TAPMI

No. 89/2011-12

Working Paper Series

Bounded Awareness and Tacit Knowledge in Managerial Decision-making: Revisiting Challenger 1986

Bounded Awareness and Tacit Knowledge in Managerial Decision-making: Revisiting Challenger 1986

J. Ajith Kumar,
Associate Professor,
T. A. PAI Management Institute (TAPMI),
Manipal 576104
Karnataka, INDIA
Email: akm@tapmi.edu.in

TAPMI WORKING PAPER SERIES No. 2011-12 / 01

T. A. PAI Management Institute
Manipal – 576104, INDIA

Bounded Awareness and Tacit Knowledge in Managerial Decision-making: Revisiting Challenger 1986

J. Ajith Kumar,
Associate Professor, TAPMI, Manipal

ABSTRACT

In this paper, I bring to fore the relationships between the boundedness of managers' awareness during decision-making and their tacit knowledge. Owing to bounded awareness, managers sometimes fail to 'see' critical information while making decisions, and this can result in costly errors. I invoke details of the Challenger disaster of 1986 to complement my conceptual discussions and essentially offer three distinct propositions: (a) managers' dependence upon their existing tacit knowledge interacts with the bounds on their awareness in a cycle of positive reinforcement, (b) different decision makers in the organization can experience differing bounds on their awareness towards the same piece of information and (c) the tension between experiences of success and failure influences the development of bounded awareness in individuals. I feel that these propositions can open useful new avenues for future research on the antecedents of, and remedies for, bounds on managerial awareness during decision-making.

Keywords: bounded awareness, tacit knowledge, self-referential, managerial decision making, path dependence.

Bounded Awareness and Tacit Knowledge in Managerial Decision-making: Revisiting Challenger 1986

Nothing succeeds like success
\- Sir Arthur Helps in *Realmah* (1868)

Success Breeds Failure
\- Paul Krugman in *The New York Times, May 5, 2008*

Failure is often better for success in the long run
\- Richard Alleyne in *The Telegraph, Aug 24, 2010*

INTRODUCTION

The term "bounded awareness" was coined by Max Bazerman and Dolly Chugh (Bazerman and Chugh, 2006a; Bazerman and Chugh, 2006b) building upon Simon's (1957) notion of bounded rationality from the field of behavioural economics. According to them, decision makers are said to experience bounded awareness when they overlook relevant and readily available information, even while using other available information, and take a decision that is either suboptimal or entirely erroneous.

Bazerman and Chugh (2006a) use several business examples to illustrate the idea. For example, executives at the pharmaceutical company Merck overlooked publicly available information for nearly four years that its pain killer drug Vioxx was possibly causing heart attacks and strokes. By the time they eventually withdrew the drug from the market, it was estimated to have caused extensive harm to its customers and damaged the company's reputation. In another article, Bazerman and Chugh (2006b) note that bounded awareness essentially manifests as 'focusing failures' that result from the *misalignment* between information ideally needed for a good decision and the information actually included in the decision-making process. Useful information – though readily available – remains out of focus of the decision maker. They discuss four literature streams from cognitive and social psychology that provide evidence of conditions leading to focusing failures: (a) inattentional blindness, (b) focalism and focussing illusion, (c) affective primacy and (d) self-relevant information (for a more detailed discussion see Bazerman and Chugh, 2006b; Chugh and Bazerman, 2007). These researchers also suggest ways in which managerial awareness can be enhanced for better decision making (e.g. Bazerman and Chugh, 2006a).

Despite strong roots in several decades of research in psychology and behavioural economics, bounded awareness is a relatively fresh concept in managerial decision-making and there is little research to be found that examines its antecedents. In this paper, I primarily explore how individual tacit knowledge can play a role in creating bounds on managers' awareness during decision making; something that has not been discussed earlier. Both awareness and tacit knowledge are fundamentally individualist cognitive phenomena in that they originate in the mind of the individual. Hence, we can intuitively expect relationships between them. Further, while an awareness that is bounded is seen as something that can influence an individual's decision-making negatively, tacit knowledge has been discussed as an asset that improves decision-making quality (e.g. Brockmann and Anthony, 1998) and creativity (e.g. Leonard and Sensiper, 1998). Hence it is interesting to highlight a relationship between them in the context of decision-making. The relationship assumes further significance when seen in light of the understanding that individual tacit knowledge is an important strategic asset that bestows competitive advantage to organizations (Grant, 1996; Nonaka and Takeuchi, 1995).

This paper's contribution is a set of three distinct propositions built around the relationship between tacit knowledge and bounded awareness. I first argue that managers' dependence upon their existing tacit knowledge and the bounds on their awareness influence each other in a cycle of positive reinforcement. Building on this realization, I then highlight the path dependent nature of the evolution of tacit knowledge to argue that different decision makers in the organization can experience differing bounds on their awareness towards the same piece of information. Finally, I supplement all this by arguing that the past history of success and/or failure experienced by the organization and its individuals also plays an important role in the relationship between the two constructs. To provide a real-life context to what is otherwise a purely conceptual discussion, I invoke the NASA Challenger disaster of 1986 and argue that NASA managers were experiencing bounded awareness while taking the ill-fated launch decision. In the next section, I begin with a description of relevant details of this disaster.

NASA’S SPACE SHUTTLE PROGRAMME AND THE CHALLENGER DISASTER

NASA’s ambitious space shuttle programme that began in the 1970s included a series of missions to outer space and back. The Space Transportation System (STS, accompanied by a mission number) was central to each mission (see Appendix A for a description of the STS and a typical mission).

