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CHOOSING INNOVATION: HOW REASONING AFFECTS DECISION ERRORS

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ABSTRACT
Human beings are inherently fallible in their intuitive decision-making due to the constraints of bounded rationality. In order to avoid cognitive biases, people make judgments using a combination of deductive and inductive reasoning, because these forms of reasoning represent a process of analytic inference and verification as the basis for justifying decisions. In this study, an experiment was conducted that simulated an uncertain environment characterized by incomplete information with members of a committee called upon to decide whether or not to invest in innovation-oriented new product projects. This study examines a third form of logic, abductive reasoning, and investigates the direction of its effect on the probability of project acceptance. The findings reveal that under abductive reasoning, individuals are more likely to accept projects. The aim is not to show how to decide what is or is not innovative, but rather to show that this decision is subject to the framing effects of logical forms of reasoning. The findings provide new psychological evidence on decision-making when choosing innovation, and raises questions on how juries choose innovative projects.

Keywords: technological innovation; decision-making processes; behavioral psychology; design thinking

1 INTRODUCTION
In a culture that demands reliability and measurement, how can professionals 'innovate' their inability to realize and capture technological innovation? The answer coming from many quarters, but especially the strategic business management literature, is that executives should adopt design thinking [1]. A range of case studies from leading companies including Proctor and Gamble and Philips Electronics is beginning to show how the adoption of the tools, methods, and 'thinking' skills of designers can help companies to solve problems associated with their inability to realize and capture technological innovation. For firms that value the goal of successful innovation, design thinking is regarded as a new movement in re-thinking competitive advantage. The problem, though, like many business trends, is that design thinking is potentially another buzzword or trend with a few case examples but no useful principles that decision-makers can apply. Thus far, design thinking has not been put through any rigorous academic tests. This study aims to change that by delivering a more lucid empirical contribution to that body of literature.

1.1 Operationalizing Design Thinking
The underlying premise of design thinking is that the way in which designers reason with the world around them is very different from the logic managers typically use in making decisions. A well-recognized characteristic of designers is their ability to devise novel ways of looking at a problem. Designers rely on abductive reasoning, which is the process of generating plausible explanatory hypotheses of 'what might be' when they analyze or evaluate a problem [2]. Abduction is a mode of reasoning in situations where data and information is limited and uncertain. For example, a board of directors might be called upon to consider multiple future states of the economy and market, where information about the future is opaque, while a promising investment opportunity must be decided upon. Charles Peirce's seminal works on abduction state that it is the only logical operation which introduces new ideas [3]. It is this element of novelty which is the lifeblood of innovation. In this way, abduction can be seen as an effective means of increasing the chance of capturing innovation by broadening the generation of alternative hypotheses and solutions when information is limited, especially in high-velocity business environments, which demand urgency in decision-making. Moore's Law is a good example wherein abductive reasoning led to an accurate hypothesis about the

development path and life cycle of semiconductors [4]. This was then used to generate a new business model with predictable patterns of revenues and costs based on what abductive thinking captures in the "Law".

In contrast, the design thinking literature asserts that managers, by instinct, rely on and reward the use of deductive and inductive reasoning when problem solving. Deduction and induction are representative of analytic and verification processes that increase certainty by 'freezing' out unreliable options and indoctrinating pattern recognition biases [5] and decision myopia. Deductive reasoning involves developing inferences from general principles of 'what should be'. For example, a consumer packaged-goods firm can use its engrained theory – 'build market share and profits will follow' – to deduce the appropriate action in a given situation [6]. What this example demonstrates is that the inferences generated by deduction have a high degree of analytic and explanatory power. However, in line with Peirce's view, deduction explicates a decision hypothesis rather than produces any new insights or information.

Inductive reasoning involves generalizations from specific instances about 'what is'. For example, a retailer may study the cost structure of its outlets to determine which has the best cost position in order to set, inductively, a cost target for the whole chain [6]. This example indicates that inductive reasoning generalizes from a number of cases of which something is true in reaching a decision hypothesis. Again, this line of reasoning does not produce new ideas, but, as Peirce recognized, it does serve as a method of testing and verifying hypotheses.

