21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

SHOW ME THE PICTURES: THE EFFECT OF REPRESENTATIONAL MODALITIES ON ABDUCTIVE REASONING IN DECISION MAKING

Arntz, Sarah; Verbaan, Ruben; Eisenbart, Boris; Cardoso, Carlos
Delft University of Technology, The Netherlands

Abstract

This paper describes a study designed to investigate the effect of concept representation types on the use of abductive reasoning by decision makers when selecting early stage innovation concepts for further development. According to prior research, abductive reasoning can be instrumental to decision makers in terms of generating testable hypotheses about an innovation concept's future developments into concrete, viable product or service offerings. It has furthermore been linked with an increase in project acceptance rates. Here, an experiment is described testing whether visual concept representations promotes higher levels of abductive reasoning than textual concept representations or a combination of visuals and text. The results show that when purely visual concept representations were used, the participants showed a significant higher level of abductive reasoning than when this visual representation was complemented with text. This has managerial implications pertaining to how innovation concepts could/should be presented to selection committees or individuals in companies seeking to increase the amount of innovation projects that pass through a first screening process.

Keywords: Decision making, Innovation, Abductive reasoning, Case study

Contact:
Dr. Boris Eisenbart
Delft University of Technology
Product Innovation Management
The Netherlands
b.eisenbart@tudelft.nl

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 8: Human Behaviour in Design, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

Early stage concept selection plays a crucial role in a company's ability to innovate successfully. Decision makers (such as company executives, venture capitalists, angel investors) have to choose which concepts to pursue before they can be fully explored and tested in the market place. The problem that companies often face, however, is not necessarily a lack of ideas, but rather the filtering and selection of the 'right' ideas (compare Dong et al., 2015). Therein, decision makers have to select the concepts that may have the potential to result in valuable innovations. Their objectives are clear: risking small stakes to find profitable investments, relying on a combination of expertise-based intuition and formal analysis in which intuition trumps analysis (Huang and Pearce, 2015). At the same time, they also have to filter out concepts that lack the necessary potential. However, the fear of misplacing an investment leads many companies to become risk averse. Consequently, many potentially successful innovative concepts are mistakenly rejected in early stages.

Current concept selection processes often include methods that use a deductive way of thinking. Deductive thinking is a form of logical reasoning that aims to prove or disprove the benefits of a concept (Dong et al., 2015; Mounarath et al., 2011). To give an example of a deductive reasoning process, we can construe the following logical chain: exercising is healthy, Tom exercises a lot, and thus we may conclude that Tom is a healthy person. Figure 1 shows the basic underlying principles of this chain of logical reasoning. Deductive logics are used when the 'result' of a scenario is unknown to which, however, an input situation ('thing' in Figure 1) and relevant rules ('working principles') are known.

Another form of logical reasoning is inductive thinking. This form of reasoning takes place when the 'how' in the equation is unknown. The 'how' is then consequently induced by generalisation from a limited number of observation to form (a) rule(s) that could explain the final outcome (i.e. the result in Figure 1). For example, Tom is a football player, most football players are good at sprinting, so Tom - in all probability - is also good at sprinting. Whilst deductive reasoning informs 'justification', inductive reasoning informs 'discovery' (Dorst, 2011).

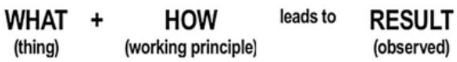

Figure 1. Chain of logical reasoning (c.f. Dong et al., 2015)

Deductive and inductive reasoning are analytical reasoning processes that lead to a prediction of an outcome. In other words, by either applying a known set of rules to a given situation or by forming such a rule based on *analogical reasoning* (i.e. reasoning that entails the comparison of structural similarities between two systems), decision makers try to compare a set of options given to them and pick the one with the best overall utility. This is in line with classical economic theories like Subjective Expected Utility (SEU, see Schmeidler, 1989; Prelec and Loewenstein, 1991). However, both types of reasoning by definition do not create new knowledge about the decision options at hand, but try to evaluate future potential based on the given, concurrent situation.

