in the worst schools. This case is a demonstration of

expert overconfidence coupled with norm theory because it is intuitive that a smaller school size may offer pupils more attention. The effect of expert intuition on the persistence of singular innovation trajectory is examined in Section 5.3.2.

Linkage to the Balance of Exploration and Exploitation: Overconfidence in one's abilities is often observed in individuals who have developed specialized learning and competences as well as individuals who have experienced repeated successes lately (Levinthal and March, 1993; Murmann and Tushman, 1997; Hannan and Freeman, 1984). This supports the findings in cognitive psychology that these individuals are likely able to recall its learning, competences, and success easily as they are recent occurrences.

To summarize, overconfidence in one's ability can significantly affect the innovation trajectory as individuals are inclined to pursue decisions that they feel confident will end in a favorable manner. Therefore, mis-estimation of one's ability can consequentially affect the decisions making in preferring decisions that optimize the chance of success; nevertheless, it guides business entities into a singular innovation trajectory.

5.2.2 Mis-estimation of Odds

During the evaluation process, in addition to the overconfidence in one's own abilities, over-estimation on the odds of an occurrence or success can also cause significant bias in the accuracy of assessment, especially if System 2 is not attentive and acquiesces to System 1. The perception of risk affects the estimation of the probability of success and failure, gains and losses. Overconfidence in the odds of an occurrence or success can be resulted by most of the cognitive biases reviewed thus far, individually and collectively.

System 1 utilizes heuristics, mental shortcuts, to assess associative memory in response to the cues and information, however, the connections brought forth can mis-represent the importance of specific cues and information in the overall assessment and decision. Certain cues and information may establish a biased causal story that renders the assessment detached from reality. The resemblance of a shy and withdrawn individual who has a need for order, structure, and detail, led System 1's to conclude that the individual resembles a librarian. The fast thinking of System 1 is unreliable in the estimation of risk as it can jump to conclusion with information and memories that resemble gains or losses.

The feeling of imminent losses, for example, the fear of cannibalization in sales, can commandeer System 2 into ignorance because of the substantial effort required to overwhelm both the casual story that System 1 has woven as well as the strong emotion attached to it. In the case of the Fukushima nuclear power plant accident, the rhetoric that followed heightened System 1's strong dislike, thus causing an overestimation of risk for similar incidents in the future. The engagement of affect heuristic hinders objective evaluations by lessening System 2's control on System 1. Consequently, affect heuristic allows System 1 to over-allocate emphasis on a future that may be improbable when other parameters are properly considered; thus, it leads to mis-estimation during risk assessment. Furthermore, the causal story and the feeling attached to it can anchor within the evaluation, motivating the outcome to remain closer to the anchor than without the presence of these cognitive biases. In other words, it instigates probability neglect because based rate is observably ignored. Ultimately, if the causal story seems normal, a display of norm theory, System 2 might not detect the errors respectively.

Linkage to the Balance of Exploration and Exploitation: This interplay of multiple cognitive biases in mis-guiding the estimation of an occurrence or success is also found in success, failure, and competency traps. Both cognitive psychology and innovation literature acknowledge the roles of overconfidence and over-estimation, although innovation literature ascribes their presences to repeated success and specialization in competences while the former opted for cognitive biases. Meanwhile, they differ in the rhetoric for the reason of mis-estimation. While cognitive psychology focuses on cognitive biases, innovation research focuses on opportunity cost. In innovation literature, the trajectories are often attributed to the increasing cost of switching and relearning, however, not all innovation decisions are decided under relative rationality. They are ultimately bounded by cognitive biases as well; therefore, arguably, some of the decisions made towards an innovation trajectory were made based on subjective deductive reasoning from strong memories and emotions. In citing Jonathan Haidt, "The emotional tail wags the rational dog (Kahneman, 2011, p. 140)," decisions are likely made with heuristics and emotion with some modifications by System 2, if any. Innovation scholars may be able to trace structured decisions that are largely based on opportunity cost when they are conducting a detailed research on a bureaucratic organization. However, more likely, the smaller decisions that have contributed into the initiation of an innovation trajectory are modified decisions from System 1.

As a result of availability heuristic, resemblance, affect heuristic, anchoring, probability neglect, base rate neglect, and norm theory, the estimation of risk can be flawed and the envisioned event unlikely to happen. These cognitive biases can limit the fuller understanding of the developing future by focusing on some cues and information while ignoring others. It is necessary to note that this paper recognizes that overconfidence and over-optimism are engines of capitalism, entrepreneurship, and innovation (Kahneman, 2011, p. 255, p. 260). Simultaneously, they are also the causes for innumerable business mortalities because of their effect on misguiding estimations. Section 5.2 concludes that cognitive biases affects estimation through overconfidence on one's abilities and the mis-estimation of favorable occurrences, therefore, leading decision makers to favor some actions more than others which can advance the business entity towards an innovation trajectory.

5.3 Cognitive Biases and the Persistence of Singular Innovation Trajectories

The examination of cognitive biases help explains the tendency to misjudge cues and information by showing how they modify the estimation mechanism in System 1 and 2. Interestingly, cognitive path dependency can begin to develop and continues despite the warnings from System 2 and outside sources such as external advices and customer feedback. This section investigates cognitive reasons for singular innovation trajectories to continue despite interventions. First, the section on intuition and expertise demonstrates the persistence of confidence in judgment by business entities in a success trap. Second, the section on Prospect Theory helps explain the reason for the persistence for business entities in a failure trap by risk insensitivity. Lastly, the section on conformity bias help explains how social interaction can magnify cognitive biases and limits deviations; thus, it can confine business entities to the trajectory despite possessing new learning that can initiate change.