1.2 Agenda and Contributions of Research

While there is documented evidence that design-led innovation can help boost the chances of successful product innovation once a project is underway, there is much less evidence whether design thinking can boost the chances of a potentially innovative product venture even 'getting off the ground'. This study aims to respond to this lack of evidence. Given the low proportion of confidence managers hold in the reliability of metrics to forecast returns from innovation [7], the desire for substantive proof of the returns on innovation in the form of profits or efficiency boosts can bias decision-makers' choices towards more certain outcomes when selecting from several potentially innovative projects. Empirical evidence of decision-making processes in industry suggests that decision-makers tend to apply deductive reasoning to variables including product timing, staffing and platform choice [8, 9] to identify the certain outcomes. The emphasis on deductive and inductive reasoning also appears in models for evaluating innovative projects [10]. Due to risk averse biases often associated with these modes of thinking, the possibilities are that a firm may refrain from acting (decision inertia), they may exit a good project too early, wait too long before entering a successful venture, or just completely reject a good project and let opportunity to innovate pass because of the strict burden of proof demanded by reliability and verification measures. These are decision errors characterized by the rejection of good projects. We will refer to this error as a Type I error. Venture capital firms are notorious for exiting successful ventures early and hence failing to maximize shareholder and long-term firm value [11], but this problem afflicts leading corporations as well. Under these circumstances, the prediction is that decisions will shift in the direction of inaction (action by omission) or rejection of action. One way to reduce Type I errors is to err in the opposite direction by exposing the company to more risk. Explorative processes attract the risk of accepting bad ideas, projects, and initiatives. This we term Type II errors. One psychological bias that causes Type II errors is optimism [5]. Another is the hindsight bias [12], which results in people remembering events as being more predictive of the future than they actually were (in other words, the 'knew-it-all-along' effect). This issue of creeping determinism can be problematic when information and data is anomalous, yet decision-makers leap to unfounded conclusions based on prior knowledge or successful experience (possibly perpetuating Type II error). The abductive reasoning frame might be productive in overcoming hindsight bias since abduction requires an explicit relaxation of the prior constraints to 'guess' a new, plausible explanation of a situation. One example where explorative process caused Type II error was in 1999. Prominent venture capitalists Benchmark Capital and Sequoia Ventures placed a $122 million bet on Internet grocer Webvan [4]. They hypothesized that there was a viable business model for an online home-delivered groceries service based on data collected during Webvan's launch period. The decision hypothesis appeared to be entirely plausible before entry, but history tells us that Webvan failed spectacularly and that online grocery retailing models have experienced limited success in the US market.

While there is research being done on the policy and financing aspects of venture capital financing [13], very little is known about the behaviors of investors in screening projects. If current knowledge on their screening practices is anything to go by, there is, perhaps, an excessive emphasis on protected intellectual property as an indicator of innovative ability [14]. We believe that investors may not have the trade-off between Type I and Type II errors optimized. Given that this study investigates the capture of innovation at the point of decision-making, the findings shed light on optimal pairings of reasoning frame and decision rule depending on error trade-off preferences.

Choosing innovation, that is, making a decision to pursue a project that has the potential for innovation, is the issue addressed by this paper. The aim of this study is to understand how a design perspective in strategic decision-making can shift decisions in line with certain conditions and expectations while minimizing systematic and predictable errors. It is hypothesized that the direction of project acceptance rates in innovation-oriented project evaluations will shift in a predictable direction according to whether an abductive reasoning frame or a deductive/inductive reasoning frame was taken by a decision-maker. Subsequently, decision errors (Type I and Type II) will also shift in line with these predictions. Priors were tested using a controlled laboratory experiment with manipulations to the reasoning frame and the decision rule followed by committees. Statistical analysis of the decision output (project acceptance or rejection) was conducted. The focus is on committee decision-making because this modus operandi most accurately reflects the commercial realities of the innovation-oriented decision-making processes of venture capital firms, small boutique private equity firms and internal innovation management (or R&D investment) committees. Additionally, there exists a long-standing theoretical question in economic theory on decisions made under uncertainty, which this study addressed. Specifically, what effect does the aggregation of individual decisions at the committee level, through the institution of a decision rule, have on project selection and decision error [15]? Research in this field has yet to provide empirical conclusions; this paper aims to deliver an empirical contribution in this space.

2 METHODOLOGY

2.1 Experimental design

An experimental and quantitative methodology was chosen in this investigation as it provided the opportunity to create the right conditions to test the underlying theory and hypotheses of the research questions posited. We hypothesize that in the context of innovation-oriented committee decision-making:

H1: *Deductive/Inductive reasoning will result in a relatively low proportion of project acceptances.*

H2*:* *Abductive reasoning will result in a higher proportion of project acceptances.*

H3*:* *An increase in the consensus level required for a project to be accepted will lower the proportion of projects accepted (good and bad) by a committee of fixed size* [15].