Dong et al. (2015), however, propose that evaluating the merits of an innovative concept should be intrinsically forward-looking. The reason is that by the time a novel idea is introduced into the market as a concrete product or service offering, market conditions may have changed severely for a number of reasons. A complementary form of reasoning to deductive/inductive logics is abductive reasoning (Roozenburg, 1993; Dorst 2011). In abductive reasoning, a hypothesis is formed of how to achieve a desired, but not yet existent, outcome when both, (a) the context under which the outcome is likely occur and (b) the means, i.e. the product or service that can produce the outcome, are not known yet (Dorst, 2011). Mounarath et al. (2011) showed that under an abductive reasoning frame manipulation, decision makers tasked with selecting innovative concepts for funding were more likely to *accept* concepts than under a deductive/inductive reasoning manipulation. Furthermore, the participants under the abductive reasoning manipulation were found to make more accurate decisions; this means they had a higher likelihood of correctly identifying concepts that carried little or large market potential (see also Dong et al., 2015). Considering this potential of abductive reasoning to improve the decision making performance in selecting early-stage innovation concepts, this begs the question if there is an effective way to induce higher levels of abductive reasoning in decision makers.

There are a number of internal and external factors that could facilitate or hinder abductive reasoning. Internal factors include an individual's knowledge, experience, personality traits, motivations and so on.

External factors are, for instance, the type of informational material decision makers are exposed to at the time of decision making or environmental and social circumstances. Whilst we acknowledge that these factors can influence one's aptitude to think in an abductive manner, in the experimental study presented in this paper, we focus on the effect of different representation modalities of design concepts when presented as external stimuli. More specifically, we focus on the most typical division between concept representations: *visual* versus *textual* concept representations. The study is guided by the following research question: "*How do different modes of representing concepts (i.e. visual versus textual) influence the use of abductive reasoning during innovative design concept selection?*"

The remainder of the paper is structured as follows. In Section 2 we examine extant research related to representational modalities and their potential effect on decision making and abductive reasoning. We derive concrete expectations as to how specifically visual representations may facilitate the use of abductive reasoning. In Section 3 we present our experimental study design and the related data acquisition and analysis. We then present and discuss the obtained findings in Sections 4 and 5. Finally, we conclude by presenting managerial implications and directions for future research.

2 THEORETICAL BACKGROUND

2.1 The role of visual representations in ideation and concept development

The role of concept representations within different stages of the concept development process, such as problem framing and idea generation, has had a lot of attention in research. However, the focus of scholars has mainly been on the benefits of sketches during a creative process (McKoy et al., 2001) and on visual reasoning being conducive to creative problem solving and innovation (Finke, 1990). Proposed benefits of sketches are the additional connections and visual insights that they convey (McKim, 1980), but also its greater effectiveness in producing novel ideas, as compared to using text (McKoy et al., 2001).

Apart from these benefits, sketches may also contribute to sense-making while making a concept selection. They can facilitate lateral transformations and prevent the early 'crystallisation of ideas', meaning that sketches facilitate the exploration and generation of alternative solutions and defer early fixation on a solution (Goel, 1995). We posit that the facilitation of lateral transformations could further contribute to abductive reasoning, since a lateral transformation is a movement from one idea to a different, new idea (across different domains of knowledge or expertise). These transformations could support a concept evaluator in seeing *more than what is presented* in the first instance, and envision what a concept *could become*. In addition, McKim (1980) suggests that sketches act as a 'map' for possible further developments, which, in turn, implies a potential support for decision makers to mentally expand a concept to hypothesise future opportunities, e.g. by association of visual input with related ideas from memory.

According to Goldschmidt (1991), the creative process is a dialectic between 'seeing as' and 'seeing that'. 'Seeing as' is the use of figural reasoning while sketching, and 'seeing that' is the use of non-figural reasoning concerning the idea that is sketched. She describes this dialectic as a cyclic process in which the translations between the 'seeing as' and 'seeing that' of sketches stimulate new ideas through reinterpretation. In other words, these dialectic hinges on the continuous production of visual representations, which are filled with cues for visual reasoning, not about what is perceived, but about something to be created. Whilst Goldschmidt's theory focuses on the ideation process, by extension, it also supports the idea that sketches can stimulate the generation of potential concept future extensions to an innovative concept into something new.

