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CREATIVITY AS A WAY TO INNOVATE SUCCESSFULLY

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Abstract

Selecting innovative design concepts for further development entails decision making under conditions of sometimes extreme uncertainty pertaining to technical feasibility and market potential. In such situations, decision makers all too often become risk averse and reliant on known metrics that are inherently based on deductive and inductive logics. In prior research, however, good decision making on innovation has been linked with the complementary use of another form of logic: abductive reasoning. Abductive reasoning changes the mind-set of decision makers to become intrinsically forward thinking and explorative towards innovation opportunity. In this paper, we present an experimental study suggesting that the cognitive, creative capabilities of humans correlate positively with their use of abductive reasoning in decision making. We are further able to show that a higher level of abductive reasoning leads to significantly better, i.e. more accurate, decisions in selecting successful innovation concepts. These findings have strong implications for companies seeking to improve their innovative performance, specifically, how and by whom decisions on innovation should be made.

Keywords: Abductive reasoning, Design thinking, Decision making, Innovation, Creativity

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1 INTRODUCTION

In recent years, market turbulence has created uncertainty that challenges companies' capabilities to create profitable growth through good strategic investment decisions. Large potential lies in the acquisition of superior resources and capabilities by becoming a first-mover through investment in innovations that are not yet established in the market, instead of relying on conversant product or service offerings (Lieberman and Montgomery, 1998). This strategy demands decision making about innovative design concepts under conditions of extreme uncertainty. Empirical studies show that these very decisions, however, are often faulty due to the bounded rationality of decision makers (Tversky and Kahneman, 1986). Humans strive for certainty; they base their choices on quantifiable metrics such as financial forecasts, the quality of a design, or formal analytics, such as Net Present Value (NPV) or Internal Rate of Return (IRR). Despite their potential to mitigate human error (Zacharakis and Meyer, 2000), quantifiable metrics heavily rely on detailed information, which is rarely available for early-stage innovation concepts. Moreover, they have strong limitations when it comes to coping with dynamically changing user needs and global competition (Garbuio et al., 2015). In fact, studies have shown that in situations that demand for decisions to be made under uncertainty, executives tend to have little confidence in formal analysis (BCG, 2010). Instead, they tend to rely on their intuition (Huang and Pearce, 2015) and screen new ideas for properties that are believed to be recurring patterns of successful projects (Baron, 2006). Yet, just like heuristics, such approaches are prone to decision myopia (Lovallo and Sibony, 2010). As a result, many innovation concepts are rejected for funding though they carry substantial potential (referred to as 'Type-I Error'), while others are funded which carry only little potential but are closer to what is known to have worked in the market earlier (i.e. 'Type-II Error').

The underlying cognitive strategies applied in such selection processes tend to be based on deductive and inductive logics, i.e. they try to prove an outcome (in this case, the market success of an innovative design) by applying known rules or by determining a sensible course of action from comparison to similar products/services that are already on the market, respectively. As an alternative, researchers promote design thinking, and its kernel, abductive reasoning (Dorst, 2011; Roozenburg, 1993), to support decision making on innovation within companies (Dong et al., 2015). In abductive reasoning, a hypothesis is formed to explain how to achieve a desired, but not yet existent, outcome when both (a) the context under which the outcome is likely to occur and (b) the means, i.e. the product or service that can produce the outcome, are not known yet (Dorst, 2011). In the field of decision making under uncertainty, decision makers thus will make a mental proposition of a scenario in which an innovative design concept will be successful and then try to generate an explanation as to how this outcome might be plausibly attained. In contrast to deductive and inductive reasoning, decision making is then no longer focused on the innovation concept as it is presented at the very point in time of the decision, but becomes intrinsically forward-thinking, trying to apprehend future market potential. Research has shown that committees tasked with selecting innovation concepts for funding performed significantly better (i.e. they made more accurate decisions) when manipulated into applying a higher rate of abductive reasoning within their selection processes (Dong et al., 2015; Mounarath et al., 2011). At the same time, more innovative projects were chosen. We therefore believe, abductive reasoning has important implications for companies that seek to launch more innovative products or services (see also Talke et al., 2009).