5.3.2 Intuition and Expertise

Individuals are confident even when they are wrong, especially when cues and information are scarce (Kahneman, 2011, p. 86). The presentation of one-sided information strengthens one's confidence in judgment (ibid), as less evidence is presented in violation with the causal story System 1 has constructed. The cognitive biases associated with mis-underestimation—namely, availability heuristic, affect heuristic, anchoring, base-rate neglect, and probability neglect—are

ubiquitous to both experts and non-experts. Intuition is closely linked to resemblance under availability heuristic. It is an efficient mental shortcut when the judgment is likely to be correct and the opportunity cost of being mistaken is rationally acceptable (Kahneman, 2011, p. 79). However, in situations that are unfamiliar, applying intuitive judgment can be risky as System 1 may overlook the new parameters through a lens of resemblance.

According to Herbert Simon, "Intuition is nothing more and nothing less than recognition (cited by Kahneman, 2011, p. 11). Kahneman (2011) distinguishes valid intuitions as ones that develop when experts have learned to recognize familiar elements in a new situation and to act in an appropriate manner, however, there are also expert opinions given with intuition that are not deduced from true expertise (Kahneman and Kline, 2009). Valid expert intuition is based on insight developed from past learning and extracting only appropriate elements in the learning to apply to new situation while misguided intuitions from experts or non-experts can be based on heuristics without modifications from System 2. Although invalid intuitions can come from experts and non-experts, the former holds a position of authority, thus, their intuitions are more damaging when others act according to the experts' judgment and recommendations. One can also argue that herd behavior[xxviii] can consequently render the misguided intuition true, but it is beyond the scope of this research.

People placing too much faith in their intuition can lead to overconfidence. Interestingly, although expert intuition can be valid or misguided, when confronted that their intuitions have proven wrong, the biased experts were found to provide a large collection of excuses (Kahneman, 2011, p. 219). Alarmingly, a twenty-years longitudinal study by Philip Tetlock found that forecasts from political experts are less reliable than simply assigning equal probability to all possible outcomes (Tetlock, 2005; Kahneman, 2011). Furthermore, the experts who know slightly more forecasted slightly better than the ones who know slightly less; meanwhile, the experts who have the most knowledge on the subject are least reliable (ibid). Tetlock reasoned that experts who are most knowledgeable are also unrealistically confident in their forecasts because of recognized expertise and competitiveness between forecasters to 'out-confident' each others (ibid). Their positions as recognized experts shroud them into an illusion of skill, both for themselves and for others. On the contrary, true expertise is based on developed skill, appropriate re-application, and not on luck and

position. Moreover, true experts are also realistic about the breadth of their knowledge; thus, act more cautiously with their intuitions.

In conclusion, misguided experts are more prone to overconfidence and over-optimism since their intuition is guided by heuristics based on cognitive biases and not heuristic based on true expertise and modifications from System 2. It was meaningful to iterate that true experts are still subjective to cognitive biases, but in the matter of their expertise, they are more capable in relying on heuristic derived from repeated experience and the intervention from their System 2.

Linkage to the Balance of Exploration and Exploitation: Overconfidence in the prediction of future occurrence relating to the imbalance of exploration and exploitation is largely observed in success and competence traps. It is an externality from accumulated competences and/or the repeated success in the execution of a task (Murmann and Tushman, 1997). Confidence increases as a function of short-term positive feedback and leads individuals to overestimate their contribution to the success and underestimate the contribution of luck (Levinthal and March, 1993). In this way, cognitive psychology and innovation management are in agreement with the effect of confidence as a modifier to the accuracy of estimation. With repeated successes in exercising local competences, one begins to be regarded as an expert in that area and his/her intuition become more valued even though it can still be misguided if one does not employ true expertise. In innovation management within the rhetoric of exploration and exploitation, cases of visionary leaders or leaders that have led an organization into demise are studied and found that both are subjected to overestimating abilities and the odds of favorable outcomes (Burgelman, 2002; Goel, and Thakor, 2000).

The Case of Amazon.Com: Amazon.com was started by Jeffery P. Bezos in 1994 with a $300,000 loan in reaction to the dot.com boom. He settled on the online book business with the reason that "Unless you could create something with a huge value proposition for the customer, it would be easier for them to do it the old way…[I want] to do something that simply cannot be done any other way (Pearlstine, 1999)". Amazon.com went public in 1997 at $18/share and by the end of 1998, it was at $53.49 (Yahoo Finance). Bezos was increasing confident in his success and he was incapable in delegating (The New York Times, 2005). Confident in his abilities and his success strategy in being first in market, he estimated that he could extend the learning and business model of Amazon.com to others analogous domains. He became confident in the market potential of