2.2 Processing visual and textual information

Zacharakis and Meyer (2000) researched how venture capitalists (VCs) screen business proposals of new ventures. VCs screen proposals to judge the venture's success potential at the start of an investment process, and thus to decide about which ventures should be further considered. Even though most people prefer more information when making complex decisions, the VCs' predictive accuracy has been found to decrease with more information becoming available to them (Zacharakis and Meyer, 2000). Possible reasons construed by scholars are 'cognitive overload' and 'story incoherence'. Cognitive overload occurs when the processing efforts evoked by a given task exceeds the processing capacity of the cognitive system of the person in question (Mayer and Moreno, 2010). Therefore, as more information is available to decision makers, it can become harder to mentally project a cohesive story or scenario in which the venture will succeed, since it is more difficult to interpret each piece of information and the impact of this information on other factors. Presenting only the most important information may improve the decision process as it allows focusing on the essential merits of an innovation (Zacharakis and Meyer, 2000). Lurie and Mason (2007) argue that visual representation of data is a possible solution to tackle information overload. According to the authors, visual information facilitates exploration and understanding, implies that such processing has its benefits in concept evaluation too by enabling easier processing of data without cognitively overloading the decision makers (Tegarden et al., 1999; see also Larkin and Simon, 1987; Birmingham 1997).

In very generic terms, whilst pictures are processed via a system of pattern perception, which includes attributing meaning to what one sees based on innate but also learned visual experiences, written words are perceived via one's knowledge of a particular language. The latter includes the use of a complex system of socially invented, (arbitrary) symbols and grammar (Ware, 2008). Ultimately, when representing the structure of simple three-dimensional objects, for instance, pictures have the potential to be more succinct and easier to perceive and interpret than written descriptions of the same object. This faster processing reduces the demand on the short term memory, which makes it easier to create novel and unexpected associations through sketched data (Mckoy et al., 2001; McKim, 1980; Newell and Simon, 1972).

Abductive reasoning is known to be supported by other cognitive processes such as mental simulation and analogising (Dong et al., 2016). Mental simulations are defined as "imitative cognitive constructions of an event or series of events based on a causal sequence of successive interdependent actions" (Gaglio, 2004). Christensen and Schunn (2009) state that the use of 'external representation systems', in particular the use of sketches, stimulate mental simulation. Since mental simulations can support the use of abductive reasoning (c.f. Dong et al., 2016), we expect that the use of sketches can facilitate the use of abductive reasoning as well. Furthermore, and based on previous research (see particularly Christensen and Schunn, 2009; Goel, 1995), we expect that visual concept representations are more likely to facilitate the use of abductive reasoning than text. Formulated as hypotheses, we derive the following proposition for H1: *The use of visual representations of an innovation concept is more likely to facilitate abductive reasoning, when compared to equivalent textual descriptions in decision making.* By extension, and considering the findings by Dong et al. (2015) and Mounarath et al. (2011) we further derive a secondary hypothesis H2: *The type of representation used influences the project acceptance rate, due to difference in the level of abductive reasoning these may induce.*

We examined these hypotheses in an experimental setting in which participants were tasked with making funding decisions on innovation concepts. We then investigated decision making behaviour and the use of abductive reasoning therein, in relation to whether the projects were presented either (1) only using visuals, (2) using text only or (3) a combination of visuals and text.

3 STUDY DESIGN

3.1 Participants

52 participants were recruited for the study coming from a professional environment in the field of design, engineering and science. Their age ranged between 25 and 60 years, with an average of 43 years. There was an equal amount of males (26) and females (26). As the study investigates the application of abductive reasoning in decision making processes in general, no preference was given to a particular level of seniority or professional experience. 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 260 individual decisions which is sufficiently large for statistical analysis.

3.2 Project Representations

The five innovation concepts were sourced from crowdfunding campaigns on Kickstarter and Indiegogo. Crowdfunding success or failure is considered a useful indicator as it represents the opinion of a large user group. Kornish and Ulrich (2014) research shows a strong correlation between the popularity of original ideas used in crowdfunding campaigns and the subsequent market success of the final offering introduced to market. The initial projects were selected according to the following criteria:

- They were all advertised on the website for the same duration, i.e. six weeks;
- They all asked for a similar amount of funding, i.e. 50,000 USD with a variance of up to 15,000 USD either way;
- All projects were built around consumer products combining hardware with electronics and, in most cases, internet or smart phone connectivity.

