

Mindful Deviation through Combining Causation and Effectuation: A Design Theory-Based Study of Technology Entrepreneurship

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Abstract
Technology entrepreneurship can be seen as building upon while also deviating from technological paths. Such deviation has primarily been described as singular events where individuals with prior knowledge discover a new opportunity. In this article, we will instead study deviation as a process of collective decision making, seen more as something mindful than singular. The purpose is to explore mindful deviation as decision-making by nascent technology entrepreneurs as they conceptualize an early platform technology. Based on case assignments undertaken by 13 teams in a venture creation program, C-K design theory is used to trace how nascent technology entrepreneurs in action combine causal and effectual decision-making logics. Individually answered questionnaires also offered insights on how the entrepreneurs perceived their decision-making in hindsight. The findings break with our received wisdom around how opportunities are recognized as well as how effectual and causal logics occur. As a result, mindful deviation through combinations of effectual and causal logic is suggested as a means to understand early-stage technology entrepreneurship.

Keywords: entrepreneurship, technology, effectuation, design theory, nascent

Introduction

Understanding how to draw from, but also deviate from, the larger technological setting is central in technology entrepreneurship (Bailetti, 2012, Garud et al., 2014, Ratinho et al., in press, Shane and Venkataraman, 2003). Technology entrepreneurship is therefore seen as more dependent upon technological paths compared to entrepreneurship in general (Garud and Karnøe, 2003b).Technology entrepreneurshipis also associated with more deviating and path breaking behavior when compared to technological innovation in general(Garud and Karnøe, 2001). In the path dependency literature, deviation is mostly depicted as a discrete or abrupt event, for example a singular event of discovery(Sydow et al., 2009). The concept of mindful deviation (Garud and Karnøe, 2001) opens up for a perspective in which articulated decision-making, rather than singular accidental events,explains how path breaking occurs.However, the field currently lacks means to effectively trace and interpret early entrepreneurial decision-making processes that lead to path breaking.

In this article, we investigate technology entrepreneurship as mindful deviation from technological paths. Nascent technology entrepreneurs are asked graphically illustrate their conceptualization of a technology platform using a design theory called C-K theory. The diagrams are interpreted into occurrence ofcausal and effectual decision-making (Sarasvathy, 2001) as are also the results from a questionnaire measuring perceived use of these logics in hindsight by the entrepreneurs.

C-K theory offers a graphical representation ofdesign activities throughdiagrams (Agogué et al., 2014, Hatchuel et al., 2004). These diagrams include the two spaces, concept-space (hereafter C-space) and knowledge-space (hereafter K-space), and illustrate the gradual expansion of these spaces as well as how new concept attributes sometimes stimulate search for new knowledge and vice versa. K-space emphasize things we know identifiable as true or false and seen as readily accessible, such as knowledge manifested in patents. C-space represent concepts, which cannot be identified as either true or false; but are more or less desirable, such as an "intelligent car". A C-Kdiagram is thus a tool that can be used to represent an early design process in which attributes for a future product are determined (see Figure 1). In this study C-K diagrams are interpreted into occurrence of causal or effectual decision-making based upon a generated framework.

Effectuation has been identified as adecision-making logic used by experienced entrepreneurs during situations of uncertainty, in collaboration with committed stakeholders(Dew et al., 2009, Read and Sarasvathy, 2005, Sarasvathy, 2008). Effectuation enablesentrepreneurs to co-create new and unanticipated effects from known means (Read and Sarasvathy, 2005, Sarasvathy, 2008, Wiltbank et al., 2006), and is acomplementary alternative to causation. Causation involves processes used to select and/or predict actions towards specifically set goals – a predictive and thus more consequential decision-making logic(Sarasvathy, 2001).

Causal and effectual decision-makinghavemainly been explored conceptually or empirically in hindsight (Perry et al., 2011). Therefore, we know less about the actual causal- and effectual-based behavior of entrepreneurs (Fisher, 2012, Nielsen and Lassen, 2012, Sarasvathy and Venkataraman, 2011). This motivates an explorative use of C-K theory to detect such decision-making in real-time.Furthermore,inalso measuring in hindsight perceptions of decision-making logicsin regards to the same situation,comparison to previous studies can be made(Chandler et al., 2011, Perry et al., 2011).Taken together, the purpose of this article is to explore mindful deviation in technology entrepreneurship as decision-making combining effectual and causal logics, using both real-time (C-K diagrams) and hindsight (questionnaire) methods.

The article is structured as follows. First of all, we propose an analytical framework for tracingconscious entrepreneurial decision-making based oncausal and effectual logics through application of C-K theory (Hatchuel and Weil, 2009). We show that the different principles of causation and effectuationcan be derived from steps illustrated through C-K diagrams. We apply the framework to a study of 13 teams ofnascent technology entrepreneurs in a venture creation program (Lackéus and Williams Middleton, 2015, van Burg et al., 2008)as they are asked to explore (and add-to) a patented technology platform. The discussion focuses on how the findings break with existing understandings of opportunityrecognition, as well as how effectual and causal logics occur. Finally, limitations of the current studyand future research needs are discussed.

