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THE LANGUAGE OF ABDUCTION IN CHOOSING INNOVATION

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Abstract: The selection of an innovation project to take forward for product development, is a complex, strategic, managerial decision which shares one key part with concept ideation and evaluation in design: assessing creativity. This problem is especially pronounced for products that do not yet exist or have never been mass-marketed. In this paper, we go beyond the question of how to select or identify the most creative project to consider the following: How can this decision be affected by forms of logical reasoning? Through a qualitative content analysis of committees selecting an innovation project to take forward, we show how forms of logical reasoning have an impact on the assessment of creativity and can alter the characterization of whether a project is creative or not.

Keywords: *decision-making, logical reasoning, innovation management*

1. Introduction

1.1. The problem of choosing innovation projects

Before an innovative product hits the market, decision-makers were trying to decide whether the project put before them has innovation potential and whether they should put the firm's resources toward developing a product. This is the problem of selecting innovation projects. Decision-makers engaged in decision-making applications of this type are making choices about potentially attractive projects such that after the decision is taken, their firm would devote considerable resources. It should be noted, however, that analysis of such projects is often carried out with the sole intention of supporting senior leaders' viewpoints rather than proving or disproving an investment hypothesis (Harreld, O'Reilly III, & Tushman, 2007; Sadler-Smith & Shefy, 2004). The problem for these decision-makers is to minimize Type-I errors (not approving good projects) while avoiding Type-II errors (approving bad projects) altogether. This type of decision shares an important aspect with the problem of selecting the most creative concept (e.g., from a design ideation stage), which is the problem of identifying what is creative, that is, what is novel and useful, to take forward for further

development. Like the standard context for studies on assessing the creativity of new concepts, researchers in strategic business management aim for reliable ways to distinguish a good project from a bad project. However, the low reliability of metrics to forecast the innovation potential for any project and the desire for substantive proof of the returns on innovation in the form of profits or efficiency boosts can bias a decision-makers' choice towards more risk averse or incremental outcomes when selecting from several potentially innovative projects. Empirical evidence of decision making processes in industry points to just this conjecture; decision-makers tend to apply variables amenable to deductive analysis including product timing, staffing and platform when evaluating innovative projects (Krishnan & Ulrich, 2001). Innovation evaluation techniques likewise employ highly deductive analysis requiring a substantial amount of information aiming to prove or disprove premises established by precedence (Udell, 1989). Similar empirical metrics are applied in assessing creativity in design projects (Maher, 2010; Shah, Smith, & Vargas-Hernandez, 2003). This paper takes on the question of how assessments of creativity can be influenced by forms of logical reasoning. Previously, we have shown a statistically significant difference between groups choosing an innovation project between a deductive and inductive or an abductive reasoning frame (Mounarath, Dong, & Lovallo, 2011). Our experiments showed that introducing an abductive reasoning frame assists in overcoming decision biases leading to higher rates of acceptance of innovation projects with no significant increase in Type-II errors (Mounarath et al., 2011). In this paper, we delve further into this problem by examining the language of the discussion within the committee as they are making the decision and the efficacy of introducing an abductive reasoning frame on individual and group level decisions in selecting innovation. Based on prior results, we predict a higher likelihood of project acceptance for individuals who apply an abductive reasoning frame, but, in this paper, we base the data on the language of abduction in the deliberations.

1.2. Logical forms of reasoning

The three forms of reasoning considered in this study are deduction, induction, and abduction. Briefly stated, deduction is a form of logical reasoning from a premise and an observation leading to a conclusion that is guaranteed to be true. An induction is a general principle derived from the observations. An abduction is the most likely explanation for a set of observations. Examples of these three forms of logical reasoning in the context of selecting an innovation project can be seen in the table below:

Table 1. Three logical forms of reasoning considered in this study

1. Deduction	2. Induction	3. Abduction
• Inaccurate location-based apps are not needed • This is a location-based app with inaccurate position data • This app is not needed	• This is a location-based app • This app is useful • All location-based apps are useful	• This app is one of the most useful • Location-based apps are useful in everyday life • This app is a location-based app

While there is a broad and deep literature on the formal logic of these forms of reasoning, the literature is nearly silent on how these forms of reasoning might appear in natural language. To enable the identification of these forms of logical reasoning in natural language dialog, we postulate their forms of linguistic realization based on the formal logic principles underlying them. We start with the two most straightforward ones, deduction and induction. Because deductive reasoning leads to a definite conclusion, we believe that an appropriate linguistic realization for deduction is an explicit appraisal or judgment of the product (Dong, Kleinsmann, & Valkenburg, 2009). Because deductive logic is guaranteed to be true or false, the direction of the decision must likewise be clear, either accept or reject. Induction involves the establishment of a general principle based on the observations. We believe that induction would be realized linguistically by a process of semantic densification (Maton, 2011), such as by packaging up a series of concepts into a single nominal group or linguistic technicalization, the use of a common word with a specialized meaning specific to the context of discussion. For example, when designers use the word 'requirements', they technicalize the use of this word both in the context of design and in the context of the specific design problem, that is, what requirements are in design processes and the specific ones associated with their current design project.