Projects from diverse categories (i.e. ‘health and safety’, ‘digital access’ and ‘on the move’) were chosen to simulate a real-life situation in which a variety of rather diverse projects have to be evaluated. To avoid an anchoring bias in the decision making task (c.f. Tversky and Kahneman, 1974), a randomised sequential monadic test (letting participants decide on one project at a time in a randomised order) was created. The five projects were:

- An in-home alert system waring about potential earthquakes or tsunamis.
- A skateboard that charges an internal battery while moving and has in-built speakers.
- A wireless bicycle taillight with direction indicators and brake light.
- A small wearable tag that automatically calls for help via smartphone when activated.
- A smartphone flash drive that automatically creates backups of your phone when connected.

The original representations of the projects from the websites were adapted to the three representation modalities used in our study. Figure 2 shows an example of a combined textual and visual representation. The texts and visuals were rigorously standardised for the different concepts. Visuals were created by a professional illustrator to create a similar look throughout. Texts were standardised in wording following suggestions by Kozminsky et al. (1981). The visuals and texts provided were to communicate a similar level of information about the project and have a similar look, as much as possible, in order to avoid a framing effect (Tversky and Kahneman, 1986). The survey was pilot-tested by five participants, with a similar profile to the main sample, and slightly adapted wherever necessary based on their feedback.

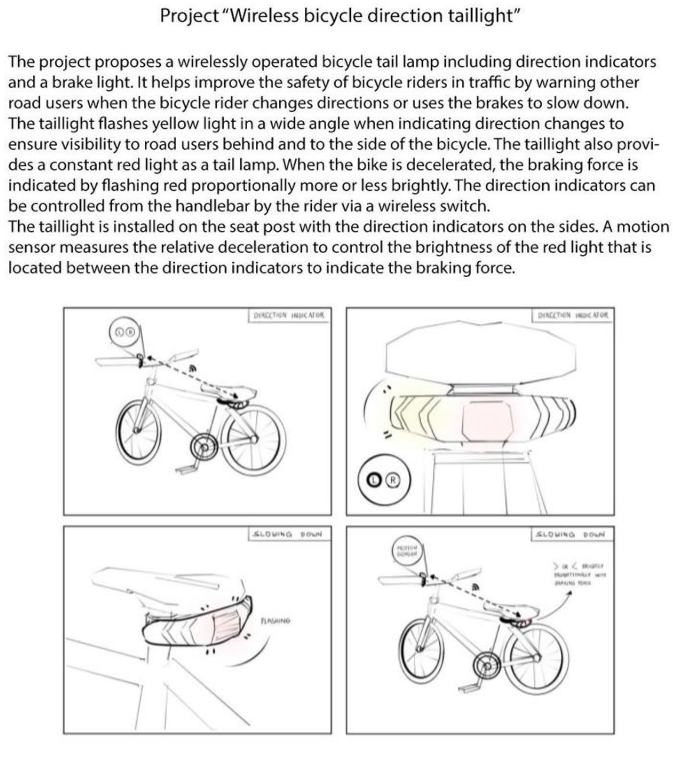

Figure 2. Example of a project representation (combination of visual and textual)

3.3 Data acquisition

The survey was administered online using Qualtrics as platform. It investigated the influence of the three different mentioned concept representations modalities (i.e. the independent variables) on the level of abductive reasoning used by the participants (the dependent variable) when making decisions during innovation concept selection. Participants were randomly allocated into one of three groups according to which representation of the projects they would be shown:

1. Visual – this comprised sketches of a project with one line of text, explaining the main function;

2. Textual – this comprised only text describing the characteristics of a project;
3. Combination of the above.

Subjects took between 30 and 45 minutes to finalise the survey. The survey contained three sections: a) demographic questions, b) an ideation exercise in which participants had to generate possible future extensions of the project; and, c) deciding whether to invest in the project or not.