STS 51-L

STS 51-L, carrying the Challenger space shuttle was manned by seven people and had several items on its agenda. Among them was the Spartan-Halley satellite to monitor Halley’s Comet and the conducting of experiments in fluid dynamics and phase partitioning. Apart from the five career astronauts who would conduct some of these experiments, there were two payload specialists, Christa McAuliffe and Gregory Jarvis. McAuliffe, a high school teacher was part of the government’s teacher-in-space project and was to conduct a series of classroom lessons and experiments from orbit. Jarvis, a representative of the Hughes Aircraft Company, was to perform a series of fluid dynamics experiments that would support satellite redesign. Lift-off happened at 11:38 hours local time and progressed as expected for a little over the first minute of its journey. But about 73 seconds into lift-off, the STS exploded and disintegrated over the Atlantic Ocean, killing all its passengers.

The Rogers Commission

Shortly thereafter, a presidential commission was set up to probe into the accident, identify the agencies responsible, and recommend ways to prevent such accidents in future. Chaired by William P. Rogers, former US Secretary of State, it was also known as the Rogers Commission and included several prominent personalities, one among who was the Nobel laureate physicist, Richard Feynman.

The Rogers Commission found that the disaster was caused by a malfunction of the O-rings used to seal a joint in the right Solid Rocket Booster (SRB), one of STS’ primary sources of thrust. This malfunction caused pressurized hot gases and eventually flames, to "blow by" the O-ring and make contact with the adjacent external tank containing liquid hydrogen and oxygen fuels, causing structural failure. It was also found that the O-ring malfunction was closely associated with the extremely low temperatures at launch that had never been experienced earlier by a NASA mission. The Rogers Commission also identified communication failure between engineers and managers across the multiple organizations, as a contributing cause of the accident. The Rogers Commission Report (which I refer to as "RCR, 1986") recommended not only a re-design of the joint seals, but also an overhauling of organizational communication and structures within NASA.

Though scholars and practitioners have analyzed the disaster from multiple perspectives (e.g. Armenakis, 2002; Boisjoly, Curtis and Mellican, 1989; Heimann, 1993) my focus in this paper is on the bounded awareness of the managers involved, as also highlighted by Bazerman and Chugh (2006a), and on relating it to their tacit knowledge. To gather relevant details, I reviewed literature that describes and/or analyzes the Challenger disaster, an important element of which was the RCR (1986). My data set consisted of facts, observations and insights presented in these pieces of literature. It was evident that technical and managerial knowledge flowed across multiple organizations that worked together in the space shuttle programme (RCR, 1986, Chapter 2). Directly relevant to the discussions in this paper are two of NASA's centres – the Kennedy Space Center (KSC), Florida and the Marshall Space Flight Center (MSFC), Alabama – and one contractor organization – Morton Thiokol Corporation (Thiokol) – located in Utah.

FACTS IDENTIFIED

My review of literature helped identify three distinct facts as directly relevant to the investigation.

Fact 1: NASA tasted plenty of success before the Challenger disaster.

Since it first became operational in 1958, NASA had a remarkable history of success that included the Apollo missions to the moon, and the Skylab space station project. Though this success trail was dotted with glitches over the years (such as the Apollo 13 in-flight emergency in 1970), the glitches were not large enough to be destructive to human life, nor to detract NASA's adventurous mindset.

From the mid-1970s, the Space Shuttle project became NASA's primary focus and progressed quickly. In the span of just fifty seven months between April 1981 and January 1986, twenty four shuttle missions involving four different shuttles – Columbia, Challenger, Discovery and Atlantis – were successfully completed one after the other (RCR, 1986, Chapter 1), at an incredible average of about 1 mission every 10 weeks. The missions accomplished various activities that ranged from launching satellites, to repairing them in orbit and to recovering and returning them to earth, as well as to carrying experiments in space, including with human agents. A remarkable feature of the STS was the recoverability and reusability of two of its three major systems – the SRB and the Shuttle – thereby fostering tremendous savings. Only the external tank would be consumed during launch and was non-recoverable.

This success story drove and was driven by NASA's legendary "can-do" attitude (RCR, 1986, Chapter 8). The organization even readily accepted challenges that might drain resources from other aspects of the space programme, and sometimes disrupt routine operations.

Fact 2: Managers and engineers were aware of problems with SRB joints and O-rings since 1977, but never considered them a threat.

The RCR (1986, Chapter 4) gives an overview of various SRB joint-related problems that managers and engineers at the three NASA organizations and Thiokol were aware of, but did not consider a threat. As early as 1977, engineers at Thiokol discovered a problem known as "joint rotation," during tests. Thiokol engineers did not believe that joint rotation would cause significant problems, but when they reported it to MSFC, engineers there thought just the opposite. MSFC engineers recommended a redesign of the joint, with specific suggestions. However, Thiokol did not consider a redesign necessary, at least at that time.

In November 1981, after the flight of STS-2, inspections by Thiokol engineers revealed erosion in the O-rings, owing to the impingement of hot gases upon, and their flow through them. The O-rings were never designed for such erosion, and in initial years, it was not frequently observed. However, when the STS 41-B flew in February 1984, the engineers found stronger evidence of erosion along with an accompanying problem known as blow-by, wherein greasy soot accumulates on the O-rings. This problem was immediately reported to MSFC engineers, who despite acknowledging that the problem could recur on future flights felt that it was not a constraint or threat (RCR, 1986, Chapter 4: 11). The erosion problem was also brought to the notice of the management at MSFC through internal communication procedures, but never became a concern.

A third major problem related to the O-rings was discovered by Thiokol engineers in 1985: the effect of low temperatures on O-ring resilience. Resilience here refers to the ability of an O-ring to regain its original shape after the squeeze on it is released. It was found that at 100^{o}F (about 37^{o}C), the O-ring functioned properly but as the temperature was lowered, it continuously lost resilience and ability to function. Concerned that this combined with the erosion problem, might lead to grave consequences, Roger Boisjoly, a Thiokol engineer directly involved with the tests, wrote to his Vice President of Engineering, Robert Lund, in July, 1985, "It is my honest and very real fear that if we do not take immediate action to dedicate a team to solve the problem, with the field joint having the number one priority, then <u>we stand in jeopardy of losing a flight</u> with all the launch pad facilities" (RCR, 1986, Chapter 6: 23, *emphasis added*).