The most complicated form of logical reasoning to identify in natural langauge is abduction, particularly since what counts as abduction in design is not entirely agreed upon. Abductive reasoning in design emphasizes the projection of a possibility rather than the explanation of observations through a plausible hypothesis. Dorst (2011) proposes that abduction in design consists of creating new frames for a new 'something' that addresses the design problem, a new 'how' or a new 'working principle' to account for the new 'something', or bringing in a new framing from the outside. It is important at this point to identify the similarities and differences between a design frame and a decision frame. Design frames provide ways of 'seeing' to establish the parameters of the design problem and its solution, or both, and set up a rationale for why courses of action were undertaken. Decision-making frames guide or limit the decision-making process by including or excluding information. The important difference between the two is that design frames impose an order on the current situation to explore possibilities, which results in new possibilities or 'moves' (Stumpf & McDonnell, 2002). This is the type of abductive design framing that Dorst refers to. Likewise, Roozenburg, citing Habermas, explains that such abduction in design is best described as innovative abduction as opposed to explanatory abduction, because innovative abduction entails a new, unexplained fact (e.g., the proposed project) for which a rule is produced to explain the fact (e.g., why the project proposed would exist) (Roozenburg, 1993). Roozenburg concluded that innovative abduction is the only appropriate form of abductive reasoning in design, because design entails determining the set of conditions for which the conceptualization of the product would be true. Adapting these theories about abduction to the empirical analysis of abduction in natural language, we define abduction as framing and projecting the conditions of possibility for the existence of the proposed product. We used this definition to produce criteria to code for abduction in the transcripts.

2. Methodology

2.1. Experiment design

An experimental and quantitative methodology was chosen as it provided the opportunity to create the right conditions to test the underlying theory and hypotheses of the research questions posited. We described the experiment design completely in another paper (Mounarath et al., 2011), and summarize the key parameters here. The experiment is a 2×2 factorial design with the factors (independent variables) being the reasoning frame (RF) as either deductive/inductive or abductive reasoning frame and the voting rule (VR) as either single vote to accept or a consensus vote to accept. Two founding

directors were assigned at random at the beginning of each experimental session. The founding directors, unknowingly, were given the special role of indoctrinating the *abductive* or *deductive/inductive* reasoning frame by reading out an address to the board at the commencement of session. The abductive address emphasized "*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.*" In contrast, the deductive address emphasized determining "*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*." Twelve groups consisting of 5 participants per group reviewed 7 projects (with controls implemented to reduce grounding bias) to decide which project would be worthy of investment for further development. Individuals and groups could select none, some, or all of the projects for further development. The 7 projects consisted 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. Projects chosen for the study, by the instructor of the course AD, have similar levels of technical feasibility, novelty, and potential customer value so that the determination of creativity and innovation, and therefore project selection, would not be obvious. 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

Decisions can be affected by the manner in which choices are presented, which is known as the framing effect (Gilovich, Griffin, & Kahneman, 2002). We minimized this framing effect by having a standard template for the presentation of the projects using line drawings of similar quality and completeness as practicable. Groups were given exactly 5 minutes to discuss each project.

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:

8. I think this project is novel
9. I think this project is creative
10. I think consumers will be accepting of this product
11. I think this project has market potential
12. I think this project is technically feasible
13. I think this project should be accepted

For questions 1 to 5, a score was allocated to each response: Strongly disagree = 1; Disagree = 2; Neutral = 3; Agree = 4; Strongly agree = 5, and a binary for question 6. The sum of responses 1-5

assigned to each project after committee deliberation provided the basis for the analysis predicting the influence of the reasoning frame and decision rule on the total score assigned to each project. Group-level decisions of accept/reject were identified with a show of hands at the end of deliberations. To motivate participants to make optimal decisions, we structured the reward such that they would receive a higher monetary reward if they selected the same projects experts had (which could have been none, some or all).