The main part of the survey (Parts b) and c)) started with a brief introduction to the goal of the investment decision making exercise: *"Imagine that you are an investment decision maker. You can decide whether your company should invest in a project for further product development or refinement. You can invest or reject as many projects as you want. The objective is to invest in successful projects and screen out unsuccessful projects."*

This was followed by a mild manipulation statement in order to lead participants to use abductive reasoning in their decision making: *"While making your decisions, please take into consideration whether you can think of potential extensions of this project that could create new, viable follow-on business opportunities over the next three years".* This manipulation was further incorporated through the subsequent task in which the participants had to write up concrete, possible extensions to each of the projects presented to them. This manipulation was determined suitable to lead participants to apply abductive reasoning by virtue of its intrinsic, forward-looking nature. In order for participants to generate hypotheses for follow-on opportunities they would have to mentally extend the pitched projects and, at the same time, form explanatory judgement about the likelihood of said hypotheses. This is concordant with abductive reasoning as proposed by Dorst (2011) and Roozenburg (1993). The manipulation has further been tested for its use in online questionnaires through two large-scale studies (210 participants in total) in thus-far unpublished work. Finally, participants had to make their funding decision and were asked to provide the reasons for their decision.

To illustrate, after reading the introduction, a participant would see the five projects in a randomised order, presented in one of the three representation modalities (as per initial allocation). Subsequently, for each project, participants filled in a set of four questions. The first two questions incorporate the abductive reasoning manipulation, while Questions C and D entail the assessment of each project:

- Question A: *"To what extent can you think of potential extensions for this project?";*
- Question B: *"Please give examples of potential extensions you see for this project";*
- Question C: *"Would you invest in this project?" (with a simple YES/NO option);*
- Question D: *"Please give the main reasons for this decision".*

3.4 Analysis

The level of abductive reasoning exhibited by participants was extracted from analysing the answers provided to the two open-ended questions B and D. 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 (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 for the evaluation, a reason mentioned for accepting the bicycle taillight for funding, for instance, read: "*I think this helps kids to be more aware of their surrounding traffic maybe add it on kids play vehicles*" (Respondent 49). The respondent suggests a new purpose (i.e. help kids' awareness) for the innovation concept or area of application respectively, without changing the product category,

however (i.e. still vehicles). This is hence scored as "2" as per definition. Another participant suggested the following change and area of application for the skateboard project: "*Can be used by various groups, e.g. people suffering from dementia who get lost; children that might get lost; specific groups of psychiatric patients that might get in a dangerous state (e.g. suicidal)*" (Respondent 14). This provides the safety tag with a new purpose for specific user groups, but remains in the same product category (i.e. a safety device). It is hence scored as "2" as well.
Initially, the responses by the first ten participants were independently rated by the two main authors of this paper. The ratings and application of the rules for abductive reasoning were compared and discussed. Thereafter, all remaining questions were independently rated. Assigned scores were subsequently compared and discussed until consensus was reached.

4 RESULTS

Of the total of 52 respondents who completed the survey, 15 were exposed to purely textual representations, 17 to purely visual representations and 20 to combined visual-textual representations. For testing our hypotheses, we calculated the average abductive reasoning score within the *extensions* and the *reasons provided* explaining the decision made per individual participant and individual decision. Furthermore, we included the acceptance rate (i.e. ratio of cases the participant invested in) in the data set for cross-analysis.

4.1 The effect of representation modalities on abductive reasoning

To test hypothesis H1, we conducted two ANOVAs, following guidelines for statistical tests by Marenco (2011). In these ANOVAs, ‘representation modality’ was the independent variable, and ‘abductive reasoning within potential extensions’ and ‘abductive reasoning within the reasons provided’ were the dependent variables. The key results are as follow (also see Figure 3):

- For the strength of *abductive reasoning* in the *reasons provided*, no significant effects were found (F(2.49)=.254, p=.777).
- For the strength of *abductive reasoning* in coming up with *future extensions*, the effect of representation format was significant (F(2,49)=3.501, p<.038).
- In terms of the level of abductive reasoning applied, the differences in relation to the representation modalities are as follows: we find no significant difference between *visual* and *textual* (p=.493; post-hoc test) and between *textual* and the *combined visual-textual* presentation of the concepts (p=.843); yet, between *visual* and *combined visual-textual* we find a significant effect (p=.033).