The experiment is a small group decision-making exercise where a committee of 5 participants are asked to decide which projects from a pool of seven are worthy of investment. Figure 1 illustrates the 2 x 2 factorial design.

		Project Acceptance Rule (C out of 5)	
		C = 1	C = 5
Reasoning Frame	Abductive	Condition 1 Group 1 (1/A) Group 2 (1/A) Group 3 (1/A)	Condition 2 Group 7 (5/A) Group 8 (5/A) Group 9 (5/A)
	Deductive/ Inductive	Condition 3 Group 4 (1/D) Group 5 (1/D) Group 6 (1/D)	Condition 4 Group 10 (5/D) Group 11 (5/D) Group 12 (5/D)

Figure 1. White cells represent the 4 conditions in this 2 x 2 factorial experiment. C represents the level of consensus. 5 participants in each group, 60 participants in total.

This experiment has two independent variables: the project acceptance rule, in other words, the decision rule or voting rule (VR); and the reasoning frame (RF). The manipulation of the project acceptance rule has two levels: (i) a permissive project acceptance rule of C=1; and (ii) a conservative project acceptance rule of C=5 (in other words, unanimity)[1]. The manipulation of the reasoning frame has two levels: (i) an abductive frame and (ii) a deductive/inductive frame. In total, there are four conditions in this experiment, and they are a combination of one level of each independent variable.

2.2 Participants

Participants were recruited using the Online Recruitment System for Economic Experiments (ORSEE) developed by experimental economists at the University of Sydney Business School. The system sends out invitations to all registered students across the university and from all disciplines. The system itself is a random selection process that operates to remove any systematic bias stemming from individual differences between groups of participants. The focus of this study was the effect which crucial manipulations in the experiments had (the reasoning frame and the decision rule) on decision output. As such, recruitment took advantage of ORSEE's random selection process and did not select participants on the basis of their year, discipline or experience to minimize systematic bias. The experiments were conducted over twelve experimental sessions lasting about 1 hour each plus 3 pilot studies. Committees were randomly allocated five individuals with experimenters checking that no one knew each other to remove as much selection and systematic bias as possible. For each session, groups were allocated to a different condition to ensure that individual differences were evenly distributed. Additionally, conditions were alternated between successive experiments. These steps were taken to try and achieve a balance of subject variables between groups and conditions. In total, 12 groups consisting of 5 persons per group were recruited. 3 groups were allocated per condition. Since each group evaluated 7 projects, a total of 420 individual decisions (5 persons × 3 groups × 7 projects × 4 conditions = 420) were obtained.

2.3 Experimental procedure

Participants were asked to choose from a randomized set of project briefs. The participants were informed that they were directors on an investment committee with equal standing and voting power. However, two of the five participants were randomly assigned the role of founding director. The founding directors were given a responsibility to address the board with the meeting agenda. This was simply an extra paragraph inserted into their instructions for the purposes of framing the committee. Participants were told that they work for a non-profit venture capital firm that invests in new business ventures and new innovative technologies. They were instructed that: "*the firm is implementing an open innovation strategy, which is directed towards improving people's lives by investing in the development of innovative mobile applications.*" The experimenter then proceeded to explain the aims of the meeting as follows:

- *You are at this meeting today to help the firm decide which projects the firm should invest in for further product development or refinement.*
- *The objective is to make the correct decisions and invest in good projects and screen out bad projects.*
- *The projects can be chosen based either on profit potential or on whether they will improve people's lives. The goal of the non-profit venture capital firm is to do both or either one.*
- *It is not expected that projects will be chosen based solely on their profit potential. This is because the projects are in their early stages of development and it is difficult to forecast the financial performance of these projects.*

The experimenter then proceeded to inform the participants that experts would determine which projects were good and which were bad. A disclaimer was made so that participants would not be anchored to the idea that there were a proportion of good and bad projects in the pool.

- *The experts may accept all projects; OR*
- *They may reject all projects; OR*
- *They may accept and reject projects in varying proportions.*

Participants were instructed to read all project briefs individually before committee deliberation began. It was crucial that participants read all projects first so that the first project they read was not used as a base line measure. This would have introduced a systematic anchoring bias [16].