With the exceptions of such individual observations, managers and engineers at both Thiokol and NASA in general continued to believe that though the O-ring problem was important and needed to be addressed, it was safe to fly without a redesign. The RCR (1986, Chapter 6: 1) summarizes this attitude of negligence towards the joint related problems as follows: " …both NASA and contractor management first failed to recognize it as a problem, then failed to fix it and finally treated it as an acceptable flight risk… Thiokol did not accept the implication of tests early in the program that the design had a serious and unanticipated flaw. …as the joint problems grew in number and severity, NASA minimized them in management briefings and reports. Thiokol's stated position was that 'the condition is not desirable but is acceptable.' …as tests and then flights confirmed damage to the sealing rings, the reaction by both NASA and Thiokol was to increase the amount of damage considered acceptable. At no time did management either recommend a redesign of the joint or call for the shuttle's grounding until the problem was solved."

<u>Fact 3</u>: NASA and Thiokol managers proceeded with the launch on January 28th 1986 despite strong appeals from Thiokol engineers not to.

Engineers at Thiokol, which included Roger Boisjoly, Arnold Thomas and Robert Ebeling appealed to managers at Thiokol and NASA's MSFC on the evening of January 27th to not launch on the 28th – and to delay the launch – owing to the low ambient temperature (RCR, 1986, Chapter 5). Boisjoly (1987) notes that the engineers were highly concerned about potential O-ring malfunction since the ambient temperatures on the 27th were much lower than what earlier launches had experienced.

The RCR (1986) describes that when engineers expressed their concerns in a meeting with the MSFC, MSFC manager Larry Mulloy first asked for the opinion of Kilminster, Thiokol's Vice President of Space Booster Programs. Kilminster sided with his engineers' advice to not launch. Mulloy then asked for his colleague George Hardy's opinion, who said that though he was appalled at the recommendation to delay launch he would still go by engineers' recommendations. Mulloy, who was not happy with this, then stated that the engineers' data was inconclusive, and did not support their recommendations. The Thiokol managers then had a 'private' five minute meeting (in the presence of the engineers) during which they decided to take a "management decision". They ignored their engineers' repeated appeals and reverted to MSFC certifying that it was safe to launch on the 28th, despite low temperature.

It is important to note here that MSFC managers, instead of proving that it was safe to fly despite the temperature, shifted the burden of proof to the Thiokol engineers, asking *them* to prove that the low temperature made it unsafe to fly (Boisjoly, 1987).

Managers' awareness was bounded

Our stance on this disaster presumes that managers at Thiokol as well as NASA were as keen to avoid disaster as the Thiokol engineers, who opposed the launch, and other like-minded well-wishers. Indeed, I found no evidence to believe that any of these decision-makers would benefit in any way from a disaster; on the other hand I assume that these managers were conscious of their accountability to the people and the government should something go wrong. Hence I assume that managers approved the launch *only because they genuinely did not think* that the explicit information, given to them by the engineers on the previous night about high failure likelihood, was relevant. In other words, even though the managers had the very information in their hands that could have prevented failure, they failed to "see" its relevance to their launch decision. Clearly, this suggests that the decision-making managers were experiencing bounded awareness during the launch decision, consistent with the observations of Bazerman and Chugh (2006a). I now raise three questions:

1. The NASA managers were highly experienced as well as knowledgeable, and had relevant technical backgrounds (RCR, 1986). The managers were also aware of problems with SRB joints and O-rings for several years (Fact 2). Yet the managers experienced bounded awareness while making a major decision. Why did that happen? Why couldn't years of rich managerial experience prevent such a thing?

2. The managers and engineers had worked closely with each other over the years. Yet, as Feynman observes, while engineers saw a fairly high 1 in 100 chance of failure, managers saw a much lower 1 in 100,000 chance (RCR, 1986, Appendix F). In other words, managers experienced bounded awareness towards the same piece of information that the engineers did not. Why?

3. The Challenger disaster was a major failure that occurred after long years of unrelenting success at NASA and exposed the bounded awareness of its managers. Can success/failure have any influence on managerial bounded awareness in decision-making?

We draw upon theory on individual tacit knowledge to discuss answers to these questions.

DISCUSSION

Tacit Knowledge, Experience and Judgment

The first question is about why decision makers experience bounded awareness while making major decisions, despite years of rich managerial experience. I explore how extant theory on individual tacit knowledge can help us address this. According to this theory, individual knowledge resides primarily in a tacit form in the human mind. Nonaka and Takeuchi (1995) note that tacit knowledge consists of subjective personalized beliefs, mental models, schemata, perceptions, feelings and intuition (the cognitive dimension of tacit knowledge) and hard-to-pin-down skills and crafts captured in the term 'know-how' (the technical dimension of tacit knowledge). These are so ingrained in the mind that its owner takes them for granted. Owing to such 'ingrainedness' tacit knowledge is difficult / impossible to articulate and we recognize it primarily through individuals' task performance (Nonaka and von Krogh, 2009).

Tacit knowledge is believed to be acquired chiefly through experience and to distinguish experts from novices (Haldin-Herrgard, 2000; Nonaka, 1994; Senker, 1995); indeed 'tacit knowledge' and ‘experience’ are often used together (Kumar and Ganesh, 2011). The ability and propensity to *use* tacit knowledge also increases with experience and experts, by virtue of their well-honed knowledge structures, achieve dramatic improvements in the speed and accuracy of task performance (Brockmann and Anthony, 1998), as well as problem solving (Leonard and Sensiper, 1998). In general, tacit knowledge has been linked to better sense making, perception and intuition-driven judgment that can foster fine decision making abilities and save time and money.