In other words, the occurrence of *abductive reasoning* was not significantly higher for the *visual representation group* (M=1.118) when compared to the *textual group* (M=.827), but it was significantly higher than the *combined visual-textual group* (M=.610).

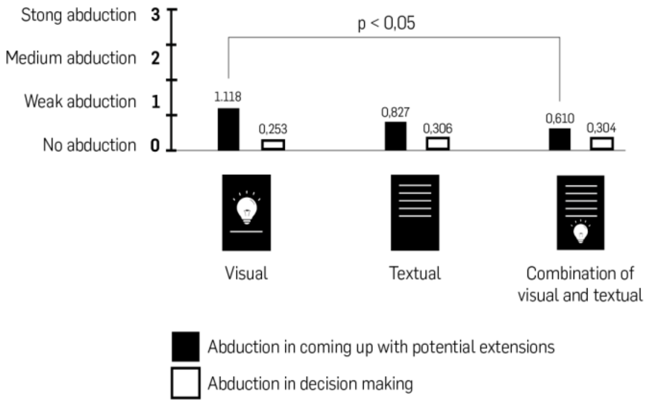

Figure 3. Means of abductive reasoning scores in the extensions and reasons provided

4.2 The effect of representation modalities on the project acceptance rate

In order to test out second hypothesis H2, we also conducted an ANOVA. Within this hypothesis, ‘representation modality’ was the independent variable, and ‘acceptance rate’ the dependent variable. Although the *visual representation* type scored highest for *acceptance rate*, no significant effects were found for this variable (F(2,49)=1,356, p=.267). Based on these results, the null-hypothesis for H2 cannot be rejected at this stage. Thus, in this experiment, the representation format type had no direct, significant influence on the decision outcomes. In spite of this missing correlation, we did see a difference in the levels of abductive reasoning applied depending on the type of representation displayed to the participants. Hence, we also test for this link in the following.

4.3 Correlation between level of abductive reasoning and project acceptance rate

A part of the second hypothesis is related to the use of visual concept representation on the acceptance rate, due to the underlying abductive reasoning process taking place. Therefore, to see whether the used level of abductive reasoning by participants had a relation with their likelihood of accepting projects, we calculated Pearson's correlations (see Table 1) between the level abductive reasoning applied and the acceptance rate. Following extant research by Mounrath et al. (2011) and Dong et al. (2015), we expect to see a positive correlation between higher levels of abductive reasoning and the acceptance rate of the participants. Yet, although the results show positive trends for the Pearson's correlations, no significant correlations were found.

Table 1. Correlation between level of abductive reasoning and acceptance rate

Abductive reasoning during extension generation	Pearson correlation	.208
	Significance	.139
Abductive reasoning found in the reasons provided	Pearson correlation	.209
	Significance	.137

5 DISCUSSION

The aim of this research was to study if different representation modalities promote the use of abductive reasoning during concept decision making. We expected that visual concept representations would facilitate the use of abductive reasoning more than textual representations. Our finding show that participants who were shown *visual* concept representations only, applied the highest levels of abductive reasoning of all groups during the task of generating extensions. On the other hand, those participants evaluating a representation of the innovation concepts *combining visual and textual*, exhibited the lowest levels of abductive reasoning. The group that evaluated the *textual* representations only scored in between the other two types.

A possible explanation for these results might be the different cognitive efforts required from participants when they were presented with the different concept representation modalities. Whilst both visual and textual representations are likely to entail a similar amount of information (Section 3), the combined representation modality conveys of a larger amount of information to process. This could mean that the combined representation not only requires a somewhat higher cognitive effort to process this information, it may also leave less room for reinterpretation (as theorised in Section 2.2). This interpretation of our findings resonates with Sweller’s (1988) cognitive load theory, according to which information redundancies should be eliminated whenever possible to reduce working memory load. A second possible explanation is that by displaying both visual and textual representations together, the available information becomes more concrete, and thus hindering the necessary level of abstraction for (creative) reinterpretation by the relevant participants. This is in line with the research by Zacharakis and Meyer (2000) discussed earlier, as to which an increase in information provided can lead to a decrease in proposal acceptance rate and deterioration in decision making performance. Despite the lack of a significant difference between the effect of visual and textual modalities, we see a non-negligible numeral trend in line with our original expectation. Based on this, we believe, the differences in stimulating creative, abductive reasoning induced by text as compared to visuals, should be investigated further in the future. In line with our initial expectations, we see a significant difference between the groups in terms of the level of abductive reasoning applied overall. The effect is largest in the level of abductive reasoning applied while generating potential extensions to the projects (see Figure 3).