[1] C=1: 1 person out of 5 must vote accept for the project to be accepted into the final portfolio.
C=5: 5 out of 5 persons must vote accept for the project to be accepted into the final portfolio.

2.4 The project briefs

The 7 projects were a collection of submissions from students enrolled in a final-year capstone design studio in the Bachelor of Design Computing at the University of Sydney who elected to participate in this study. The projects were:

1. A daily medication box that reminds patients to take medication by SMS
2. A mobile phone application that assists the visually impaired to navigate using Google Maps
3. A child's necklace that helps parents to track where their child is and with whom
4. A beer holder that monitors alcoholic consumption rate to avoid (or detect) inebriation
5. A mobile phone application to assist in tracking urban re-vegetation
6. A jacket with sewn-in electromechanical navigation aids using data provided by Google Maps
7. A device that activates appliances using gestures and wireless communication

These 7 projects were selected from an initial set of 15 as the most fully developed and well-communicated projects so that the committees could understand them. Projects were aimed at new mobile phone based products with the motivation of designing an innovation that does not yet exist or has not been mass-marketed. The stimulus materials are geared towards innovative and novel projects that utilize technology to mediate the interaction between humans and a task or activity.

2.5 Payoffs

An incentive compatible payoff mechanism was developed so that participants would be motivated to vote honestly and take the experiment seriously. Every decision they made had the potential to earn a AUD30 payout if the group decided correctly. Otherwise, all participants walked away with a base rate amount of AUD15. A payoff test was included to mitigate random error stemming from the possibility that some participants would not comprehend the payoff mechanism. All 60 participants passed the test. This was important to indoctrinate incentive compatibility and maintain the internal validity of the data set collected.

2.6 Decision-making

Each experimental condition had 1 of 2 voting rules, which were made apparent to the participants before they entered group discussion. That is, depending on the treatment group, the project acceptance rules were either permissive, C=1, or conservative, C=5.

To obtain individual decisions on project acceptance, each individual was given assessment sheets, both before and after group deliberation. The assessment sheet consisted of five-level Likert scales and a sixth question for the accept/reject decision. The questions were as follows:

1. *I think this project is novel*
2. *I think this project is creative*
3. *I think consumers will be accepting of this product*
4. *I think this project has market potential*
5. *I think this project is technically feasible*
6. *I think this project should be accepted*

For questions 1 to 5, a score was allocated to each response. The scores for each response were:

- *Strongly disagree = 1*
- *Disagree = 2*
- *Neutral = 3*
- *Agree = 4*
- *Strongly agree = 5*

The total score assigned to each project after committee deliberation provided the basis for the regression analysis predicting the influence of the reasoning frame and decision rule on the total score assigned to each project by each participant (which is described later in the paper).

Two founding directors were assigned at random at the beginning of each experimental session. The three remaining participants each held a seat on the board of directors and had the same voting powers minus the responsibility of addressing the board at the commencement of session. The founding directors, unknowingly, were given the special role of indoctrinating the *abductive* or *deductive/inductive* reasoning frame in the collective decision-making. This framing manipulation was implicit as the founding directors were instructed to read out the address to the board at the commencement of session.

Founding director address: abductive reasoning frame.

The objective of today's meeting is to capture and invest in new product innovation. For the purposes of this meeting, we will determine a possible future in 2-3 year's time wherein further development of a project will lead to something new that becomes adopted and leads to a sustained change in behavior or behavioral patterns. The selection criteria:

1. *Novelty (is it new?)*
2. *Creativity*
3. *Consumer acceptance*
4. *Market potential*
5. *Technical feasibility*

This decision framing was designed to elicit an *abductive reasoning* by virtue of the hypothetical nature of the statement. The aim was to frame the committee's discussion toward creative search and idea generation of the possible future wherein the product could co-exist. The notion of sustaining change aimed to motivate the participants to look beyond the superficial facts presented in the project briefs and engage in explorative search. The selection criteria were copied from the individual assessment sheet so that participants had it for reference.

Founding director address: deductive/inductive reasoning frame.