How is tacit knowledge stored in the mind? Nonaka (1994) holds that the cognitive elements of tacit knowledge are centred on the individual’s mental models, or “working models” consisting of managers’ schemata, paradigms, beliefs and viewpoints that help them perceive and define their world. Described thus, tacit knowledge can be understood to be stored analogously as a set of “mental frames of reference”. Earlier research on mental frames (e.g. Gitlin, 1980; Lamprinakis and Fulton, 2011) has described them as the principles of selection, emphasis, and presentation composed of little tacit theories about what exists, what happens and what matters. Managers use mental frames to represent, understand and interpret the world they are observing and to help them enact the decision-making process.

In sum, tacit knowledge (stored as a set of mental frames of reference) is a very useful resource to decision makers, and it is beneficial for managers to depend upon it while making decisions. Paradoxically however, this very act of dependence on tacit knowledge can create bounds on their awareness. This is because of the self-referential nature of tacit knowledge.

The self-referential nature of individual tacit knowledge

By ‘self-referential’ I mean that individuals acquire new tacit knowledge only by using at least some of their existing tacit knowledge, that is, new tacit knowledge depends upon existing tacit knowledge for its development. Thus, there is a continuous relationship between the existing and the future tacit knowledge sets of an individual.

Though I found little research that has directly discussed the self-referential nature of tacit knowledge, several scholars have alluded to it. For example, von Krogh, Roos and Slocum (1994: 58) note, “self-referentiality means that new knowledge refers not only to past knowledge but *also* to potential future knowledge... managers use already established knowledge to determine what they see, and they use what they already know to choose what to look for in their environment" (*emphasis in original*). Citing Bateson (1972) and Weick (1979), Lewis (2000) acknowledges that actors often use their extant mental frames to construct new frames. Cognition is understood to be a self-referential process as actors <u>filter their experiences through their extant frames</u>, choosing explanations that confirm their existence. Consistent with this, Henderson and Clark (1990), in their work on architectural innovation, noted how engineers over time acquire a store of knowledge to specific kinds of problems that have arisen in previous projects. When confronted with a new problem, an engineer, instead of re-examining all possible alternatives, first focuses on those that s/he has found to be helpful in solving previous problems, suggesting a clear link between new and existing mental frames or tacit knowledge sets.

All this means that decision makers not only use some of their existing tacit knowledge to acquire new tacit knowledge, but also filter new data, information and knowledge through its lens. Further, as Russo and Schoemaker (1989) note, frames are powerful since they exert a strong influence over the decision maker's perception of a situation and <u>can generate blindness</u> resulting in narrowing the decision maker's focus and placing an artificial boundary while excluding other elements. When a new knowledge element is presented, one's existing tacit knowledge act as a 'mental filter' in judging the meaningfulness and relevance of that element, and <u>can make something that is actually very relevant appear irrelevant to the decision making situation</u>. Thus, the decision makers' dependence on their existing tacit knowledge sets can create bounds on their cognitive abilities, and in turn on their awareness.

It is pertinent to note that the relationship between bounded awareness and tacit knowledge can also work the other way. As managers' awareness becomes increasingly bounded it makes them depend more on their existing tacit knowledge sets, interpreting the world through them, and in turn, reinforcing them. Thus managerial bounded awareness and dependence on existing tacit knowledge interact with each other in a cycle of positive reinforcement (see Figure 1). Formally expressed,

> **Proposition 1**: Owing to the self-referential nature of tacit knowledge, managerial dependence on existing tacit knowledge interacts with their bounded awareness in a cycle of positive reinforcement.

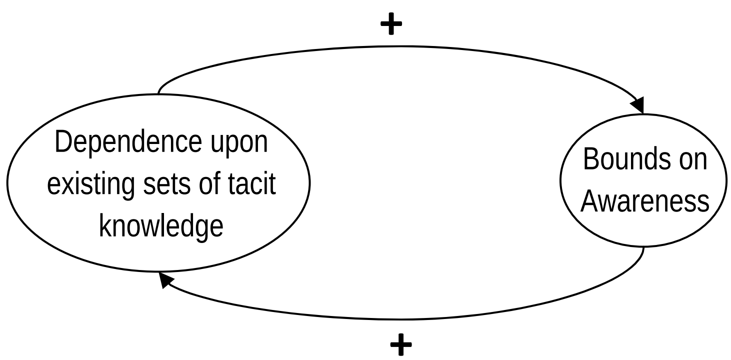

Figure 1: Interaction between bounded awareness and individual dependence on existing tacit knowledge as a cycle of positive reinforcement

NASA managers being experts in their domains possessed rich and relevant tacit knowledge to enable them to make a typical launch decision. Now we can think of this very tacit knowledge as having acted as a filter when the information about O-ring failure likelihood under low temperature was made available. Even as the engineers appealed for a 'no launch', the managers' tacit knowledge made this new information appear irrelevant to them. In general, this means that <u>bounds on managerial awareness arise not *despite* experience and tacit knowledge, but *because* of them, and in turn reinforce dependence on existing tacit knowledge</u>.

The second question concerns the differences between manager and engineer perceptions. I argue that the self-referential nature of tacit knowledge makes its evolution over time path-dependent. By "path-dependent" I mean that individuals' successful acquisition of new tacit knowledge depends not only on their existing tacit knowledge sets but also on the history of their learning, or the "knowledge-path" they have taken over time. Descriptions in the RCR (1986) suggest that (Chapters 4, 5 and 6 and Appendix F) the engineers' knowledge sets developed through a path different from that of the managers. The former evolved through the engineers' engagements with the engineering and technical aspects of SRB design. The engineers got to observe first hand problems such as O-ring erosion, blow-by, and the effects of low temperature on the O-rings' ability to seal joints, and became more and more aware of their implications. They did detailed tests and experiments on O-ring resilience in low temperatures, had several realizations, and intuited that the O-rings might malfunction if the launch happened at low temperature. Despite the lack of supporting data that could have fortified their case, the engineers' had strong convictions against the launch on January 28th. The managers, however, were not as exposed to this type of knowledge. Rather their engagements revolved around getting sanctions and permissions, coordinating activities, meeting deadlines and making things happen; thus their tacit knowledge evolved on a very different path.