Finally, the results of our experiment did not show a significant effect of the concept representation type on the acceptance rate of the projects. Since we expected the acceptance rate to be affected via the use of abductive reasoning, the correlation between the level of abductive reasoning and the acceptance rate was analysed as well. Although, again, no significant correlation was found, we see clear numeral trends suggesting that participants demonstrating higher levels of abductive reasoning also showed a higher acceptance rate in this study. This increase of acceptance is in line with prior research that relates abductive reasoning to more projects being accepted (Mounarath et al., 2011; Dong et al., 2015), and to research that showed that abductive reasoning can help to get early stage innovation off the ground (Dong et al., 2015).

6 LIMITATIONS

The sample size of participants in our study limits generalisability of our findings. Yet, the amount of information provided in the responses was rather rich and raises our confidence in the findings. Another potential limitation concerns the intelligibility of the survey. We tried to prevent any such problems as much as possible through pilot-testing and adaptation based on the obtained feedback. Though in very few cases participants commented that they were not entirely sure what the word "extension" exactly entailed in the survey, we did not notice any differences in relation to the specific extensions that these participants provided compared to others.

7 CONCLUSIONS, MANAGERIAL IMPLICATIONS AND FUTURE DIRECTIONS

This study shows a first indication of the effect that the concept representation type may have on the application of abductive reasoning by individuals during decision making on innovation concepts. Abductive reasoning was found in earlier research to be able to increase the amount of potentially successful projects to be selected for further exploration (Dong et al., 2015; Mounarath et al., 2011). This can be especially important in early stage concept selection, in order to mitigate the risks of prematurely rejecting potentially good innovation ideas. Thus, the findings from the presented research contribute to the stream of extant research in the field of abductive reasoning and early stage decision making. Our results show that, at least within our experimental setting, *visual concept representations* are more likely to prompt decision makers in engaging in *abductive reasoning* than the use of *combined visual-textual concept representations*.

Based on these outcomes, we propose that primarily using visual concept representation types can enhance the use of abductive reasoning by the decision makers and thus, by extension, change their decision making behaviour (accept/reject) in a foreseeable manner. This is particularly interesting since product or service designers tend to present their innovation concepts and ideas in detailed visuals complemented by (some) textual explanations. Decision makers, however, typically prefer large amounts of textual (or maybe diagrammatic) information when making decisions, even though this has been found to lower the chance of projects being accepted (Zacharakis and Meyer, 2000). By exposing decision makers to mainly visual representations, companies may discover new innovation possibilities in early stage concept selection.

Further research should be conducted with actual decision making professionals as participants. Also, further research should be done on the tailoring of visuals as different decision making professionals can require different kinds of visual representation. In line with our current findings, we expect that reducing the amount and concreteness of information provided for an innovation concept can contribute to the use of abductive reasoning and thus their likelihood to be accepted for further exploration. This can be crucial for companies that struggle with too many projects being rejected due to risk aversion.

REFERENCES

Birmingham, R. (1997), *Understanding Engineering Design: Context, Theory, and Practice*, Prentice Hall: New York.

Christensen, B. T. and Schunn, C. D. (2009), "The role and impact of mental simulation in design", *Applied Cognitive Psychology*, Vol. 23 No. 3, pp. 327-344.

Dong, A., Garbuio, M. and Lovallo, D. (2016), "Generative sensing in design evaluation", *Design Studies*, Vol. 45, pp. 68-91.

Dong, A., Lovallo, D. and Mounarath, R. (2015), "The effect of abductive reasoning on concept selection decisions", *Design Studies*, Vol. 37, pp. 37-58.

Dorst, K. (2011), "The core of 'design thinking' and its application", *Design Studies*, Vol. 32 No. 6, pp. 521-532.

Finke, R. A. (2014) *Creative imagery: Discoveries and inventions in visualization*. Psychology Press.