The objective of today's meeting is to capture and invest in new product innovation. For the purposes of this meeting we determine whether each project matches people's needs with what is technically feasible and what a viable business strategy can convert into market opportunity and customer value. The selection criteria:

1. *Novelty (is it new?)*
2. *Creativity*
3. *Consumer acceptance*
4. *Market potential*
5. *Technical feasibility*

The second decision frame was designed to induce a strong inclination towards evaluating project briefs as they appeared in the portfolios with participants anchored on criteria that required *deductive/inductive* logic to answer (i.e. technical feasibility and market opportunity). The use of criteria in-text increases the salience of the framing and enhances the probability that receivers will perceive the information, discern meaning and thus process it, and store it in memory [17]. We considered the use of existing instruments for the analysis of innovative projects [18]. The trade-off would have been that the participant population would need a technical and financial background to understand and assess many of those dimensions accurately, because these instruments include assessments on product family, platform, strategic fit, and expected financial performance. Such expertise is beyond the capability of the recruited participants. Finally, the use of these instruments requires more information on projects than could feasibly be provided and would likely have only increased the number of rejected projects in the *deductive/inductive* framing. Furthermore, this manipulation was gentler than it might have been and so if the hypotheses hold under this construction they would be likely to obtain in a more heavy-handed manipulation.

After the participants were given a brief amount of time to discuss the decision objectives, the experimenter then opened the committees to group deliberation. Five minute intervals of discussion per project were strictly abided by to ensure internal consistency and validity. Final individual assessment sheets were distributed and filled out individually with no communication permitted between participants. Sheets were collected at the end of the session and participants were paid.

2.7 Expert Evaluations

In the experiment, all 12 groups were shown the same portfolio of projects (7 total). They were informed that experts were going to decide which projects were good and bad. This external evaluation would form the basis of what would be deemed a Type I error (a good project was rejected) and a Type II error (a bad project was accepted). A senior advisor from a global management consulting firm was invited to evaluate which projects were good and which were bad using his extensive experience and dealings with global private equity and venture capital firms. The lecturer in charge of the design students' projects was the second evaluator. The two experts came to agreement and concluded that project 1 and project 7 in the portfolio were good (best-in-class) and the remainder were bad (worst-in-class) *before the experiments began*. There is no denying that this is a subjective evaluation; however, we argue that it is the most informed prediction that can be made considering the backgrounds of the experts. Their evaluations will be used as one possible scenario to determine the instances of Type I and Type II errors that the committees made.

3 RESULTS AND DISCUSSION

3.1 Descriptive statistics

Figure 2 summarizes and tallies the means of group project acceptance in each condition. What is observable is a relatively high project acceptance rate of 52.38% in *Condition 1* as compared to an aggregate average project acceptance rate of 29.53%. *Conditions 2* and *4* also have project acceptance rates above the average, with *Condition 4* only marginally, so ***H1*** cannot be confirmed. Referring to ***H2***, the expectation is that *abductive reasoning* will result in a high proportion of project acceptances, and this is confirmed in the total individual project acceptances. In ***H3***, the expectation is that there will be a higher proportion of projects accepted in the permissive rule (C=1) than in the conservative rule (C=5). Comparing between *Condition 1* and *Condition 2* confirms the direction and expectations of Sah & Stiglitz [15] canvassed in ***H3***. The data are unable to support the attribution of the high proportion of projects accepted to the abductive reasoning frame or the permissive project acceptance rule when we compare *Condition 3* to *Condition 4*. There is a confounding result where the levels of project acceptances are slightly higher in the conservative rule (C=5) at 30.48% as compared to the permissive rule (C=1) at 26.67%. ***H3*** does not hold up in this comparison because Sah & Stiglitz [15] expect that there should be a higher level of acceptances in the permissive rule (C=1) as compared to the conservative rule (C=5) because a significantly lower level of consensus is required to get a project accepted. The only conclusion on the sample may be that the voting rule does not significantly affect project acceptances at the individual level due to confounding results when comparing *Condition 3* and *Condition 4*.

		Project Acceptance Rule (*C* out of 5)	
		C = 1	*C* = 5
Reasoning Frame	Abductive	Condition 1 Group 1 accepted **15 / 35** projects Group 2 accepted **23 / 35** projects Group 3 accepted **17 / 35** projects TOTAL individual acceptances = **55 / 105** projects On AVERAGE **52.38%** of projects were accepted in the 105 individual project evaluations	Condition 2 Group 7 accepted **10 / 35** projects Group 8 accepted **10 / 35** projects Group 9 accepted **13 / 35** projects TOTAL individual acceptances = **33 / 105** projects On AVERAGE **31.43%** of projects were accepted in the 105 individual project evaluations
	Deductive / Inductive	Condition 3 Group 4 accepted **6 / 35** projects Group 5 accepted **13 / 35** projects Group 6 accepted **9 / 35** projects TOTAL individual acceptances = **28 / 105** projects On AVERAGE **26.67%** of projects were accepted in the 105 individual project evaluations	Condition 4 Group 10 accepted **12 / 35** projects Group 11 accepted **10 / 35** projects Group 12 accepted **10 / 35** projects TOTAL individual acceptances = **32 / 105** projects On AVERAGE **30.48%** of projects were accepted in the 105 individual project evaluations

Figure 2. Summary of project acceptance.