Owing to this path-dependent evolution of tacit knowledge, different individuals in an organization will have different tacit knowledge sets over time even if they started out with similar ones at the beginning. This is consistent with the notion of a firm as a distributed knowledge system (Tsoukas, 1996). The differences between individuals will be more marked when the individuals play distinctly different roles in the organization over time as with NASA's managers and engineers. Owing to the differences in their tacit knowledge sets the same piece of information can appear very meaningful to some people in the organization, but completely irrelevant to others even when they are working together on the same project. This further implies that the bounds on the awareness of different decision makers working together can be different towards the same piece of information. In summary,

> **Proposition 2**: Even within the same organization, diversity of tacit knowledge sets can mean that different people will experience differing bounds on their awareness towards the same piece of information.

Success, failure and bounded awareness

The third question pertains to the relationship between success/failure and the bounded awareness of managers. In the Challenger case, various problems, failures and glitches continued to occur and were informed to both managers and engineers (Fact 2). While Fact 2 is only about problems related to the SRB joints and O-rings, there is evidence that minor problems also occurred in several other aspects of the STS design that too were considered non-threatening and not requiring design changes. For example, Feynman (RCR, 1986, Appendix F) describes problems with regard to engine turbine blades that had occurred earlier.

However – Feynman (RCR, 1986, Appendix F) observes – obvious weaknesses were accepted again and again without a serious attempt to remedy them, and the success of the flights (Fact 1) was taken as an evidence of safety. Using a lethal game metaphor, he comments, "when playing

Russian Roulette the fact that the first shot got off safely is little comfort for the next." He also notes that in spite of peculiar variations in the O-ring erosions, NASA officials fooled themselves into thinking that they had adequate knowledge to proceed with the launch. Instead of being a cause for concern, the O-rings were mistakenly rated in terms of a safety factor depending upon the extent of the erosion. For example, in STS 51-C, the erosion depth was only about one-third the radius of the O-ring; hence a safety factor of three was assigned to the O-ring. Feynman goes on to argue that since the O-rings were not designed to erode, any erosion in them should have been taken to indicate no safety factor at all. The RCR (1986) in general notes that there was a slow shift toward decreasing safety factor over time and that this was driven by the continuing success of NASA's missions.

Feynman infers that past successes of the STS missions (and the success of NASA in general) had created a sense of quiet confidence in the managers. This belief grew deeper with each subsequent instance of success. Consistent with Feynman, Starbuck and Milliken (1988: 322) note, "a number of statements by Thiokol and NASA personnel suggest they believed the Challenger's probability of success was already so high that they had no need to raise it further." They propose that repeated success combined with gradual acclimatization alters decision makers' probabilities about future success and can make them sense reduced failure likelihood. Thus, despite deficiencies, the steady stream of successful missions over the years (Fact 1), as a whole, seemed to have created a belief, or a perception that 'all is well with us'. I suggest that <u>such feelings and perceptions were a part of managers' tacit knowledge sets</u> at the time of the STS 51-L launch. Building on the above discussion I suggest that the experience of success is likely to do two things to the mind of a decision-maker:

(a) create bounds on a manager's awareness of his/her ignorance, or the absence of important knowledge, when it is really needed, and

(b) make important knowledge appear trivial and/or irrelevant and in turn reduce the perceived likelihood of failure risk.

Failure and crisis – on the other hand – incites effective soul-searching into why a decision went wrong (Gino and Pisano, 2011) and urges people more conscious of their limitations and to be more open to the relevance of new information/knowledge. This also resonates well with Theory 3 of Starbuck and Milliken (1988, p. 323), which states that "success makes a subsequent success appear more probable, and failure makes a subsequent success seem less likely." Thus, the experiences of failure can reduce the bounds on awareness.

In short,

> **Proposition 3**: The experience of success is likely to enhance, while the experience of failure is likely to reduce, the presence of bounds on a decision maker's awareness. In other words, the bounds on individual awareness are shaped by the ongoing tension between successful and failed experiences.

Bounded awareness and tacit knowledge within stagnating and learning cycles

To capture the essence of this discussion I suggest that the bounds on a managers' awareness can be represented by a set of simultaneous stagnating and learning cycles (Figure 2), denoting the tension between the experiences of success and failure on his/her path. This is an extension of the simple model of interaction between bounded awareness and tacit knowledge proposed earlier (Figure 1). I elaborate on this using the Challenger example itself.

Assume that TKS represents the tacit knowledge set of a manager who has been involved with making decisions on the STS project. In other words,

> <u>TKS</u>: Scientific, engineering, technical, procedural and managerial knowledge possessed and used by a NASA manager with respect to the STS project.

Each STS mission can then be thought of as a trial, or test, of the utility of TKS (which is continuously but gradually evolving) to meet its purpose. As history had it, the manager's dependence upon TKS contributed to success in the trails before the Challenger disaster. This is shown by Arrow 1 in Figure 2. Each time a mission is successfully completed, a belief about the validity of TKS is reinforced in the mind of the manager. This belief in essence is that since dependence on TKS led to success in previous missions, it is reliable and will foster success in the next mission as well. This belief itself becomes a distinct element in the manager's tacit knowledge set. It is a "meta-logic", or a "meta-knowledge set", since it represents knowledge about knowledge. Let this be MKS 1. In general, MKS 1 is a conditional and inductive logic as follows:

> <u>MKS 1</u>: Dependence upon TKS led to success in previous trials, and hence it will lead to success in the next trial as well.