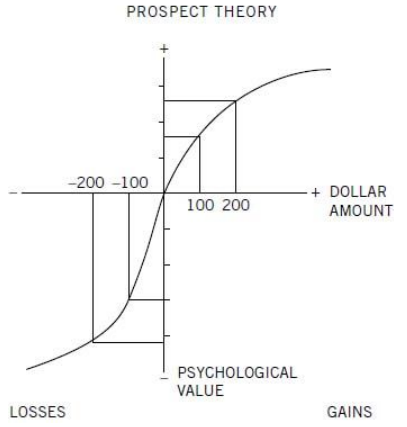
customers switching all purchases online and decided to expand into pet food through Pet.com. However, the intuition and assessment was faulted by his confidence in the repeatability of Amazon.com's success through Pet.com. In his evaluation, he ignored the implications of selling pet food online including the cost of delivery, the cost of setting up new IT servers in the 1990s for Pet.com, and the lack of customer value with a larger selection of pet food (Van Pelt, 2008; Wolverton, 2000). It appears that Bezos had forgotten his business model of offering customers a service that is best executed online. In addition, Bezos' desire to become the biggest online retailer anchored the business entity to an expansive and exploitative trajectory. His repeated successes was a confirmation to his entrepreneurial abilities and his success in the online business make him over-estimate the potential of online pet food service in the 1990s. Therefore, his expertise in building an online business and his intuition in the growth of the online market was shrouding him from the true estimated potential of online pet food at the time. In the end, Pet.com bankrupted within two years. Bezos recalls the experience as a root canal without anesthesia (New York Times, 2005).

5.3.3 Prospect Theory

Risk-avoidance and risk-seeking behaviors are typical behaviors of exploiting or exploring business entities, respectively (March and Levinthal, 1993). In order to understand risk and decision-making with risk and uncertainty, Daniel Kahneman and Amos Tversky developed Prospect Theory in modification to Expected Utility Theory. The latter theory by Daniel Bernoulli postulates the relationship between wealth and expected utility, psychological value, has a diminishing return. It explains why expected utility from the same amount of change in wealth can mean differently to wealthy people than less wealthy people. It explains that people with different states of wealth will perceive loss and gain differently. A wealthy person gains less expected utility from the same amount as do a less wealthy person.

Prospect Theory updated Bernoulli's theory in three ways: *first*, it recognizes that individuals like winning and dislike losing, therefore, the curve on the loss side is steeper than on the side of the gain. *Second*, it recognizes that a reference point matters when people make decision regarding to risk and uncertainty because the psychological gain and loss changes according to a reference point, which can be current wealth or just an anchor. Therefore, it is not the state of wealth per se that changes psychological value but the relative gain and loss. *Third*, it explains both risk avoidance and risk seeking and not only the former. It stipulates that a wealthy person tends to be risk avoiding because the potential gain is often not meaningful in increasing perceived utility,

Figure 6: Prospect Theory psychological value graph



therefore, has less effect on psychological value. Contrarily, a person in debt will exhibit more risk-seeking behavior as the possible loss in utility tapers off. It is similar to anchoring and insufficient adjustment that when a large loss is expected, System 2 became less sensitive to objective estimation. Kahneman (2011) confesses that the shortcomings of Prospect Theory reside on its inability to explain disappointment and regret. The first refers to the disappointment from zero gain, which is psychologically a loss. The second refers to when regret modifies the change in utility; for example, if a business entity decided to forgo a project that later became a cash cow with another business entity, the regret will intensify the loss in psychological value.

The main contribution for Prospect Theory to singular innovation trajectory is to explain the risk-related behaviors especially risk-seeking behavior described by failure trap. It stipulates that in a situation with both the risk of success and failure, a business entity is emotionally motivated by the cognitive strain of losing; therefore, System 2's logic imposes that if a loss of an imaged magnitude is at risk, there needs to be a sufficiently larger gain to justify the probability to lose. This correlates to a loss-aversion coefficient, which increases when the magnitude of probable loss increases. Kahneman (2011) posits that this coefficient increases to infinity when the loss reaches a point that will induce a maximal level of negative psychological value, such as when the loss can threatened the current lifestyle of the individuals. On the other hand, Prospect Theory confers that if the possible decisions presented will all lead to losses of different magnitudes and probabilities, the individual becomes loss insensitive and being to exhibit risk-seeking behaviors.

Prospect Theory help reconciliate the economic meanings of risk-aversion and risk-seeking by recounting that the slope of the gain curve is less steep that the slope relating to loss. However, his controlled research may present some deficiencies empirically. For individuals to become risk-insensitive to loss, it implies that the individuals are knowledgeable to their repeated failures. In that conscious knowledge, they developed a 'numb' reaction to failure because the psychological value for another failure is less pronounced. However, arguably, if the individuals are not consciously

recognizing that they are failing, as they attribute the loss in wealth to a lack of success but not a failure, it is reasonable to suggest that the loss curve is less steep than depicted since the psychological effect is not catalogued. Furthermore, Prospect Theory is built on psychological experiment based on personal wealth. Risk-related judgments can also be decided differently when the wealth is not your own to win or lose. For instance, the failing new entrant who is burning venture capital can reasoned to have a less intensive slope on the loss curve, although they are still risk-seeking. The possible empirical deviations are not posted as to question the validity of Prospect Theory, but to be made aware that individual loss curve might not always be as steep as it appears in the idealized illustration.

Linkage to the Balance of Exploration and Exploitation: Prospect Theory has strong links to the study of the imbalance of exploration and exploitation. In explaining the different psychological value relating to the risk of gain and loss, Prospect Theory clarifies the motivation for risk-averse behavior as loss avoidance—individuals are not affected by risk but by the possible loss implied—and the motivation for risk-seeking behavior as loss insensitivity because individuals become 'numb' to the loss, therefore, risk has less psychological effect on the individual than innovation studies have emphasized. It is loss aversion that contributes to the risk-avoiding and risk-seeking behaviors.