In designing, abductive reasoning is considered vital to find novel solutions, just as the creative cognitive processes inherent to it, specifically divergent thinking (Finke et al., 1992). By extension, it stands to reason that people who have higher creative capabilities should also have higher capabilities in applying abductive reasoning. This link has, however, not been investigated thus far. Typically, creativity is linked in research with personality traits such as extroversion and intelligence (Batey et al., 2009). Yet, the cognitive strategies that are vital for creative, divergent thinking, such as the use of analogies and associations in generating novel design solutions (Gilhooly et al., 2007), are indeed very similar to the process of abductive reasoning (compare Dorst, 2011; Gonzalez and Haselager, 2005).

In the study presented in this paper, we investigate differences in the use of abductive reasoning among highly creative individuals in comparison to less creative ones in decision making on innovation concepts. If creative thinking and abductive reasoning capabilities are indeed linked, we expect to find evidence of stronger abductive hypotheses made during decision making with highly creative people. Following the prior research by Mounrath et al. (2011) and Dong et al. (2015), these participants should also make more accurate decisions in selecting innovations. We conduct an experimental study of individuals selecting real-life innovation concepts to either fund their further development or waive them early. In the following, we first review extant literature on abductive reasoning and creativity, then we present our study and the obtained findings in Sections 3 and 4. We conclude in Section 5 with a discussion of our results and their implications for research and industrial practice.

2 ABDUCTIVE REASONING AND CREATIVITY

2.1 Forms of reasoning

The theory of abductive reasoning goes back to Peirce (1932), who worked on it for several decades. Abductive reasoning introduces hypotheses and theories to explain a given result and is the only form of reasoning that can produce new knowledge. Deductive and inductive reasoning, conversely, build upon existing knowledge and established rules (see, e.g., Fischer, 2001). Deduction forms conclusions based on what is already known and what can be categorised as fundamental principles or general laws (if this, then that). Induction uses observations of a phenomena (effect or outcome) in a specific context to build an explanation (or hypothesis) of the mechanism (cause) that led to the observed effect (that, because of this). For both induction and deduction (nearly) all relevant parameters and contingencies must be known to draw reliable conclusions.

We will illustrate this with a simple example. We know the fundamental physio-chemical laws that apply to water. A deductive way of predicting the state of water would be to simply apply the known rules to a known set of environmental conditions. Without seeing it, we can easily deduct that water in a glass in the office next to ours will under all probability be liquid right now. For induction, we recall our last 20 observations of water in a glass and based on them form a rule stating that "water is typically liquid". The reliability of this rule is, of course, strongly dependent on the variation of external conditions under which we have observed the glass of water in the first place. When it comes to early-stage innovation, these two ways of reasoning provide little help, as by the time of market introduction, the water may have been developed further into a new type of lemonade.

This comparison is arguably much too simplistic, yet it does shed light onto the conditions of extreme uncertainty that decision makers are faced with in relation to filtering early-stage innovation. Despite the described fallacy, humans tend to predominantly rely on deductive and inductive reasoning in such selection processes (e.g., Cornelissen and Clarke, 2010). Often, deductive/inductive logic proves to be very useful in relation to rejecting unsuccessful projects. Conversely, however, it is extremely hard to prove future success of innovation by relying solely on the same deductive/inductive logics. Decision makers, therefore, all too often become risk averse and revert to scrutinising proposed innovation concepts mainly for resemblance to patterns that are believed to apply to successful designs (Baron, 2006). Hence, truly innovative design concepts are all too often dismissed as they naturally show dissimilarities to these patterns.