Table 1. Decision errors.

	Abductive		Deductive/ Inductive	
	C=1	C=5	C=1	C=5
Type I Errors	12	14	16	8
Type II Errors	37	17	14	10

Table 1 summarizes the decision errors. The *abductive reasoning* frame results in a higher number of Type II errors (accept bad projects), in line with the predictions and the prior results that the *abductive reasoning* frame results in more projects being accepted. This necessarily entails bad projects being accepted. It is not possible to demonstrate that the abductive reasoning frame reduces Type I errors (reject good projects) except between *Condition 1* and *Condition 3* under the permissive rule, C=1. These results suggest that applying design thinking may not necessarily help committees to identify good projects, although it may help more projects 'get over the line'. If a firm perceives the 'acceptance of bad projects' as costly especially in environments characterized by low quality project pools, we would advise that a conservative decision-making structure such as a unanimous consensus decision rule should be instituted to mitigate Type II error. However, for firms such as IDEO, that

have routinized the low cost of failure, or for very early stage product development, a permissive decision-making structure is preferable.
There are major limitations to what can be inferred from the descriptive statistics. The study now turns to regression models that will allow statistical inferences about the effect that each level of the independent variable has on the dependent variable.

3.2 Regression on individual decisions per project

An OLS regression is used to model individual decisions per project where the outcome, the dependent variable (DV), is the TOTAL SCORE per project. The purpose is to determine whether the voting rule or the framing provided a more significant effect on the outcome, the TOTAL SCORE per project as assigned by the committee. The equation used is shown below (Equation 1).

$$\text{TOTAL SCORE} = con + \beta_1(p_1) + \beta_2(p_2) + \beta_3(p_3) + \beta_4(p_4) + \beta_5(p_5) + \beta_6(p_6) + \beta_7(p_7) + \beta_8(VR) + \beta_9(RF) \qquad (1)$$

The variables in the OLS model have the following attributes:

- The dependent variable (DV) is the predicted "TOTAL SCORE" assigned to a project by each individual (after committee deliberation) based on the sum of the five variables in the assessment sheet (ref section 2.6). The predicted TOTAL SCORE for an individual project is used as the dependent variable (DV) because the desired observations are which variables determine the TOTAL SCORE people are likely to award to a project.
- "con" is the constant value in the OLS regression model.
- β_1 to β_7 are the predicted coefficients for each respective project.
- p_1 to p_7 are dummy (project) variables that take on the value of 0 when the project is not being observed and 1 when the project is being observed. (Project 4 serves as the basis for these dummy variables since it has the lowest rate of acceptance.) The coefficients for the rest of the variables are interpreted as whether or not there are significant differences from Project 4's acceptance rate.
- VR is the dummy variable for the voting rule with the permissive project acceptance rule (C=1) coded as 1, and the conservative project acceptance rule (C=5) coded as 0.
- β_8 = the predicted coefficient of the project acceptance rule.
- RF is the dummy variable for the reasoning frame, with the *abductive reasoning* frame coded as 1, and the *deductive/inductive reasoning* frame coded as 0.
- β_9 = the predicted coefficient of the reasoning frame.

The results of the OLS regression are tabulated in Table 2. The model *p-value* is < 0.01 with an R-squared value of 0.2662, so valid interpretations of the outputs from the model can be made. The key result is that there is a significant ($p < 0.01$) difference between the *abductive reasoning* frame and the *deductive/inductive* reasoning frame. Where individual TOTAL SCORES per project are the DV, the reasoning frame (RF) is significant ($p < 0.01$). Participants under the *abductive reasoning* frame tend to put a TOTAL SCORE 0.8 higher than those in the *deductive/inductive reasoning* frame. Participants under the *abductive reasoning* frame have a more optimistic scoring attitude than those in the *deductive/inductive* reasoning frame. This result matches a corollary of the prior intuition, which is: *abductive reasoning* results in the creation of alternative decision hypotheses and with the greater variation in optionality comes the greater propensity to act. Due to the statistical significance of the reasoning frame at conventional levels of confidence, it can be inferred that it is a better predictor of how individuals assessed the TOTAL SCORE of projects than the voting rule (VR). In other words, the reasoning frame significantly affected the scoring of projects at the individual level more than the voting rule.