In the study of exploration and exploitation, risk-avoidance is usually associated with exploitative business entities that have made their fortunes and become cautious. Prospect Theory stipulates that it is not necessarily risk-avoidance behavior but loss aversion. On the other hand, innovation studies attribute risk-seeking behavior to exploratory business entities that are disregarding the risk involved in exploration. Prospect Theory offers a reconciliation that the business entities are not necessarily becoming risk-seeking (a conscious desire to engage in activities that have higher and higher risk) during failures but that they are becoming insensitive to losses. It can be reasoned that the increasing engagement to risky actions is a demonstration of insufficient adjustment by System 2 possibly due to the high level of cognitive strain experienced by the individuals. Levinthal and March (1993) also recognize the cognitive element with desperation and insufficient adjustment in failure a trap. Although they offer no explanation to the counter-intuitiveness between desperation and insufficient adjustment (Section 2.1.1), cognitive psychology can help explain the relationship by comparing the aspiration as an anchor. When reality deviates from the anchor, System 2 tries to

adjust risk perception but eventually the mind became insensitive to further loss, perhaps as a show of prolonged depletion effect from continuous self-control and engagement of System 2.

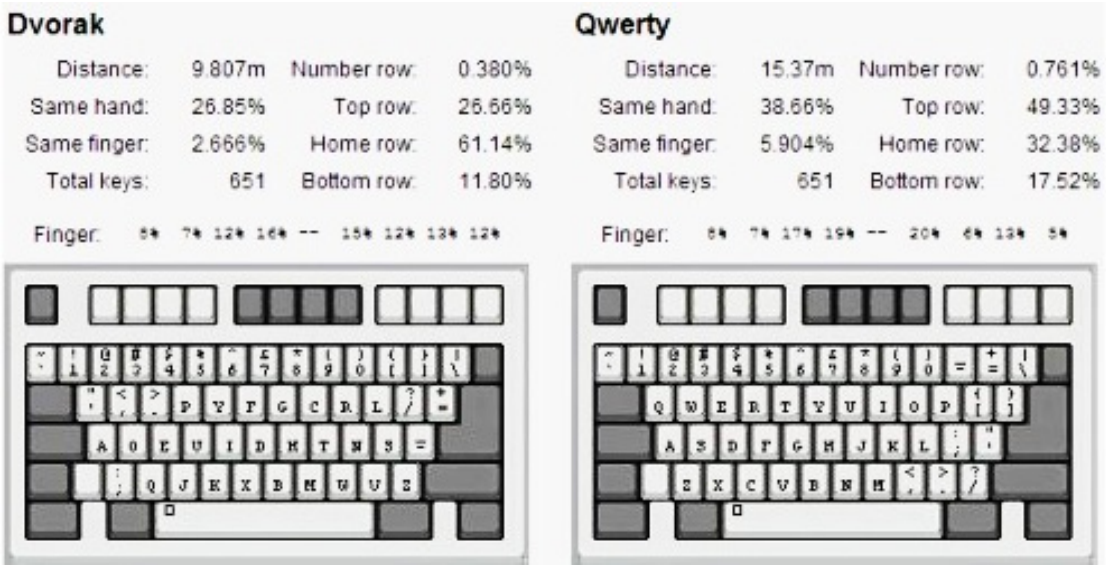
In addition, both Levinthal and March (1993) and Kahneman (2011) acknowledge that there exists a survival point on the loss curve, where the loss in psychological value is so potent that individuals are not willing to bear the risk any longer. However, it can be reasoned that both loss-aversion and loss-insensitivity are contributing factors to the behaviors during failure trap as the individuals can still be hopeful of a large enough gain in order to recover the loss in the beginning, and then become insensitive to loss when the losses mount.

Finally, Prospect Theory reconciles the contradiction of business entities in a failure trap as being both overestimating risk and risk seeking (Levinthal and March, 1993). During a period of loss, individuals become risk seeking due to a developed insensitivity to loss. Therefore, one can be overestimating risk and risk seeking at the same time if one has developed insensitivity to loss. If one does not care at decision time, the preceding estimation of risk does not matter.

The Case of Dvorak Keyboard:

Professor August Dvorak, an educational psychologist at the University of Washington realized in the early 1900s that the contemporary QWERTY keyboard was noticeably inefficient because the modern QWERTY keyboard was designed to scatter common letters in order to slow down typists and resolve the initial typewriter jamming problem (Rogers, 1995). In 1914, forty years after the QWERTY keyboard had been commercialized, August Dvorak realized the inefficiency and set out to create an ergonomic and speedy keyboard with his brother-in-law. He conducted time-and-motion studies and placed the ten most typed letters on the home roll (the middle), centering 70% of typing, so the typists' hands did not have to move as much (ibid). Additionally, he placed letters in an arrangement that optimize the strength between right and left fingers while designing the successive keystrokes to fall on alternative hands (ibid). After two decades of exploration and R&D, the invention was launched in 1932, but it never gathered enough customer-base to become successful. He repeatedly tried to secure tenders from the U.S. government albeit unsuccessfully (ibid). Dvorak died in 1975 a bitter man, and reportedly said, "I'm tired of trying to do something worthwhile for the human race. They simply don't want to change!" (Diamond, 1997). When Dvorak started researching for a more ergonomic keyboard in 1914, the QWERTY keyboard did

Figure 7: The Simplified Dvorak keyboard vs. Qwerty keyboard



not have a large adoption base as keyboard was a rather new innovation. During his exploration (20 years), he was so engulfed by creating a keyboard based on science and research that he became insensitive to the risk of failure by the lack of market demand. More importantly, he ignored any plan for commercialization strategy during development, a lack in exploitation. Even after the unsuccessful launch and the subsequent rejections, he continued to market the product. This story displays how the repeated failure[xxix] in perfecting a scientifically superior product while ignoring needs for exploitation can lead one into a failure trap. During development, he did not register a prolonged period of R&D as a failure but a lack of success. Later, during marketing, unable to recognize the market preference and his sunk costs, he continued to commit more time and resources to the project.