Abductive reasoning, in contrast to deductive and inductive logics, generates possible hypotheses based on the information available at the time to explain given facts (or observations, respectively). Two different types of abduction are differentiated: explanatory abduction and innovative (or creative) abduction (Dorst, 2011). The first synthesises complex, contradictory or incomplete information to determine a likely cause of an effect (see also Kolko, 2010). The latter predefines unknown variables to explain how it will effect a given parameter. This means that abductive reasoning can help build mental models of future scenarios and their likelihood. Following this argumentation, Mounarath et al. (2011) and Dong et al. (2015) suggest that this type of reasoning can also be used to evaluate the merits of innovation concepts by virtue of mentally expanding the given idea from a concurrent state to a likely future situation. Hence, especially during earlier development phases when market conditions are likely to change, abductive reasoning can help to explain the causal reasons for future opportunities. In fact, their research showed that when stimulating groups of decision makers into using a higher ratio of abductive reasoning during design concept selection, their decision-making accuracy rose. That means groups performed better at identifying successful and unsuccessful innovation concepts correctly. At the same time, the effects of pattern recognition biases were reduced due to the intrinsic change in the form of reasoning applied, leading to a more thorough future-oriented exploration of the projects' potentials. Extending from these findings, two central hypotheses are formulated:

> H1) A higher level of abductive reasoning leads to more accurate decisions on the successfulness of innovation concepts.
>
> H2) A higher level of abductive reasoning leads to a higher rate of project acceptances.

2.2 Creativity, divergent thinking and abductive reasoning

Innovative abductive reasoning relies on mental capabilities that are also inherent to creativity (see above). In the creative process, ideas are often the result of an association process, which evolved based on a clearly defined set of limitations and objectives (Davies and Talbot, 1987). This process requires the identification and implementation of an idea generation strategy and recognition of unsuitable and/or non-original ideas (Nusbaum and Silvia, 2011). While scholars are at a strife if creativity is dependent on the intelligence of an individual, it has credibly been linked to personality traits and cognitive strategies (see Silvia, 2008; Batey and Furnham, 2006). Cognitive strategies applied by creative people are related to abstraction of knowledge and semantic relation (Gilhooly et al., 2007). This entails abstraction and recombination of remotely related concepts across domains by use of analogies.

Both creativity and abductive reasoning aim to produce something novel for the future, i.e. something that does not exist yet in the market place in a similar form or proliferation. Due to this, we expect abductive reasoning to contribute to the creative process and therefore it is likely that creative people apply higher levels of abductive reasoning. This then begs the question whether creative people will perform better when making decisions on innovation concepts than less creative individuals. Formulated as hypotheses, we therefore advance H1 and H2 into the following propositions:

H3) More creative people apply more abductive reasoning than less creative people.

H3.1) More creative people make more accurate decisions when selecting innovation concepts than less creative people.

H3.2) More creative people accept more innovation concepts than less creative people.

3 STUDY

In order to test the formulated hypotheses, we used a combined qualitative and quantitative approach in investigating individual investment decisions on innovation concepts. The purpose was to test whether highly creative people use more abductive reasoning than less creative individuals, and whether abductive reasoning has an effect on both accuracy and the overall amount of the chosen innovation projects. We conducted an experiment comprising a creativity test and subsequent individual decision making on real-life innovation concepts sourced from renown crowdfunding portals. The participants were first asked to complete an Alternative Use Test to measure their creative capabilities. They were then presented with briefs of five innovation projects for which they had to make funding decisions. We followed clear criteria in selecting the projects and generating the related design briefs (see below); the projects' success was determined based on their reception by a large user group. This information was then used to evaluate the accuracy of the decisions made by the participants. Three projects are deemed unsuccessful, two successful.

3.1 Participants

We recruited 51 participants (35 males, 16 females) from Dutch universities via email. On average, the participants were 24.5 years old (SD = 3.75, range from 19 to 39 years). Participants' educational backgrounds comprise design, engineering, business, and science. All of them have attained a high school degree and subsequent tertiary education ranging from ongoing Bachelor degrees to Master and PhD degrees. We chose this sample as most crowdfunding campaigns target – and also attract – younger generations and students. Participants should hence be well suited to evaluate the proposed projects. For the experiment, all participants completed an online survey on a voluntary basis. The participants were presented the same survey with the same five projects displayed in randomised order. Each participant was asked to make 5 investment decisions, amounting to a total of 255 individual decisions which is sufficiently large for statistical analysis. The survey was pilot-tested to ensure intelligibility.