MKS 1 is reinforced with every instance of success (Arrow 2), and creates in the manager a sense of increased utility of TKS to his/her purpose. However, as MKS 1 is reinforced, it develops in him/her the tendency to persist with the same knowledge and activity sets, while sometimes making relevant information such as "the O-rings will fail at low temperature" seem trivial or lacking in credibility. In other words, MKS 1 increases the bounds on the manager's awareness (Arrow 3). In turn, this leads the manager to depend more upon his/her existing TKS (Arrow 4). Arrows 1-2-3-4 together constitute a positively reinforcing cycle that represents the reinforcement of a manager's dependence upon his/her existing TKS. In general, this cycle tends to reduce the manager's willingness to accept information inconsistent with what is believed and as a result, is stagnating in nature.

Now, although dependence on TKS concurs with the success of missions as a whole, it does not pre-empt the occurrence of some failures, small or large. Typically, such failures are seen in malfunctions of sub-system, or their parts (such as O-ring erosion, or a computer failure on board), that might cause concerted localized disturbances, but may not disrupt or destroy the mission as a whole. In other words, dependence upon TKS also concurs with failures at the same time that it does with successes (Arrow 5). A failure generates another meta-knowledge set (MKS 2) which runs counter to MKS 1 and is reinforced with each occurrence of failure (Arrow 6).

> <u>MKS 2</u>: Dependence upon TKS did not prevent failures in previous trials, and hence failures can occur in the next trial.

As it runs counter to MKS 1, MKS 2 challenges the bounds on awareness (Arrow 7) and urges the manager to be more open to new information. Together, Arrows 5-6-7-4 constitute a balancing cycle that represents failure breaking bounds on awareness and driving learning. Thus, 5-6-7-4 is a learning cycle.

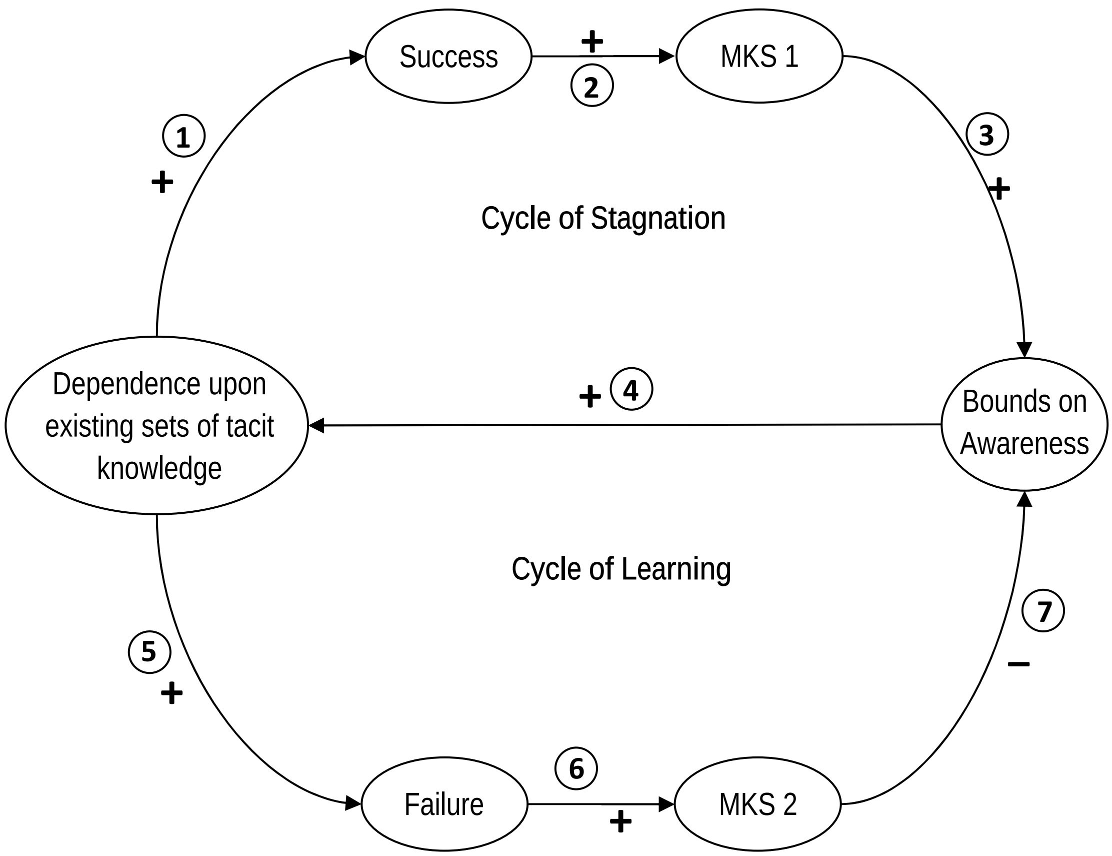

Figure 2: Cycles of stagnation and learning driven by success and failure in the interactions between bounded awareness and individual tacit knowledge.

We note that at any given point in time, both cycles are in motion since a manager can experience both success and failure while using his existing tacit knowledge sets. Often, a learning cycle is set in motion when environmental factors change, placing demands that were not experienced earlier and causing more failures to occur, while using existing knowledge sets. This in turn drives the manager to seek fresh knowledge, learn and change. If success happens at a rapid rate, the stagnating cycle becomes strong and the learning cycle weakens. Decision makers may miss or minimize warnings of potential failure, even when such warnings are explicitly discernible.

In the Challenger case, the STS 51-L was the twenty fifth trial, following twenty four successful trials (Fact 1). The space shuttle programme itself was following NASA's success with the Apollo and Skylab programmes. As a result, MKS 1 had developed in depth in the minds of the decision-making managers at NASA and Thiokol, and the stagnating cycle had become strong.