5.3.4 Conformity Bias

Understandably, individuals behave differently in social settings because there are more parameters at work. The study of group behavior is most prominent displayed by psychologist, Solomon Asch, who conducted a series of social experiments in the 1950s (Levine, 1999) to investigate conformity in a controlled environment. Two illustrative examples are found by the elevator experiment and the line experiment.

Asch's elevator experiment[xxx] is less academically structure, nevertheless, it visually illustrated that unsuspected test subject conformed to other's behavior. It involves several confederates, actors that

Figure 8: Asch's elevator experiment on conformity bias

Asch had hired to play a role, who held or changed orientation during a short elevator ride. It was designed to uncover if the test subjects will conform to the new orientation, which was not facing the exit (the norm). This experiment illustrates that people's propensity to conform is strong.

The line experiment involves a figure with four lines and noticeably, two of the lines, X and B, have equal length. Asch (1952) had a test subject size of 50 male students from Swarthmore College. The participating group included one actual test subject and seven enlisted confederates, who had arranged to act outspokenly that the longer line, either A or C, is the same length as X. There were eighteen trials, of which twelve are critical trials when the confederates deliberately and uniformly gave a wrong answer. Additionally, there was also a control trial in which there was no confederate participation. The general conclusion of this experiment is that 32% of test subjects conformed during critical trials while in control trial, less than 1% conformed. During the critical trial, only 25% of participants never conformed and therefore, were independent. In subsequent experiment, Asch (1952) found that the percentage of conforming test subject decreased dramatically from 32% to 5.5% if one of the confederate, who had given the erroneous answer, changed to the correct answer; in doing so, the confederate became a supporter to the test subject.

Figure 9: Asch's line experiment on conformity bias

This experiment confirms that conformity bias exists and can drastically affect one's decision and judgment. Having a large group pointing to a uniformed answer can make the test subjects experience uncertainty and conform to the norm. Moreover, if the group contains member(s) that are liked by the test subjects, affect heuristic can intervene and oppresses System 2 into conforming to the group behavior. It is necessary to acknowledge that the studies were conducted in the 1950s and researchers have argued that the high results in conformity is a reflection of the belief system in the McCarthy era (Bond and Smith, 1996); therefore, presently, the conformity bias is perhaps less protruded.

In conclusion, the cognitive biases within oneself can be amplified by conformity bias. Therefore, when a business entity is pursuing a singular innovation strategy, namely exploration or exploitation, there is a high probability that those within the business entity will not voice the concern unless they are very confident about the course of action and/or have social supporters within the business entity who share similar views, especially if the instigator is authoritative and liked by the group members. Even then, it is difficult to redirect a singular innovation trajectory when the trajectory is supported by conformity bias.

At the same time, Asch (1952) argues that conformity promotes efficiency within a group because it induces the construction of a shared reality, which simplifies and streamlines the operations. The study into the collective minds in organizations that require zero error such as airlines by Weick and Roberts (1993) found that the deliberately interrelated social activities, which they called 'heedful interrelating' activities promote the development of a group mind, a higher order of consciousness without completely overtaking the individual mind; in do so, the individuals are more alert and detailed, still able to think independently while the organizational performance increases because operations are more seamless and reliable. Therefore, conformity does not necessarily represents the destruction of variation but can be a tool toward efficiency, reliability, and a separate collective reality.

Linkage to the Balance of Exploration and Exploitation: Drawing on March's (1991) seminal work on organizational learning, his model stipulates that actions in ensuring variation—such as personnel turn-over, slower socialization rate (as to reduce speedy conformity), heterogeneous

population with fast and slow learners— within an organization helps balance exploration and exploitation. March's finding supports Weick and Roberts (1993) in showing that slow and deliberated convergence of knowledge does not necessarily lead to the dominion of one set of knowledge over another, but to a synergy that heightens overall knowledge and reliability. Therefore, when exploration and exploitation are in relative balance in relations to the business entity's context, conformity bias can be useful in creating a group culture that fosters both short-term and long-term agendas. However, when conformity is unchecked by System 2, it can have less synergic effect and prevent decisions that leads to variation and learning.