3.2 Data acquisition

The online survey was administered on Qualtrics. Subjects took between 30 and 45 minutes to finalise the task. Three different parts had to be completed: (1) the Alternative Uses Test, (2) reading the design briefs and making investment decisions, and (3) demographic questions. The Alternative Uses Test evaluates cognitive processes closely related to the cognitive processes of analogy, association, and combination (Welling, 2007). The test consisted of two questions granting participants two minutes each time to come up with as many alternative uses as possible for two objects, a brick and a jar (compare Guilford, 1971).

In the next part, the five project briefs were presented in a randomised order. After having read all projects, subjects would then see the projects again in a randomised order and asked to make their assessments. It is vital for participants to read all projects prior to making any decision, as the first project viewed might otherwise lead to an anchoring bias (compare Tversky and Kahneman, 1974). The assessment comprised three steps. First, participants were asked *to "list up to 10 possible extensions of this project that could create new, viable follow-on business opportunities in the next 2-3 years*". Asking the participants to generate such extensions to the projects stimulates abductive reasoning by virtue of manipulating the participants to mentally expand the projects into a future outcome scenario, which necessitates making and explaining hypotheses about future developments for the products. This is more than a simple divergent thinking exercise as the hypothesised scenarios also need to be feasible within the given time span (i.e. 2-3 years) and have to likely entail viable business ventures. The latter requires more than just future thinking, but also to link such thought with societal, market-related and technological trends. This is concordant with innovative abductive reasoning after Dorst (2011) and Roozenburg (1993, see Section 2.1). Generating the extensions to the projects was succeeded by a simple YES/NO decision on whether the participants *"would fund this project"*. Finally, participants were asked to *"give 2 to 5 reasons for their decision"*. Both the project extensions and reasons provided to explain the investment decisions were later used to analyse the level of abductive reasoning applied.

3.3 Project selection and briefs

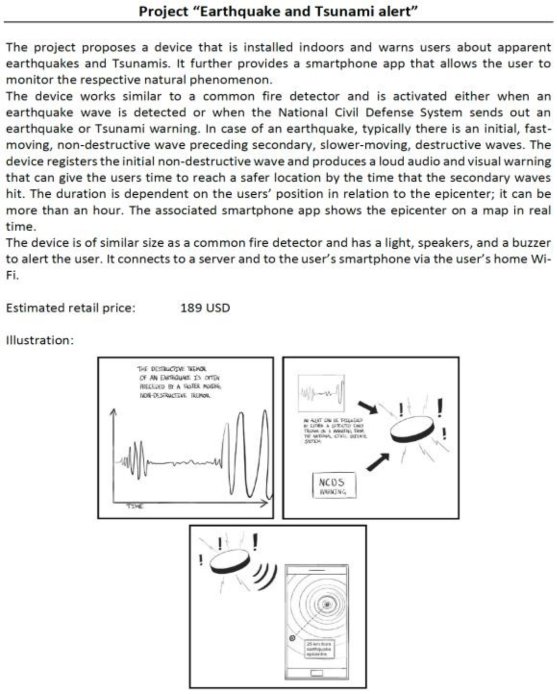
The projects presented were derived from innovation concepts pitched on popular crowdfunding platforms: Kickstarter.com and Indiegogo.com. Following Kornish and Ulrich (2014), the success or failure of the crowdfunding campaign was used to determine the project's success/failure on a real market. The success of the crowdfunding campaign was deemed a suitable criterion as the status of the projects presented on these websites resembles that of early-stage design concepts and the outcome of the funding campaign was found to correlate with eventual market success (Kornish and Ulrich, 2014). To avoid ambiguity in our analysis about the potential success of the selected projects, successful projects selected had to have reached at least 200% of their initial funding goal of the crowdfunding campaign, whereas unsuccessful ones needed to remain below 50% of the targeted sum. The projects chosen were all advertised for the same duration on the websites (6 weeks) and requested a similar funding around 50.000 USD (with a variance of 15.000 USD either way). All projects were consumer products with extendable features that combined hardware and software parts in the field of electronics or Internet of Things (IoT) through smartphone connection. The projects chosen for the study were:

- A smartphone case with an inbuilt electronic writing board for notes (unsuccessful, -41.873 USD).
- A wristband that can be programmed via a smartphone app to follow certain behaviours and administer pre-programmed rewards or punishments accordingly to help users change habits (successful, 198.002 USD).
- An earthquake and tsunami alert system including a smartphone app that allows the user to monitor the respective natural phenomenon (unsuccessful, -34.521 USD).
- A wirelessly operated bicycle tail lamp including direction indicators and a brake light (unsuccessful, -38.197 USD).
- A portable electronic musical instrument that can play sounds of over 50 different instruments (successful, 182.576 USD).

The projects were rigorously turned into succinct briefs following strict rules to avoid systemic errors from a potential framing effects:

- Start: Two sentences describing the central function of the proposed product, i.e. what is it for?
- Main part: Two to four sentences about how the product fulfils the intended purpose, i.e. how does it work?
- End: Two sentences describing the structure, its appearance, and relevant technical specifications, i.e. what is it made of and what does it look like?

Sentence structures in all parts were standardised as much as possible following inspirations by Kosminsky et al. (1981). Furthermore, following suggestions by Goldschmidt and Sever (2011), the text was complemented by small visuals illustrating how a user is supposed to use the product. Visuals were produced by a professional illustrator in the form of three to five pictures storyboards. An example of a project brief is provided in Figure 1.


Project "Earthquake and Tsunami alert"

The project proposes a device that is installed indoors and warns users about apparent earthquakes and Tsunamis. It further provides a smartphone app that allows the user to monitor the respective natural phenomenon.
The device works similar to a common fire detector and is activated either when an earthquake wave is detected or when the National Civil Defense System sends out an earthquake or Tsunami warning. In case of an earthquake, typically there is an initial, fast-moving, non-destructive wave preceding secondary, slower-moving, destructive waves. The device registers the initial non-destructive wave and produces a loud audio and visual warning that can give the users time to reach a safer location by the time that the secondary waves hit. The duration is dependent on the users' position in relation to the epicenter; it can be more than an hour. The associated smartphone app shows the epicenter on a map in real time.
The device is of similar size as a common fire detector and has a light, speakers, and a buzzer to alert the user. It connects to a server and to the user's smartphone via the user's home Wi-Fi.

Estimated retail price: 189 USD

Illustration:

Figure 1. Example of a project brief

3.4 Measures

3.4.1 Assessment of creativity

In order to measure the creativity of the participants, we adopted three alternate scoring systems, namely *Yamamoto sum-scoring* (Yamamoto, 1964a, 1964b), *ideational sets* (Runco and Mraz, 1992), and *weighted flexibility* (adopted from *weighted fluency scoring*, Runco et al., 1987), to arrive at a grouping of highly creative and less creative individuals. The results from the Alternative Uses Tests for a brick and a jar were first rated using an adaptation of Runco et al.'s (1987) weighted-fluency score. While they calculate the sum of the frequency of each individual idea given by a participant, we calculated the sum of the frequency of each individual category given by a participant, turning the measure into weighted-flexibility. As an example, a category given by 5 participants receives an initial popularity score of 0.098 (5 divided by 51). Since we are interested in rating original ideas more highly, the popularity score is subtracted from 1, arriving at a uniqueness score of 0.902 for this category. The uniqueness scores for each individual's categories are then summed. To refine this initial grouping, the responses for the ten persons with a sum score between 5 and 7 were analysed using the ideational set (Runco and Mraz, 1992), and the summation of fluency, flexibility, and originality scores proposed by Yamamoto (1964). The two lowest scoring individuals as per the summation method were also deemed less creative per ideational sets, hence they were classified as less creative. The eight remaining persons were classified as highly creative. Using these scoring systems enabled us to group the 51 participants into 33 less creatives and 18 highly creatives. Since each participant was shown five projects, there are 165 total investment decisions from less creative and 90 decisions from highly creative participants.