MKS 2 existed largely in the minds of engineers, who had witnessed O-ring failure, first hand in their experiments, but engineers had little say in final approval of the launch.

In summary, I note that decision makers nurture knowledge in order to increase their likelihoods of success. Yet, when they actually achieve success, they unwittingly develop meta-knowledge sets about their own infallibility, leading to increased bounds on their awareness. This blunts their sensitivity to risk and cripples their ability to recognize the relevance of critical new information even when it is readily given to them.

CONCLUDING THOUGHTS

The primary contribution in this paper lies in making connections between individual tacit knowledge and bounded awareness during managerial decision-making in organizations; something that has not been studied earlier. I propose that managers' dependence upon their existing tacit knowledge interacts with their bounded awareness in a cycle of positive reinforcement and in doing so, influences the (non-)rationality of their decision making. I have invoked details of the Challenger disaster of 1986 to complement my conceptual discussions on the same. My arguments also implicitly underscore a paradoxical property of individual tacit knowledge: it benefits decision makers by enabling them to make wise judgments on the one hand, but also plays a role in creating limits on their knowing and inducing bounds on their awareness. The paper further argues that different decision makers in the organization can experience differing bounds on their awareness towards the same piece of information and highlights the roles of success and failure in the development of bounded awareness in individuals. I feel that this can open useful new avenues for future research. For example, studies can aim to build and test falsifiable hypotheses around these proposed relationships.

In the Challenger case, it is important to note that there was enormous pressure on the decision-makers to avoid launch delays, owing to the rapid rate at which the missions were conducted (Fact 1), the multiplicity of *stakeholders* in each launch such as the US government, universities and corporate parties, the urgency of the immediately succeeding launch after STS 51-L, which had a probe to examine the Halley's comet, and finally, the fact that STS 51-L itself was rescheduled four times in a period of six days before it finally lifted off (RCR, 1986). Given all this, it may appear that intense time pressure can easily explain managers' bounded awareness and their ignoring engineers' appeals to not launch (Fact 3). My arguments however have shown that the roots of bounded awareness run deep into the human mind and can originate in the dynamics of tacit knowledge taking place therein. Time pressure – not explicitly addressed in this paper – can be considered a contextual variable and further exploration can be done to understand how it plays a role in inducing bounded awareness in managers. Other variables that can also be considered are 'peer pressure' / 'superior pressure' under which decision-makers take decisions that they themselves are not fully convinced about.

We would also like to add that bounded awareness at the individual level seems to be closely related to the constructs of path dependence, persistence (*cf* Schreyogg and Sydow, 2011) and inertia at the organizational level. Inertia, or the tendency of an organization to persist with activities that contributed to its past success despite changes in its environment, has been discussed in literature over the years (e.g. Hannan and Freeman, 1984; Lieberman and Montgomery, 1988; Sull, 1999; Tripsas, 2009; Tripsas and Gavetti, 2000). An interesting avenue for future research is exploring the relationships between individual bounded awareness and organizational inertia. The notions of individual tacit knowledge and organizational knowledge can be useful in constructing models for the same. Earlier research that has discussed the self-referentiality of knowledge at the organizational level and linked it to autopoetic systems theory (e.g. Morner and von Krogh, 2009) could also be useful here.

ACKNOWLEDGMENT

I thank my colleagues Prof. A. Sivakumar, Prof. V. Vijaya and Prof. Sabuj Mandal for their comprehensive review of different versions of this paper and offering me multiple useful inputs for its improvement. I also thank Prof. Amaresh Chakrabarti of the Center for Product Design and Manufacturing, Indian Institute of Science, Bangalore for his kind support in providing me space to work in his IDEAS lab at the institute, where the ideas for this paper were first developed, for his various insights and suggestions in shaping them and for assisting with my accommodation on the IISc campus during that period.

REFERENCES

Armenakis, A. A. (2002), "Boisjoly on ethics: An interview with Roger M. Boisjoly", *Journal of Management Inquiry*, Vol. 11 No. 3, pp. 274–281.

Bateson, G. (1972), *Steps to an Ecology of Mind*, Chandler Publishing, San Francisco, CA.

Bazerman, M.H. and Chugh, D. (2006a), “Decisions without blinders”, *Harvard Business Review*, Vol. 84 No. 1, pp. 88–97.

Bazerman, M.H. and Chugh, D. (2006b), “Bounded awareness: focusing failures in negotiation”, In L.L. Thompson (Ed.), *Negotiation Theory and Research: Frontiers of Social Psychology*, Psychology Press, New York, N.Y., pp. 7–26.

Boisjoly, R.M. (1987), “Ethical Decisions – Morton Thiokol and the space shuttle Challenger disaster”, *American Society of Mechanical Engineers Annual Meeting*, accessed online at http://www.onlineethics.org/CMS/profpractice/exempindex/RB-intro.aspx on June, 1 2011.

Boisjoly, R.P., Curtis, E.F. and Mellican, E. (1989), “Roger Boisjoly and the Challenger disaster: The ethical dimensions”, *Journal of Business Ethics*, Vol. 8 No. 4, pp. 217–230.

Brockmann, E.N. and Anthony, W.P. (1998), “The influence of tacit knowledge and collective mind on strategic planning”, *Journal of Managerial Issues*, Vol. 2, pp. 204–222.

Chugh, D. and Bazerman, M. (2007), “Bounded awareness: What you fail to see can hurt you”, *Mind and Society*, Vol. 6 No. 1, pp. 1–18.

Gino, F. and Pisano, G.P. (2011), “Why leaders don’t learn from success”, *Harvard Business Review*, Vol. 89 No. 4, pp. 68–74.

Gitlin, T. (1980), *The whole world is watching: Mass media in the making and unmaking of the New Left*, University of California Press, Berkeley, CA.