The case of Polaroid: For Polaroid, it has enjoyed tremendous success in the business of chemical film while maintaining exploratory efforts for decades. In 1977, its try to diversify with a movie camera, Polarvision, failed miserably. It was both a technically inferior product from the customer's perspective and an expensive investment for a contemporary market size of 3%. Edwin Land, the founder, resigned, having been the instigator for the launch even when other senior managers opposed. When William McCune took tenure, Polaroid was still financially robust and valuing exploration despite the loss. Having experienced the loss with Polarvision, he vowed to base exploratory efforts on market research and decided to invest in digital imaging in the early 1980s (Bonanos, 2012). In 1986, Polaroid committed $30 million into a new unit called The Microelectronics Laboratory (MEL), and by 1989, more than 40% of Polaroid's R&D budget was spent on digital imaging technology. Even with the continuation of exploration after Land's departure, senior management at Polaroid had switched to a more market-focused approach, perhaps as a consequence of the loss experienced by Polavision. When digital photography was beginning to gain market attention in the late 1980s, Polaroid estimated that it was not a threat to its core business because the money is in the razor-and-blade business mode—the Polaroid films (ibid). Tripsas and Gavetti (2000) studied Polaroid extensively during this period and found that the inertia on the business model has driven the company to confine all activities around it. Exploratory projects were only supported if they can succeed with the same business model. In addition, during this period, senior management remained relatively constants, thus, no one has the hierarchical power to seriously challenge their razor-and-blade perspective, not that new employees at MEL did not try (ibid). This is a display of conformity bias even though it was not a case of conforming a new board member. The conformity bias in this case comes from the board members' initial consensus on the success of the razor-and-blade business model. Subsequently, with no

change in the tenure of the board, they reinforce each other's belief on the importance of fitting all businesses into this framework. For them, the thought of moving to digital photography was unnerving because it would cannibalize the still profitable chemical film business. Referring to March (1991)'s study on long-term knowledge stock, without new perspectives from turn-over or slow learners, conformity sets in quickly and limits the exploration of a business entity. In the end, the preference of concentrating on chemical film business was consequently anchored to the trajectory for Polaroid after it sold its Microelectronics Laboratory to MIT in 1993. The case of Polaroid not only illustrates an example of negative conformity, but also an example of a business entity that is both exploring and exploiting can still submit to a singular innovation trajectory by competency trap.

6.0 Conclusion

This research aims to investigate the correlations between cognitive biases, the imbalance of exploration and exploitation, and the vulnerable states of success trap, failure, and competency traps (states resulted from singular innovation trajectories). It sets out three objectives: 1) to identify specific cognitive biases that can contribute to mis-estimation in one's abilities and the odds of favorable occurrences, 2) to understand the persistence of singular innovation trajectories from cognitive biases. These two objectives embody the two strategic points of a singular innovation trajectory—its initiation and its persistence. 3) to investigate an alternative perspective on balancing exploration and exploitation at an individual level.

In innovation management, decision makers are subjected to cognitive biases in the matters of balancing exploration and exploitation. Innovation literature attributes tenacious behaviors in success, failure, and competency traps to the overconfidence in one's abilities and the over-optimism in the odds of success (Levinthal and March, 1993; Burgleman, 2002; Hannan and Freeman, 1984; Murmann and Tushman, 1997). In the perspective of cognitive psychology, they are manifestations of cognitive biases. In connection with mis-estimation, of selves and risk, three sets of cognitive biases were examined: heuristics and associative memory, anchoring, and risk assessment. This thesis finds that the ease of recalling certain memories and the emotion attached to them can greatly contribute to the initiation of a singular innovation trajectory. Business entities tend to increase frequency in actions that they associate positively with, which can be tasks that they can easily recall in association with success. This proclivity can anchor into subsequent

decisions and affect the risk assessment by neglecting the base rate and altering probability for the occurrence of specific events. Cognitive biases filter cues and information and can affect the estimation of their values per se as well as their relative contributions to subsequent assessments. Therefore, cognitive biases contributes to the overconfidence and over-optimism observed in success, failure, and competency traps by affecting the objectivity in estimation. By finding this linkage between cognitive biases and the imbalance of exploration and exploitation, this thesis finds support to the assumption that the mis-estimation induced by cognitive biases is a key in initiating singular innovation trajectories.

For the persistence of singular innovation trajectory, this research investigates three cognitive biases that are reasoned to amplify the innovation trajectories. *First*, experts are overconfidence in their abilities as a result of recognized local expertise. The recognized statuses offer them more credibility and they have a rallying effect on others within the business entity as well as externally. Therefore, the legitimized assessment from a recognized expert can amplify the persistence of an innovation trajectory. *Second*, Prospect Theory modifies current perspective on the imbalance of exploration and exploitation. Instead of the current rhetoric on risk tolerance for both successful and failing business entities, Prospect Theory proposes that all business entities are loss averse. Moreover, they will become loss insensitive and unconsciously submit themselves into activities that are considered high risk if caught in a failure trap. Therefore, being emotionally influence by perceived loss can also keep the trajectory from changing. *Third*, conformity bias can encourage individuals to incline toward a group consensus or maintain the existence of it. Although it is beneficial to have conformity in a business entity at times, when consensus is self-reinforcing, it prevents learning deviation (March, 1991) and affect the business entity's accuracy in estimation and flexibility to adjust to market development. Therefore, the proclivity to conform is a cognitive bias that can buttress the persistence of an innovation trajectory.

Lastly, in investigating the balance of exploration and exploitation on an individual level, this thesis examines the relationship between System 1 and System 2, which can be synergic or conflicted. According to dual process theory, System 1 is responsible for intuitive thinking by accessing a vast associative memory network through heuristics, mental shortcuts, while System 2 is responsible for slow and deliberate thinking that involve calculation and objective comparisons. Cognitive biases are the results of heuristics in the associative memory because they have a tendency to direct

cognition in biased ways. When System 2 endorses biased assessments from System 1 without scrutiny, they can initiate a singular innovation trajectory. Therefore, by enabling System 2's monitoring and lessoning the negative effect of cognitive biases, innovation decision can ideally be more objective in addressing both the short-term and long-term needs of the business entity in exploration and exploitation.