3.4.2 Assessment of abductive reasoning

To assess the level of abductive reasoning that each participant used while generating extensions to the projects and justify their investment decisions, we used a qualitative, semantic analysis. First, we divided each answer given into separate ideas, both for the reasons and the extensions. That means, we looked at whether the reasons or the extensions would entail a forward-thinking hypothesis about the project. Based on an individual screening of the ideas and subsequent discussions between the two main researchers conducting the study and two additional experienced researchers in the field who were not involved in conducting the experiment, four scales were developed ranging from 0 (no abductive reasoning) to 3 (strong abductive reasoning) using the following criteria:

- *0 (no abductive reasoning)*: No extensions suggested or only minor design changes proposed, such as simple accessories or colour options.

- *1 (weak abductive reasoning)*: Product-related changes proposed in form and/or structure, how the product achieves its purpose or how a user interacts with it (rule of thumb: variation in the product but the same purpose).
- *2 (mediocre abductive reasoning)*: New context for application proposed, such as place of use but not in the same product category, i.e., the same function is applied in a new context; new type of product that would be in the same product category, addressing similar needs and competing for the same customers (rule of thumb: new type of product/product category or new purpose, but not both).
- *3 (strong abductive reasoning)*: Different kind of concept altogether and possibly a new product category and/or marketing strategy (rule of thumb: new purpose and new product category).

To give an example, as a possible extension of the bicycle taillight (see above) a participant wrote: *"Add GPS tracker pad in case [it is] stolen"*. Here, the bicycle taillight is complemented with a new purpose (in the same product category, i.e. bicycles). This is hence scored as "2" according to the above rules. An example for reasons provided by a participant explaining the decision to accept the wristband project for funding reads like this: *"It could reduce the amount of people who don't take their medicine in time, which could reduce [health] costs"*. The person is suggesting a new context of use and subsequent value proposition strategy (i.e. reduce health costs) that will make the project a market success. Yet, the product itself does not change significantly and still targets the same users. Hence, this is scored as "2". Using the above scales, the two main researchers independently scored all provided extensions and all reasons provided by each participant for the level of abductive reasoning shown. The scores were subsequently compared. All inconsistencies between the scores were discussed between the researchers until consensus was reached.

4 RESULTS

To investigate the effect of abductive reasoning on the decision-making behaviour (i.e. pertaining to H1 and H2) we first calculated Pearson's correlations for all participants. The correlation links the level of abductive reasoning found in the analysis of the provided reasons (REASONING, see Table 1) and the extensions generated (EXTENSIONS) with the decision outcome, i.e. acceptance or rejection of the projects for funding (ACCEPTANCE), and the level of creativity (CREAVITY). Lastly, we tested if the decision correctly coincided with the categorisation into (un)successful projects according to the crowdfunding success (ACCURACY). We find a significant, positive correlation between the level of abductive reasons provided and both project acceptance and the decision accuracy (see Table 1).
We then calculated a linear regression to verify whether the accuracy of a decision can be predicted based on the level of abductive reasoning used, which would be strong evidence for H1. We found that abductive reasoning in the reasons provided indeed explains a significant amount of the variance in the decision accuracy ($F(1, 253) = 5.59$, $p = .019$, R2=.022, R2Adjusted =.018). Abductive reasons provided are a valid predictor of the decision accuracy ($\beta = .147$, $t(254) = 2.365$, $p = .019$). In other words, the more abductive reasoning is applied while making a funding decision, the more likely participants are to make accurate decisions. The level of abductive reasoning found in the generated extensions, however, does not correlate with the decision accuracy. This suggests that only if abductive reasoning enters the explanatory reasoning for or against accepting a project does it lead to a better decision-making performance. Table 1 also suggests that a higher level of abductive reasons provided during the decision-making process led to a higher project acceptance rate. Again, this is confirmed by linear regression (with $\beta = .107$, $t(253) = 2.9$, $p = .004$), which is in strong support of H2.