Gaglio, C. M. (2004), "The role of mental simulations and counterfactual thinking in the opportunity identification process", *Entrepreneurship Theory and Practice*, Vol. 28 No. 6, pp. 533-552.

Goel, V. (1995), *Sketches of thought*. MIT Press, Cambridge (USA).

Goldschmidt, G. (1991), "The dialectics of sketching", *Creativity Research Journal*, Vol. 4 No. 2, pp. 123-143.
Huang, L. and Pearce, J. L. (2015), Managing the unknowable: The effectiveness of early-stage investor gut feel in entrepreneurial investment decisions. *Administrative Science Quarterly*, *60*(4), 634-670.
Kornish, L. J. and Ulrich, K. T. (2014), "The importance of the raw idea in innovation: Testing the sow's ear hypothesis", *Journal of Marketing Research*, Vol. 51 No. 1, pp. 14-26.
Kozminsky, E., Kintsch, W. and Bourne, L. E. (1981), "Decision making with texts: Information analysis and schema acquisition", *Journal of Experimental Psychology: General*, Vol. 110 No. 3, pp. 363-380.
Larkin, J. H. and Simon, H. A. (1987), "Why a diagram is (sometimes) worth ten thousand words", *Cognitive Science*, Vol. 11 No. 1, pp. 65-100.
Lurie, N. H. and Mason, C. H. (2007), "Visual representation: Implications for decision making", *Journal of Marketing*, Vol. 71 No.1, pp. 160-177.
Marenco, A. (2011), *When to use a particular statistical test*. California State University: Northridge. Retrieved from http://www. csun. edu/~ amarenco/Fcs
Mayer, R. and Moreno, R. (2010), "Techniques that reduce extraneous cognitive load and manage intrinsic cognitive load during multimedia learning", *In Cognitive load; Theory and application*, J. L. Plass, R. Moreno, and R. Brunken (Ed.), pp. 131–152. New York: Cambridge University Press.
McKim, R. H. (1980), *Thinking visually: A strategy manual for problem solving*. Lifetime Learning Publications.
McKoy, F. L., Vargas-Hernández, N., Summers, J. D. and Shah, J. J. (2001), "Influence of design representation on effectiveness of idea generation". Proceedings of the ASME IDETC Design Theory and Methodology Conference.
Mounarath, R., Lovallo, D. and Dong, A. (2011), "Choosing Innovation: How Reasoning Affects Decision Errors". *Proceedings of the 18th International Conference on Engineering Design (ICED 11)*.
Newell, A. and Simon, H. A. (1972), *Human problem solving*. Prentice-Hall: Englewood Cliffs (NJ).
Prelec, D. and Loewenstein, G. (1991), "Decision making over time and under uncertainty: A common approach", *Management Science*, Vol. 37 No. 7, pp. 770-786.
Roozenburg, N. F. (1993), "On the pattern of reasoning in innovative design", *Design Studies*, Vol. 14 No. 1, pp. 4-18.
Schmeidler, D. (1989), "Subjective probability and expected utility without additivity", *Econometrica: Journal of the Econometric Society*, Vol. 57 No. 3, pp. 571-587.
Sweller, J. (1988), "Cognitive load during problem solving: Effects on learning", *Cognitive Science*, Vol. 12 No. 2, pp. 257-285.
Tegarden, L. F., Hatfield, D. E. and Echols, A. E. (1999), "Doomed from the start: What is the value of selecting a future dominant design?", *Strategic Management Journal*, Vol. 20 No. 6, pp. 495-518.
Tversky, A. and Kahneman, D. (1974), "Judgment under Uncertainty: Heuristics and Biases", *Science*, Vol. 185 No. 4157, pp. 1124-1131.
Tversky, A. and Kahneman, D. (1986), "Rational Choice and the Framing of Decisions", *The Journal of Business*, Vol. 59 No. 4, p. 251-278.
Ware, C. (2008), "Toward a perceptual theory of flow visualization", *IEEE Computer Graphics and Applications*, Vol. 28 No. 2, pp. 6-11.
Zacharakis, A. L. and Meyer, G. D. (2000), "The potential of actuarial decision models: can they improve the venture capital investment decision?", *Journal of Business Venturing*, Vol. 15 No. 4, pp. 323-346.