This thesis set out to investigate *How cognitive biases can help explain the imbalance of exploration and exploitation that leads to singular innovation trajectories?* In short, cognitive biases help initiate a singular innovation trajectory by over- or under-valuing some cues and information, which manifest into behaviors of overconfidence and over-optimism. Moreover, cognitive biases also help maintain the persistence of a singular innovation trajectory. Therefore, to balance exploration and exploitation on an individual level, cognitive biases need to be managed by debiasing and training a more disciplined System 2.

7.0 Implications, Learning, and Future Research

7.1 Theoretical Implications

Current innovation research on the balance of exploration and exploitation stipulates that the organizational imbalance is a result of opportunities cost in any deviation from current learning, competences, and resources as well as overconfidence of abilities and overestimation of success. This research posits that examination of the imbalance on an individual level can illuminate cognitive biases as a more relevant, albeit complex, source of proclivities.

In the examination, linkage between cognitive biases and innovation management is established based on the mutual accord on mis-estimation as the points of connection. Cognitive biases in the forms of availability heuristic and cognitive ease are attributed to the elevated evaluation of abilities. Thereafter, overconfidence of abilities induces biased innovation behaviors that lead to success, failure, or competency traps. Similarly, cognitive biases in the forms of availability heuristic, resemblance, affect heuristic, anchoring, base-rate neglect, and probability neglect contributes to the mis-estimation of risk that leads business entity into overestimating the odds of success.

In addition to establishing a linkage between cognitive biases and innovation management, this research also provides an alternative explanation to the initiation and persistence of singular innovation trajectories.

Furthermore, employing cognitive biases as an explanation avoids the hindsight biases from current understanding of singular innovation trajectory based on observations from case studies. Even though this research also provided illustration of cognitive biases in innovation that can contain hindsight bias, the effect of cognitive biases on decision making is irrefutable.

Lastly, this research offers an alternative view in balancing exploration and exploitation. This is based on two reasons: *first*, innovation needs business entities that are overconfidence, overestimating success, and have a degree of conformity; second, System 1 cannot be turned off but System 2 can exert control if needed. Therefore, it seems theoretically plausible that providing guidance to System 2 in recognizing signals of undesirable mis-estimation can assist in restoring the balance of exploration and exploitation when overconfidence and overestimation is less needed in the innovation process.

7.2 Learning and Managerial Implications

Even though cognitive biases cannot be turned off, one can manage them by encouraging System 2 to be more attentive (Kahneman, 2011). In other words, one can opt for the balance of System 1 and System 2 so they are working in synergy instead of conflict. Deviation from singular innovation trajectory is possible by enabling System 2 to manage the cognitive preferences developed by biases. Furthermore, some cognitive biases can be primed such as anchoring and cognitive ease, which are useful in affecting the preferential directions of cognitive biases. Planting a divergent idea while creating familiarity around it can motivate System 1 to feel at ease with the deviation as well as making System 2's self-control task less effortful. In addition, training System 2 to understand and employ base-rate as well as questioning the parameters in assessments have significant impact on maintaining the balance. To quote Daniel Kahneman (2011), 'One cannot decide to see the lines as equals but one can learn to mistrust her own impressions and assessment (Kahneman, 2011, 27)'.

7.3 Future Research

As this research is an exploratory inductive reason, it can be less structured in its investigation. However, the linkage between cognitive biases and innovation management through mis-estimation is a recurring observation; therefore, future research can further solidify the linkage by testing empirically the effect of the identified cognitive biases on confidence and risk perception. In doing so, research can assess objectively the relative effects of the cognitive biases on the preference of exploration or exploitation during scenarios of success, failure, or competency trap. In addition, future research can test for the effect of training System 2 in relations to mis-estimation of innovation decisions.

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Appendix

Endnotes

[i] Cognitive biases are biases that are inherent in our information processing system. They are essentially cognitive

[ii] Raw ideas according to Stevens and Burley (1997) are unwritten ideas in the first step of new product development.

[iii] Even though the Dvorak Simplified Keyboard is often an example of network effect, the increasing adoption due to preceding adoption; however, it is also an illustration of failure trap, in which an inventor is trapped by his exploration effect because he believes that a technically superior product is the key to winning market share. On the other hand, as innovation studies have shown, it depends on the timing and the company's strategy in exploiting the innovation. An invention without a commercialization strategy, or plans of exploitation, will never become an innovation.

[iv] 24/7 Wall street is a subsidiary of the Wall Street Journal. < http://247wallst.com>

[v] ANACO, Atari, Atriton, Bell, Budweiser, Bulova, Citizen, Coca-Cola, Cuisine Art, Dentyne, Hilton, Jovan, JVC, Koss, l.a. Eyeworks, Lark, Marlboro, Million Dollar Discount, Mon Hart, Pan Am, Polaroid, RCA, Remy, Schiltz, Shakey's, Toshiba, Star Jewelers, TDK, The Million Dollar Movie, TWA, Wakamoto. < http://www.imdb.com/title/tt0083658/faq#.2.1.28>

[vi] Edwin Land held over 500 patents

[vii] Capabilities is used interchangeably with competences, although capabilities refer more to the abilities to use competences.