Table 2. OLS regression with 8 dummy variables: Projects 1-7 (excluding Project 4), Voting Rule (VR) and Reasoning Frame (RF).

Independent Variable	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Voting Rule (VR)	Reasoning Frame (RF)	Constant (con)
OLS	5.033 (0.548)	2.9167 (0.548)	1.933 (0.548)	Base Case	4.55 (0.548)	1.117 (0.548)	3.967 (0.548)	-0.595 (0.293)	0.790 (0.293)	13.707 (0.439)
p-value	*p<0.01*	*p<0.01*	*p<0.01*	-	*p<0.01*	*p<0.01*	*p<0.01*	*p<0.10*	*p<0.01*	*p<0.01*

The last model used for analyzing the individual decisions per project is presented below. This model uses the same econometric methods as the previous model with the only difference being that the dummy variables for Projects 1-7 are dropped. This follows the common approach to purposeful selection of variables in logistic regression by minimizing the amount of explanatory variables until the most parsimonious model that explains the data is found, which also satisfies the requirements of numerical stability and the generalizability of results [19]. The only explanatory variables included in the right hand side of the Logit and Probit models are the voting rule (VR) and reasoning frame (RF). The equations are as follows:

Logit model:
$$\Pr(accept) = \frac{\exp\left[con + \beta_8(VR) + \beta_9(RF)\right]}{1 + \exp\left[con + \beta_8(VR) + \beta_9(RF)\right]} \tag{2}$$

Probit model:
$$\Pr(accept) = \Phi\left[con + \beta_8(VR) + \beta_9(RF)\right] \tag{3}$$

$\Phi(z)$ is the standard normal density. The results are tabulated in Table 3. Both the overall Logit and Probit models are statistically significant (*p<0.01*). The effect of the voting rule (VR) is somewhat diminished in this analysis – it is not statistically significant at alpha=.05 confidence but is at alpha=.1. The reasoning frame (RF) is significant (*p<0.01*). The positive coefficient of the reasoning frame indicates that when the reasoning frame is *abductive*, the predicted probability of acceptance increases. The conclusion is that the shifts in the predicted probabilities are attributable to the effects of the reasoning frame – even more so than the voting rule. Based on these results, predicted probabilities of project acceptance are calculated to compare the effects between the 4 conditions. Table 4 provides the strongest confirmation of our hypotheses. There is a consistent drop in the probability of project acceptance between the *abductive* and *deductive/inductive* framing and between the permissive and conservative voting rules. Thus, ***H1***, ***H2*** and ***H3*** are accepted if the word ‘proportion’ is replaced with ‘probability’.

Table 3. Logit and Probit with 2 dummy variables, Voting Rule (VR) and Reasoning Frame (RF).

Independent Variable	Voting Rule (VR)	Reasoning Frame (RF)	Constant (con)
Logit	0.363* (0.208)	0.574*** (0.208)	-1.105*** (0.190)
Probit	0.217* (0.127)	0.348*** (0.127)	-0.675*** (0.112)
p-value	* *p<0.10* ** *p<0.05* *** *p<0.01*		

Table 4. Predicted probabilities of project acceptance

	Abductive		Deductive/ Inductive	
	C=1	C=5	C=1	C=5
Logit	0.4583	0.3703	0.3227	0.2488
Probit	0.4560	0.3718	0.3234	0.2498

4 CONCLUSION

This paper aimed to respond empirically to the practitioner driven and anecdotally supported design thinking literature and to the theoretically based economics literature on committee decision-making. We examined whether the operation of group decision-making is itself subject to biases, which shift the direction of individual project acceptance rates in line with certain experimental conditions and our expectations. In line with expectations, we found that the use of an abductive reasoning frame increases the likelihood of an innovative project being chosen. The implication is that design thinking has a strong effect on decision-making, as shown by the statistically significant increase in the probability of project acceptance at the individual level. However, this increase can lead to higher Type II errors (accepting bad projects) and may not completely resolve Type I errors (rejecting good projects). We should note that our basis for determining the ‘good’ projects was somewhat artificial, since we used the expert opinion of two authors (as opposed to actual venture capital decisions). The preferred way to perform such a determination more objectively is to identify a set of successful products, as determined by a true market, that committees have never seen before. We believe this is possible for products normally used by professionals but not by consumers, and aim to conduct such a study in the future.