Grant, R.M. (1996), “Toward a knowledge-based theory of the firm”, *Strategic Management Journal*, Vol. 17, pp. 109-122.

Haldin-Herrgard, T. (2000), “Difficulties in the diffusion of tacit knowledge in organizations”, *Journal of Intellectual Capital*, Vol. 1, pp. 357–365.

Hannan, M.T., and Freeman, J. (1984), “Structural inertia and organizational change”, *American Sociological Review*, Vol. 49 No. 2, pp. 149–164.

Heimann, C.F.L. (1993), “Understanding the Challenger disaster: Organizational structure and the design of reliable systems”, *The American Political Science Review*, Vol. 87 No. 2, pp. 421–435.

Henderson, R.M. and Clark, K.B. (1990), “Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms”, *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 9–30.

Kumar, J.A. and Ganesh, L.S. (2011), “Balancing knowledge strategy: Codification and personalization during product development”, *Journal of Knowledge Management*, Vol. 15 No. 1, pp. 118–135.

Lamprinakis, L. and Fulton, M. (2011), “Mental frames and organizational decision-making: facing the challenges of change”, *Paper prepared for presentation at EAAE 2011 Congress Change and Uncertainty Challenges for Agriculture, Food and Natural Resources, Zurich, Switzerland*.

Leonard, D. and Sensiper, R. (1998), “The role of tacit knowledge in group innovation”, *California Management Review*, Vol. 40, pp. 112–132.

Lewis, M.W. (2000), “Exploring paradox: Toward a more comprehensive guide”, *Academy of Management Review*, Vol. 25 No. 4, pp. 760–776.

Lieberman, M.B. and Montgomery, D.B. (1988), “First-mover advantages”, *Strategic Management Journal*, Vol. 9 No. 5, pp. 41–58.

Morner, M. and von Krogh, G. (2009), “A note on knowledge creation in open-source software projects: What can we learn from Luhmann’s theory of social systems?”, *Systemic Practice & Action Research*, Vol. 22, pp. 431–443.

Nonaka, I., and Takeuchi, H. (1995), *The Knowledge Creating Company*, Harvard Business School Press, Boston, MA.

Nonaka, I. and von Krogh, G. (2009), “Tacit knowledge and knowledge conversion: Controversy and advancement in organizational knowledge creation theory”, *Organization Science*, Vol. 20 No. 3, pp. 635–652.

Nonaka, I. (1994), “A Dynamic Theory of Organizational Knowledge Creation”, *Organization Science*, Vol. 5 No. 1, pp. 14–37.

RCR (1986), *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, accessed online at science.ksc.nasa.gov/shuttle/missions/51-l/docs/rogers-commission/table-of-contents.html on June 1, 2011.

Russo, J.E. and Schoemaker, P.J.H. (1989), *Decision traps: The ten barriers to brilliant decision making and how to overcome them*, Simon & Schuster, New York, NY.

Schoemaker, P.J.H. and Russo, J.E. (2001), “Managing frames to make better decisions”, in Hoch S.J., Kunreuther H.C. and Gunther R.E. (Eds.), *Wharton on Making Decisions*, John Wiley & Sons, New York, NY.

Schreyogg, G. and Sydow, J. (2011), “Organizational path dependence: A process view”, *Organization Studies*, Vol. 32 No. 3, pp. 321–335.

Senker, J. (1995), “Tacit knowledge and models of innovation”, *Industrial and Corporate Change*, Vol. 4, pp. 425–447.

Simon, H.A. (1957), *Models of man: social and rational*, Wiley, New York, NY.

Starbuck, W.H. and Milliken F.J. (1988), “Challenger: fine-tuning the odds until something breaks”, *Journal of Management Studies*, Vol. 25 No. 4, pp. 319–340.

Sull, D.N. (1999), “The dynamics of standing still: Firestone tire & rubber and the radial revolution”, *Business History Review*, Vol. 73 No. 3, pp. 430–464.

Tripsas, M., and Gavetti, G. (2000), “Capabilities, cognition and inertia: Evidence from digital imaging” *Strategic Management Journal*, Vol. 21, pp. 1147–1161.

Tripsas, M. (2009), “Technology, identity, and inertia through the lens of ‘The Digital Photography Company’ ”, *Organization Science*, Vol. 20 No. 2, pp. 441–460.

Tsoukas, H. (1996), “The firm as a distributed knowledge system: A constructionist approach”, *Strategic Management Journal*, Vol. 17, pp. 11–25.

von Krogh, G., Roos, J. and Slocum, K. (1994), “An essay on corporate epistemology”, *Strategic Management Journal*, Vol. 15, pp. 53–71.

Weick, K.E. (1979), *Social Psychology of Organizing*, Addison-Wesley, Reading, MA.

APPENDIX A

Description of the Space Transportation System (STS)

The STS was composed of four key sub-systems: the space shuttle which looked like a modern airplane and could be manned by mission pilots, two Solid Rocket Boosters (SRBs), containing solid fuel that provided nearly 80% of the thrust at launch, and an external tank containing liquid hydrogen and oxygen to provide additional thrust at launch. The external tank served as the backbone of the STS since the shuttle as well as the SRBs, were mounted on it. It had no engine of its own, and its fuel would be taken in and burnt by the shuttle’s three engines. About 120 seconds after lift-off, when the STS had acquired a height of about 70 kilometres above sea-level, the SRBs would first be separated from the external tank and would float on parachutes into the ocean. They would then be recovered by mission tracking ships and reused in future launches. The STS would continue with the shuttle and external tank, until it gained adequate height to be placed into orbit. Here, the external tank would separate from the shuttle to re-enter the earth’s atmosphere and fall into the ocean. It would not be recovered. The shuttle would orbit the earth for the designated time period, execute its activities, re-enter the earth’s atmosphere, and land in one of the country’s Air Force Bases.