[viii] A tendency to stay on a trajectory

[ix] Reliability means a low variance in performance (Hannan and Freeman, 1984, p. 153)

[x] Accountability means that a decision maker must account rationally for his actions (Hannan and Freeman, 1984, p. 153)

[xi] Reproducibility means that structures of roles, authority, and communication must be reproducible from day to day (Hannan and Freeman, 1984, p. 154)

[xii] In coevolutionary lock-in, Burgelman (2002) studies a balancing mechanism called punctured equilibrium, which suggests that the exit to the trajectory can be found by keeping managers mindful of autonomous innovation within the organization. It will be discussed in the later section. It is not mentioned here because this part refers to the inertia and not the balancing mechanism.

[xiii] Exploration is 'search, variation, risk taking, experimentation, play, flexibility, discovery, innovation (March, 1991)' and exploitation is 'refinement, choice, production, efficiency, selection, implementation, execution (March, 1991)'

[xiv] Unfortunately, the 20% time program has been shut down in August, 2013 after running for 6 years. < http://www.wired.com/insights/2013/08/innovate-or-die-why-googles-8020-rule-is-a-red-herring/>

[xv] crowd sourcing is a new search concept meaning getting ideas from the crowd

[xvi] It is noted that innovation research do include behavioral theories, which is the manifestation of cognitive biases, however, the direct link between cognitive biases and innovation studies remain rare.

[xvii] 1) Awareness of novelty is hard, 2)Knowing how novelty affect you is hard, 3) Selecting among many new ideas is hard, 4) Open innovation and learning from outsiders is hard, 5) Being rational about innovation is hard, 6) Incentivizing novelty creation and innovation is hard, 7)Thinking about innovation portfolio is hard, 8) Investing in innovation is hard; getting cooperation for a new idea is hard, 9) Creating space for innovation is hard, 10) Coping with innovation failure is hard.

Table 1. Common heuristics and biases affecting economic choice

Bias	Definition
Risk aversion	Choice over uncertain outcomes is biased toward certainty
Loss aversion	Equivalent losses and gains are experienced unequally
Myopia/hyperbolic discounting	Overweight the near future and underweight the distant future
Status quo bias	Overly strong preferences for current states
Sunk cost effects	Treating sunk costs as significant
Endowment effects	Overvaluing assets you have, undervaluing assets you do not have
Availability biases	Treating recent or high-profile information as excessively salient
Framing biases	Organizing information on inappropriate templates
Optimism bias	Systematic overestimation of one's own abilities
Confirmation bias	Tendency to ignore evidence not supporting existing hypotheses

[xviii]

[xix] The two systems were first proposed by Keith Stanovich and Richard West, two psychologists (Kahneman, 2011); subsequently, the concept is studied more extensively by Daniel Kahneman, psychologist and Nobel price winner in economics in 2002.

[xx] Instead of disbelieve, which can be an assessment outcome. Un-believe signifies that first System 1 believes, then System 2 has to undo the belief.

[xxi] 124 entrepreneurs and 95 managers

[xxii] Rule of thumbs: in replacing one bias with another that is more accurate. For example, the rule 72, that investment doubles every (72/ x) years, where x is the interest percentage.

[xxiii] http://en.wikipedia.org/wiki/List_of_cognitive_biases

[xxiv] ANACO, Atari, Atriton, Bell, Budweiser, Bulova, Citizen, Coca-Cola, Cuisine Art, Dentyne, Hilton, Jovan, JVC, Koss, l.a. Eyeworks, Lark, Marlboro, Million Dollar Discount, Mon Hart, Pan Am, Polaroid, RCA, Remy, Schiltz, Shakey's, Toshiba, Star Jewelers, TDK, The Million Dollar Movie, TWA, Wakamoto. < http://www.imdb.com/title/tt0083658/faq#.2.1.28>

[xxv] In the first three parts, they presented to 133 experienced judges or prosecutors a fictional criminal case with detailed information simulating a real trial. The participants are informed to make ruling impartially then divided into three groups. The first group was given a sentencing recommendation through a journalist then advised that the demand comes from an irrelevant source. The second group was given a sentencing recommendation from the defense and prosecutor then advised that the demand was randomly determined. The third group was given no sentencing recommendation and told to roll a dice to determine the upper and lower limit proposed by the defense and prosecutor.

[xxvi] Base Rate Neglect

An individual has been described by a neighbor as follows: "Steve is very shy and withdrawn, invariably helpful but with little interest in people or in the world of reality. A meek and tidy soul, he has a need for order and structure, and a passion for detail." Is Steve more likely to be a librarian or a farmer?

[xxvii] Part 1

Tom W is a graduate student at the main university in your state. Please rank the following nine fields of graduate specialization in order of the likelihood that Tom W is now a student in each of these fields. Use 1 for the most likely, 9 for the least likely.

business administration computer science engineering
humanities and education law
medicine
library science
physical and life sciences social science and social work

Part 2

The following is a personality sketch of Tom W written during Tom's senior year in high school by a psychologist, on the basis of psychological tests of uncertain validity:

Tom W is of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally

enlivened by somewhat corny puns and flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to have little feel and little sympathy for other people, and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.
Now please take a sheet of paper and rank the nine fields of specialization listed below by how similar the description of Tom W is to the typical graduate student in each of the following fields. Use 1 for the most likely and 9 for the least likely.

[xxviii] Herd behavior is a psychological concept relating to conformity. It stipulates that once a behavior/idea gains momentum, others tends to follow like a herd.

[xxix] Repeated failure because the development took 20 years

[xxx] Asch's elevator experiment is recorded and accessible on YouTube.
http://www.youtube.com/watch?v=2BqL9Dm7PCM