In summary, our results confirm that design thinking shifts decision-making towards exploration and optimistic search and action. The advice that this research provides to firms already implementing design thinking is to indoctrinate design thinking into the decision processes for project screening as well, particularly at the early stages. Our aim is not to show how to decide what is and what is not innovative, but rather to show that this decision is subject to framing effects. While it is known that the advantage a product offers to users is the key factor for its commercial success, taking an abductive reasoning frame in screening projects early on may prevent firms from pulling out from a potentially innovative and commercially successful project before its advantage can be developed.

REFERENCES

[1] Brown, T., Design Thinking. *Harvard Business Review*, pp82-92 (Harvard Business Publishing, Cambridge MA, 2008).

[2] Dorst, K., The Nature of Design Thinking. In Dorst, K., Stewart, S., Staudinger, I., Paton, B. and Dong, A., eds. *Design Thinking Research Symposium 8*, pp131-139 (DAB Documents, Sydney, 2010).

[3] Peirce, C.S., *The Essential Peirce: Selected Philosophical Writings, Volume 2: (1893-1913)*. (The Peirce Edition Project, eds. Bloomington, Indiana: Indiana University Press, 1998).

[4] Dew, N., Abduction: a pre-condition for the intelligent design of strategy. *Journal of Business Strategy*, 2007, 28(4), pp38-45.

[5] Lovallo, D.P. and Sibony, O., The case for behavioral strategy. *McKinsey Quarterly*, 2010.

[6] Martin, R., Creativity That Goes Deep. *Business Week*, 2005.

[7] Boston Consulting Group. *Innovation 2010: A Return to Prominence - and the Emergence of a New World Order*. (Boston Consulting Group Report, 2010).

[8] García-Melón, M., Aragonés-Beltrán, P., Poveda Bautista, R. and Zabala Iturriagagoitia, J.M., Analysis of the Decision-Making Processes in NPD Projects of Innovative Companies. In Samuel, A. and Lewis, W., eds. *Proceedings of the 15th International Conference on Engineering Design (ICED05)* (Institution of Engineers, Australia, Melbourne, 2005).

[9] Krishnan, V. and Ulrich, K.T., Product Development Decisions: A Review of the Literature. *Management Science*, 2001, 47(1), pp1-21.

[10] Tan, A. and McAloone, T., Understanding and Developing Innovative Products and Services: The Essential Elements. In Marjanović, D., ed. *Proceedings of the 9th International Design Conference DESIGN 2006*, pp647-654 (The Design Research Society, Dubrovnik, 2006).

[11] Gompers, P.A., Grandstanding in the venture capital industry. *Journal of Financial Economics*, 1996, 42(1), pp133-156.

[12] Christensen-Szalanski, J.J. and Willham, C.F., The hindsight bias: A meta-analysis. *Organizational Behavior and Human Decision Processes*, 1991, 48(1), pp147-168.

[13] Cumming, D., Government policy towards entrepreneurial finance: Innovation investment funds. *Journal of Business Venturing*, 2007, 22(2), pp193-235.

[14] Lerner, J. and Watson, B., The public venture capital challenge: the Australian case. *Venture Capital*, 2008, 10(1), pp1-20.

[15] Sah, R.K. and Stiglitz, J.E., Committees, Hierarchies and Polyarchies. *The Economic Journal*, 1988, 98(391), pp451-470.

[16] Tversky, A. and Kahneman, D., Judgement under uncertainty: heuristics and biases. *Science*, 1974, 185(4157), pp1124-1131.

[17] Fiske, S.T. and Taylor, S.E., *Social Cognition*. (McGraw-Hill, New York, 1991).

[18] Roucoules, L., Lutz, P. and Gartiser, N., Several Dimensions for Characterizing Innovation: A Technical and an Economical Approach. In Folkeson, A., Gralen, K., Norell, M. and Sellgren, U., eds. *Research for practice: innovation in products, processes and organisations, Proceedings of the 14th International Conference on Engineering Design* (The Design Society, Stockholm, 2003).

[19] Bursac, Z., Gauss, C.H., Williams, D.K. and Hosmer, D.W., Purposeful selection of variables in logistic regression. *Source Code for Biology and Medicine*, 2008, 3(17), pp1-8.

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