2.2. Coding development and scheme

We followed a three stage process to code the transcripts. Given that the research literature on the linguistic realization of logical reasoning in natural language is non-existent, in the first stage, we started with theoretically-grounded criteria, as described above, for ways in which deduction, induction, or abduction could be linguistically realized. RM and AD read several transcripts, highlighting portions of the text realizing a deductive, inductive, or abductive reasoning frame. In the second stage, they met to discuss the initial criteria and associated examples to determine if the coding scheme provided sufficient coverage of instances of forms of logical reasoning in natural language and clarity to reduce disagreement. Based upon this discussion, a final set of criteria was produced to code the transcripts. A spare transcript was coded and arbitrated with further clarification of the criteria until the inter-coder reliability (based on Krippendorf's alpha and Cohen's kappa) on this transcript was higher than 0.80, which is considered acceptable (Lombard, Snyder-Duch, & Bracken, 2002). The final coding scheme is shown in Table 2.

Table 2. Coding scheme for reasoning frame

Reasoning Frame	Criterion	Example
Deductive	Drawing a conclusion based on implicit or explicit premise but observation explicit	*Because GPS do exist today and we have seen this sort of stuff existing already, so it's not a completely new idea, I guess.*
Deductive	Stating the premise and/or observation for a deductive conclusion in relation to established decision criteria	*I think that iPhone apps are like everyone has an iPhone so you're already tapping into a huge potential clientele and then after that I mean lots of old people like 80 percent of old people go to nurseries and all that kind of stuff and like flowers and plants, so they're going to like it.*
Deductive	Personal judgment on the value of the project if decision maker accords the judgment sufficient priority in determining acceptance or rejection	*It's just another gadget though. I don't think that it's going to work. I don't think it's that big.*
Inductive	Generalization based on specific instance	*We're so lazy, that anything that saves us walking up to switch the light switch on and off is everyone's.*
Abductive	Reframing users/users' needs in a different way than as proposed in the project brief	*I think this would be good for sick people who are like alone. They don't have any friends or families and this helped them to remind them to take their medicine.*
Abductive	Framing conditions (causal precedents) for future (im)possibility of the project	*You're already looking at the necessity for a widespread use from the very beginning to make this work.*
Abductive	Framing or simulating alternative contexts of use	*But you can also use it for like busy people for terminal disease or something like that.*
Abductive	Reframing the product as a different kind of product from what is actually	*Let's say it's not a jacket anyway. I don't think the jacket matters right now. Because it does make a point*

Reasoning Frame	Criterion	Example
	proposed	*because you're not looking at a full map. You're looking at just lights blinking.*
Abductive	Modifying structural or behavioural aspects of the product	*Unless there's a lid on there's not even going to be vaguely effective. If there's a lid just that like seals.*
Decision	Accept, reject or unknown decision (abduction only) preceded by a form of logical reasoning	*But on the other hand I see … direct selling this to mothers who are really afraid, that sort of market. That's about the only thing I see and because it's cheap they could turn a profit from it. I don't think it's very good.*

RM and AD both coded all the transcripts for form of logical reasoning and decision direction according to the criteria described in Table 2. Because discussions were limited to 5 minutes, almost all of the content was relevant; there was very little idle banter. We were careful not to code discussions that were only about the analysis of a project without the committee member according sufficient priority to the analysis as the basis of an evaluation. For example, in discussing a device to help parents track their children, a committee member states, "*You don't just know where your college kid is. You know where someone else's kid is too. It gets a bit too-- I have some privacy issues with it.*" While there is a clear negative tone in the needs analysis (location of child), it is not clear how the analysis contributes to a conclusion based on logical reasoning, and thus it was not coded for a reasoning frame. In short, we were not simply coding product appraisals (Dong et al., 2009); rather, we were aiming to code instances of logical reasoning. The Krippendorf alpha (Hayes & Krippendorff, 2007) and Cohen's kappa coefficients across all the transcripts were calculated after both coders completed a transcript. When they were below the 0.80 threshold, the transcript was re-coded until an acceptable level was reached, which is a stricter methodology than generally required (Lombard et al., 2002). The final inter-coder reliability statistics are reported in Table 3 and Table 4 (Cohen's kappa only due to correspondence between α and κ in Table 3).