Literature review

To exploredecision-making as a way of understanding deviation and path breaking in technology entrepreneurship, we review literature addressing mindful deviation. We go on to link this literature to developments around entrepreneurial decision-making through causation

and effectuation.Finally C-K diagrams areintroduced as well as how they can be interpreted into occurrence of causal and effectual logics.

Mindful deviation in technology entrepreneurship

Recent research has investigated processes leading to the creation ofnew opportunities that deviate from established technological paths(Beckman et al., 2012, Doganova and Eyquem-Renault, 2009, Marvel and Lumpkin, 2007).Such processes tend to be studied from a social perspective: for instance, Doganova and Eyquem-Renault (2009) explore how technology entrepreneurs use business models as devices to interact with potential stakeholders and explore different market opportunities. Focusing on reasoning processes, Marvel and Lumpkin (2007) describe the cognitive mechanisms technology entrepreneurs mobilize to shape innovation radicalness. This is done by stressing the role of different types of knowledge in the construction of radical innovation. A challenge for the technology entrepreneur is to draw from technological paths while also becoming path-breaking and deviating towards new opportunities. The current dominant view is that entrepreneurial opportunities stem from discovery rather than from deliberate process(Shane and Venkataraman, 2000). Such essentially 'singular' events of discovery have been related to persons either with more prior knowledge in an area (Shane, 2000) or having strong pattern-recognition capabilities (Baron, 2006).

Mindful deviation has been defined as technology entrepreneur articulating and creating relevance around opportunities that are path-breaking(Garud and Karnøe, 2001, Garud and Karnøe, 2003a). In emphasizing articulation and relevance, the concept possible to relate to a collective decision-making involving others to be on-board or at least convinced about a deviation. Mindful deviation, to our knowledge, has not been used to empirically study initial identification of a new concept or opportunity. If mindfulness, in terms of articulated decision-making, could be conceptualized and empirically traced, then early-stage

path-breaking behaviors could be demystified, be made more manageable, and be seen as less associated with individual creativity or capabilities only. Before introducing a means for tracing early stage-decision making we first need theory to appraise decision-making.

Principles of Causation and Effectuation

The two decision-making logics of effectuation and causation can help us understand the process of mindful deviation. We have already introduced causation as a commonly applied logic in which a course of action is based upon a pre-determined goal, including the marshalling of resources to achieve that goal(Sarasvathy, 2001, Sarasvathy, 2008). Causation operates on a set of principles: set a goal and focus on what ought to be done to achieve that goal, pursue the best opportunities towards achieving the goal, surprises or deviations from the goal should be prevented whenever possible, set up contractual relationships that facilitate achieving the goal, and predict the future in order to control it. Causation is seen as a viable decision-making logic under known or knowable conditions (Sarasvathy, 2001).

Effectuationisthe logic utilized to make decisions based on readily available means, rather than on predetermined goals (Sarasvathy, 2001, Sarasvathy, 2008). Effectuation argues that (expert) entrepreneurs develop a decision-making capacity that allows them to explore new opportunities jointly with committed stakeholders, particularly in situations of uncertainty or unknowable future consequences.Researchers claim that the (expert) entrepreneurs use their available means to develop opportunities based on guesses about uncertain future preferences (Dew et al., 2009, Read and Sarasvathy, 2005, Read et al., 2011, Sarasvathy, 2001, Sarasvathy, 2008, Sarasvathy and Dew, 2005). Thus, effectual decision-making is seen as more viable than other decision-making logics when operating in uncertain and unpredictable circumstances, because it emphasizes the entrepreneur's own action as the basis for control and progress (Sarasvathy and Dew, 2005).

Effectuation is proposed as an alternative and complementary approach (not a replacement) to causation (Chandler et al., 2011, Sarasvathy, 2001, Sarasvathy et al., 2008). Thus, mirroring causation, effectuation also builds upon five core principles: start with a given set of means focusing on what can be done, risk no more than you can afford to lose, leverage contingencies, form alliances with committed stakeholders, and focus on the things you can control to shape the future when it is seen as unpredictable (Read et al., 2011, Sarasvathy, 2008). The principles of causation and effectuation are summarized as part of Table 1.

Just as mindful deviation emphasizehuman actions of articulation and making relevant, effectuation also positions human action centrally but as the "predominant factor shaping the future" (Sarasvathy, 2008, pg 87).However, methods to detect effectual logic in actionremains underdeveloped (Fisher, 2012, Obrecht, 2011). Causation requires one to make sense of a linear process of aligning resources towards a pre-defined goal. Detecting effectuation implies highlighting the expansiveness of the process, i.e. the possible different paths that entrepreneurs explore (Sarasvathy, 2003, Sarasvathy et al., 2008). One way to model decision-making is to model the diversity of the explorative activities that an entrepreneur undertakes. These activities would include the conceptual ideasan entrepreneur explores but chooses not to build upon, the knowledge an entrepreneur both starts with and acquires, and the resources an entrepreneur mobilizes in his/her network of stakeholders. These actions of entrepreneurs can be seen as a design process. This is why C-K design theory is used here to detect occurrence of decision-making.