Table 1. Pearson's correlations for all participants

	REASONING	EXTENSIONS	ACCEPTANCE	ACCURACY	CREATIVIY
REASONING	1	.140*	.181**	.147*	0.22
EXTENSIONS	.140*	1	.192**	-.103	.176**
ACCEPTANCE	.181**	.192**	1	-.212**	.128*
ACCURACY	.147*	-.103	-.212**	1	.032
CREATIVITY	0.22	.176**	.128*	.032	1

***Correlation is significant at the 0.01 level (2-tailed).*
** Correlation is significant at a 0.05 level (2-tailed).*

In the second part of the statistical evaluation, we performed a between-group analysis using the differentiation into highly creative and less creative participants as grouping variable in order to test H3. The results show a significant difference in the use of abductive reasoning during the generation of extensions between the highly creative group compared to less creative participants (with t(253) = 2.15, p = .015), while the level of abductive reasoning found in the provided reasons is similar between the groups (Table 2). This suggests that creative people, overall, indeed use more innovative abductive reasoning. Though this effect primarily shows during ideation rather than in explanatory abductive reasoning in our study, these findings strongly support H3. This is in line with the positive correlation found between the individual creativity scores (CREATIVITY) and the abductive reasoning scores during ideation (see Table 1) (F(1, 253) = 8.10, p = .005, R2 = .031, R2Adjusted = .027). This means that creativity is a valid predictor of abductive reasoning during ideation (β = 0.35, t(254) = 2.85 p = .005). In addition we found a positive correlation between the individual creativity score and the sum of accepted projects. The creativity score predicted the number of accepted projects (F(1, 49) = 6.34, p = .013, R2=.119, R2Adjusted =.10). This means, creativity is a valid predictor of the sum of cases accepted (β = .036, t(49) = 2.576, p = .013), thus supporting H3.2. Furthermore, we observe clear numeral (yet not statistically significant) trend (see Table 2) pertaining to a higher decision accuracy for the highly creative sample (t(253) = 1.37, p = .086). Though this is a strong indicator supporting H3.1 for the moment, the related null-hypothesis cannot be rejected.

Table 2. T-test for between-groups analysis (df=253)

		Mean	SD	sig (2-tailed)	t
EXTENSIONS	Highly creatives	2.377	1.808	.015	2.154
	Less creatives	1.878	1.745		
REASONING	Highly creatives	.455	.836	.438	.155
	Less creatives	.472	.852		
ACCEPTANCE	Highly creatives	.510	.500	.148	1.049
	Less creatives	.472	.852		
ACCURACY	Highly creatives	.488	.491	.086	1.369
	Less creatives	.400	.502		

Further examinations of the data show a negative correlation of abductive reasoning during selection and Type-I errors (r(255) = -.419, p < .001) and a positive correlation between abductive reasoning during ideation and Type-II errors (r(255) = .267, p < .001). We conducted a between-group analysis using the differentiation into highly creative and less creative participants as grouping variable in order to test whether the error-rates differ per group. The results show a nearly significant difference in the occurrence of Type-I errors in the highly creative group (M = .5, SD = .5) compared to the less creative group (M = .7, SD = .46); t(100) = 1.93, p = .058, while the level of Type-II errors is similar between the groups (M = .518, SD = .504; M = .535, SD = .501, respectively, with t(151) = 1.98, p = .84). This means that highly creative people reject less successful projects while accepting nearly equally many (numerally less) unsuccessful projects for funding compared to less creative individuals.