Table 3. Inter-coder reliability for reasoning frame

Group	1	2	3	4	5	6	7	8	9	10	11	12
α	.8244	.9001	.9747	.8295	.8196	.8487	.8410	.851	.8737	.9487	.8746	.8458
κ	.824	.9	.975	.829	.820	.849	.841	.8508	.874	.949	.874	.846

Table 4. Inter-coder reliability for decision direction

Group	1	2	3	4	5	6	7	8	9	10	11	12
κ	.824	.883	.924	.805	.836	.791	.842	.852	.812	.932	.875	.830

3. Results

The effect of taking a deductive or abductive frame is that a deductive reasoning frame leads to project rejection and an abductive reasoning frame is used to support project acceptance. This is exemplified by the following discussion between two committee members about the mobile phone application that assists in tracking urban re-vegetation. In the excerpt, we italicize portions of the dialog that realize deductive or abductive frames. In the deductive framing, there is a tendency toward rejecting the project, whereas the abductive reasoner tries to identify potential contexts of use and users. Further, this case is representative of many discussions wherein abductive reasoning is used to

counter negative deductive reasoning or when the discussion is trending toward rejecting the project. Deductive: So wouldn't all sort of the success of this hinge on lots of users using it, like wanting to use it? So *there has to be a demand. If there's not,it's totally useless, because it relies on users going around and taking photos of plants*. And say you're in an area where it wasn't taking off,it wasn't popular, then the whole thing just failed, because why would you use it when there's one or two plants around the whole of Sydney? And *then you wouldn't have any sort of motivation to find*...Abductive: But then I think also you've got to take into consideration-- like *maybe around Sydney it's a bit different when you're in a city, but, I mean, if you take like an entire country*, for example, I think there are definitely more specific areas where there's obviously a lot more vegetation, plant life. I mean, yeah, it's not something that's definitely for everyone, but I just think there would be a lot of-- there are a lot of people who just try and-- *it could be everyday people who are just trying to find a certain plant*, and *people who are interested*. I don't know. I really like the technical side of this one, and I...In deductive framing, the committee members generally start from a premise, often unstated, describe one or more characteristics of the proposed project as satisfying the premise to draw a conclusion. Premise: Products with limited features are not suitable for the market. [Implied by decision criteria] Observation: *... more features than this, so this is very, very basic. Too basic.* Conclusion: *No, this will definitely need a lot more details.* In contrast, in abductive framing, the committee makes one or more observations about the proposed product, but rather than reaching a logical conclusion, the committee members attempt to explain through questioning, proposing, or hypothesizing the conditions of possibility for the existence of the product. In the following excerpt, a committee makes an observation about a problem with the pricing for a proposed product. To explain that this is not actually an issue, the committee member proposes a plausible scenario personal and context of use. Observation: *You need the gadgets though, the actual sense of. That might be a problem in terms of pricing.* Hypothesis: *Just aim for rich people. … I mean rich people like new things because they always want to show it off to their friends and stuff. [unintelligible] pour me a drink. Make me a sandwich. Pretty cool.* Perhaps the most important consequence of taking an abductive reasoning frame is that abduction can change a committee member's preference toward a project: In my self-evaluation I wasn't that keen on it but now that I think about it, *homeowners that you've got a garden will work out what kind of plant you'll put in there will be a great resource*. We performed statistical analyses to determine the effect of the reasoning frame and the voting rule on project acceptance. An OLS regression, Equation 1, was used to determine the effect of the following independent variables: (i) percentage of abduction per project; (ii) percentage of deduction per project; (iii) voting rule; and, (iv) reasoning frame, on the dependent variable, total score per project assigned by each committee member. The regression variables are: (i) LR = percent of form of logical reasoning; (ii) $p_1 - p_7$ 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; (iii) 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; and (iv) 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. We combined these two reasoning frames due to the extremely limited cases (less than 5) of inductive reasoning in the data. The total recorded observations of abduction or deduction per project were aggregated between the coders, RM and AD, followed by a determination of the average occurrence of logical reasoning per project (LR).

$$\text{TOTAL SCORE} = con + \beta_1(LR) + \beta_2(p1) + \beta_3(p2) + \beta_4(p3) + \beta_5(p5) + \beta_6(p6) + \beta_7(p7) + \beta_8(VR) + \beta_9(RF) \quad (1)$$

Table 5. OLS regression with Total Score per project as the dependent variable

Independent Variable	% Logical Reasoning per project (LR)	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Voting Rule (VR)	Reasoning Frame (RF)	Constant (con)
OLS (LR = % Abduction per project)	2.081*** (0.568)	5.360*** (0.547)	3.558*** (0.568)	2.090*** (0.542)	Base Case	4.487*** (0.540)	1.157** (0.540)	4.120*** (0.542)	-0.678** (0.292)	0.839*** (0.289)	12.833*** (0.494)
OLS (LR = % Deduction per project)	-2.591*** (0.555)	5.44*** (0.542)	3.391*** (0.544)	2.128*** (0.536)	Base Case	4.363*** (0.536)	0.735 (0.541)	4.050*** (0.535)	-0.689** (0.289)	0.943*** (0.288)	15.148*** (0.528)
p-value	* $p<0.10$	** $p<0.05$	*** $p<0.01$								

The results of the OLS regression (model significant at the $p<0.01$ level) confirm that the effect of all four independent variables are significant ($p<0.05$ *two-tailed*). The key results relevant to this study is that the coefficient of the percentage of abduction per project (LR) indicates that groups under abductive framing tend to put a total score 2.08 greater than those that are under the deductive framing. The coefficient of the percentage of deduction (LR) indicates that groups under deductive framing tend to put a total score 2.59 less than those that are under the abductive framing. What is significant about this result is that reasoning frames are an effective intervention confirming our prior findings (Mounarath et al., 2011), that is, an abductive reasoning frame tends to result in a higher level of project acceptance whereas a deductive reasoning frame tends to result in a higher level of project rejection. We similarly ran a probit analysis (Equation 2) with the same regression variables to determine the probability of project acceptance.

$$\Pr(\text{accept}) = \Phi[con + \beta_1(LR) + \beta_2(p1) + \beta_3(p2) + \beta_4(p3) + \beta_5(p5) + \beta_6(p6) + \beta_7(p7) + \beta_8(VR) + \beta_9(RF)] \quad (2)$$

Table 6. Probit regression with Individual accept/reject decisions as the dependent variable

Independent Variable	% Logical Reasoning per project (LR)	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Voting Rule (VR)	Reasoning Frame (RF)	Constant (con)
Probit (LR = % Abduction per project)	0.856*** (0.309)	6.137 (105.477)	5.637 (105.477)	4.563 (105.477)	Base Case	6.077 (105.477)	3.940 (105.477)	5.745 (105.477)	0.266* (0.153)	0.523*** (0 .152)	-6.408 (105.477)
Probit (LR = % Deduction per project)	-1.015*** (0.305)	6.244 (104.732)	5.631 (104.732)	4.641 (104.732)	Base Case	6.119 (104.732)	3.840 (104.732)	5.790 (104.732)	0.291* (0.152)	0.595*** (0.156)	-5.596 (104.732)
p-value	* $p<0.10$	** $p<0.05$	*** $p<0.01$								

The results of the probit regression (model significant at the $p<0.01$ level) are consistent with that of the OLS regression and confirm our priors with the key results being that the percentage of abduction per project ($p<0.05$), percentage of deduction per project ($p<0.05$), voting rule ($p<0.10$) and reasoning frame ($p<0.05$) all have a significant effect on the likelihood of acceptance/rejection of projects by individual committee members. Due to lack of space, we do not present the full statistical analysis to show that percentage of logical reasoning per project (LR) was not statistically significant when analyzed at the group level. In other words, there is no causal relationship between the frequency of occurrence of abductive or deductive forms of logical reasoning and each committee's final accept/reject decision. The implication of this finding is that in a committee structure, having too few people who are abductive 'design thinkers' can result in a decrease of project acceptance. This may depress innovation if the committee ends up letting an opportunity for innovation pass by. In the "fuzzy front end of design" wherein groups of people are (still) trying to decide what is an innovative

product or service under incomplete information, this research shows that cognitive strategies have a significant influence on decisions.

4. Conclusions

We described a qualitative content analysis of forms of logical reasoning in natural language. We applied a set of criteria for the analysis of forms of logical reasoning to experiments on committees selecting innovation projects, which entailed judging the creativity, novelty, market acceptance and technical feasibility of the projects. Consistent with our prior statistical analysis, we showed that abductive reasoning generally leads in or is used to support project acceptance, whereas deduction is associated with project rejection. Further, committee members applied abductive reasoning to counter negative deductive logic by other committee members. We do not prescribe abduction as the preferred mode of reasoning in choosing innovation; rather, we point out that the determination of the innovation of projects is altered by the form of logical reasoning. If firms wish to accept more innovation projects at early stages of development, they may do well to inculcate abductive forms of reasoning in the selection process so as not to 'kill off' potentially lucrative and innovative projects prematurely. Recognizing when forms of reasoning occur may also help committees to take opposing strategies so as to minimize Type-II errors (Gebert, Boerner, & Kearney, 2010).

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