5 DISCUSSION AND CONCLUSION

The insights obtained in the presented experimental study strongly support our hypotheses H1 and H2. This means, while literature advises the use of formal analysis rooted in deductive and inductive logics to inform the selection of options out of a given set of alternatives in innovation management, our research suggests that the complementary application of abductive reasoning can significantly improve the likelihood of decision makers to accurately identify potentially successful and unsuccessful opportunities. Thereby, we were able to confirm the effects of abductive reasoning in supporting early-stage innovation concept selection previously suggested by Mounarath et al. (2011) and Dong et al. (2015). Beyond this prior work though, we further investigate the ability of people to think abductively based on their creative cognitive abilities. We hypothesised that, due to the fact that both creative thinking and abductive reasoning intrinsically rely on a similar set of cognitive strategies (see Section 2.2), people with stronger creative capabilities should be able to apply higher levels of abductive reasoning (H3). Our findings strongly support this central hypothesis showing that more creative people scored significantly higher in the application of abductive reasoning during the extension generation.

In line with H2 (a higher level of abductive reasoning leads to a higher rate of project acceptance), we furthermore hypothesised that highly creative people accept more successful projects than less creative individuals. Our data showed a significant correlation between the individual creativity level and the amount of projects accepted, which supports H3.2. Theoretically, this would automatically entail that more creative people should also be able to more accurately identify (un)successful projects (H3.1). Our analysis provides numeral evidence supporting this connection. Further evaluation of the obtained data suggests that – analogue behaviours assumed – a participant sample of circa double the size of the one used in this study would, however, have already resulted in statistical significance of the observed, numeral trends related to H3.1. For the current sample size already, we calculate an effect size of 0.49 (Cohen's D) for the decision-making accuracy between groups. Though this suggests a "mild" effect only, considering the sample size, it further substantiates our hypotheses. However, in financial decision making, already a small variance often has a huge impact (see Lovallo, and Sibony, 2010). Calculating the actual win/loss of each group, we found that the highly creative group had an actual mean win/loss of ca. 153.000 USD compared to 70.000USD of the less creative group. Furthermore, the former group showed a 22,2% higher decision accuracy compared to the latter.
A potential explanation for the finding that creative people use significantly more innovative abduction during the extension generation but not significantly higher explanatory abduction during reasoning can be found when looking at the theory of creativity and abductive reasoning from a philosophical perspective. The philosopher Kapitan (1990) argues that it is primarily in the knowledge-related part of abductive reasoning, i.e. in our case when available knowledge is appropriated and reinterpreted to build a hypothesis for potential extensions of the innovation concepts, when creativity is used. Hence, the second inference, that is the subsequent evaluation as to how and why the hypothesised extension of the concept is a plausible scenario, is less likely to include creativity. This could explain our findings.
The limited sample size in our study represents a limitation for generalisability of our results. In future research we aim to corroborate the insights obtained. Provided that our findings are substantiated further, this could have important implications as to *how* and *by whom* strategic decisions on innovation should be made within an organisation. Not only did more creative participants select more successful projects for funding, they generally outperformed the less creative group in terms of decision accuracy. Our data also confirmed the results found in prior research that abductive reasoning during selection leads to a decrease of Type-I-errors while the amount of Type-II-errors remains equal. We also found numeral evidence that highly creative people reject less successful projects more often than less creative people. Our research suggests that by selecting individuals with strong creative capabilities (using established creativity tests) to perform the filtering of early-stage innovation concepts within an organisation, a company may be able to boost their growth through innovation substantially.
As a final note, Ames and Runco (2005) and Dyer et al. (2008) performed research in which they showed that successful entrepreneurs produce more creative ideas in comparison to less successful entrepreneurs, and that successful entrepreneurs draw more upon their own thinking to find solutions, instead of using routine ones. Combined with our findings, this would suggest that creative capabilities of entrepreneurs could similarly be used as selection criterion for whom to support. Again, the implication for innovation management, particularly for venture capitalists or angel investors, are substantial and beg further research.

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