C-K theory

C-K theory is a theory of design, based on empirical studies ofmore or less radical development of technology-based products (Hatchuel et al., 2013, Hooge et al., 2012). In C-K

theory, design is defined as the process of generating new things (Chakrabarti and Blessing, 2014, Hatchuel et al., 2013), and involves both a specific mode of reasoning (Simon, 1996), and a collective process that enables individuals and/or organizations to propose innovative products or services,and new business models or strategies.(Hatchuel et al., 2005). C-K theory relies on modeling expansion, understood as the extension of existing definitions of objects in diverse directions (Hatchuel and Weil, 2009) with the objective to both explore and substantiate new ideas. Among the diverse theoretical frameworks proposed in the field of design, C-K theory (Hatchuel and Weil, 2009) holds specific properties (Sharif Ullah et al., 2012) that can be of particular interest towards further understanding of causation and effectuation.

C-K theoryestablishes distinction between two spaces: a space of knowledge (K-space), defined as a set of propositions that all have a logical status and thus are recognized as either true or false; and a space of concepts (C-space) defined as a set of undecidable propositions – propositions that have no logical status and thus cannot be proven as either true or false. The K-space maps all theknowledge necessary to understand and develop an idea into action.The C-space is a tree-structure of undecidable propositions, where each node of the tree corresponds to a partition (in the mathematical sense) of the mother concept into several sub-concepts (see Figure 1).Thus, the C-space maps explorable alternatives, but alternatives which require new knowledge in order to be put into action. C-K theory links the exploration of different alternatives (labeled as ‘concepts’ and positioned in the C-space) to the resources required to address and develop these potential ideas by mapping the knowledge associated to each alternative in the K-space. Through this modeling process, C-K theory can illustrateapplication of different types of decision-making. Mapping in the C-space allows for discussion associated to effectual logic, where means (existing knowledge/resources) are used to explore and expand on new concepts. The convergence on a particular goal, use of causal

logic, is done by bringing together different sets of knowledge, modeled as a single path in the C-space with the knowledge associated to each attribute that constitutes the idea at the core of the design process. C-K theory allows for parallel exploration of several ideas as different paths in the C-space, as well as surprising discovery of new areas of knowledge.

Insert Figure 1 about here

Graphical representation of design activities is possible throughC-K theory-based tool called a C-K diagram (Agogué et al., 2014). A C-K diagramillustratively maps the C-space and the K-space, representing the modeling expansion of these two spaces, and distinction of differentiating alternatives. It is therefore a tool that can be used to model a design process, including the status, at a precise time, of the available knowledge and various attributes added to the initial concept during the design process. A C-K diagramcan be applied in different ways, but it is particularly useful in allowingrepresentations of a design process andthus support an enriched discussion with other actors(for example see Hooge et al., 2012 for an extensive list of applications). C-K theory is unique in that it has focused on specific design processes that lead to disruptive ideas(see Agogué and Kazakçi, 2014 for an extensive literature review on C-K theory).Thus,a C-K diagramcan be seen as a useful and unique tool for studying mindful deviation in early stage idea development, as it accounts for diverse paths of exploration and the necessary learning associated, through knowledge acquisition, in order to make concepts actionable. Moreover, by using a C-K diagram, an individual or a group can generate discussions covering several dimensions: what knowledge or attributes have been deepened, what are the alternatives that have been discussed and/or chosen, what design paths remain unexplored and, eventually, which path to pursue(Agogué et al., 2014).

Using C-K diagrams to detect causation/effectuation: ananalytical framework

Building on mindful deviation, causation/effectuation, and C-K theory, we propose an analytical framework to tracecausal and effectual decision-makingusingC-K diagrams(summarized in Table 1), in a vein similar to previous work matching causation and effectuation to R&D context dimensions (see for example Brettel et al., 2012 pg. 169).

Insert Table 1 about here

Addressing Table 1, causation, in general terms, involves the development of optimal scenarios and reaching preset goals. This can be interpreted as determining a defined goal for the development of an idea, and then explicitly identifying the knowledge required to reach that goal, including identifying how to obtain the knowledge required. Knowledge identification emphasizes validating what is known because the outcome should be predictable. Anticipating expected returns (third row in Table 1) equates to exploring one linear path (alternative) in the C-space, identifyingthe knowledgeassociated to this alternative in the K-space, and evaluating the value and the associated risks of this single path. In this sense, a causal process would appear as a single path in the C-space that stimulates the gathering of relevant pieces of knowledge, such as potential economic gains or strategies to face potentials risks.

The focus on the competitive landscape involved in the causal decision-making(fourth row in Table 1) can be seen as focusing on the paths that already exist and that are currently explored by different stakeholders. Exploitation of these existing known paths triggers positioning ofthe chosen path in a more strategic way, stressing the similarities and differences between the chosen path and paths explored by competitors, with the aim of gaining competitive advantage. Avoiding environmental contingencies means avoiding surprises, such as the emergence of disruptive concepts (fifth row in Table 1).A C-K diagram

of a causal decision-making process would not display new surprising paths in the C-space, or expansion in the knowledge space. Last, the predictive principle in a causal logic refers to the control and anticipation of all known possibilities, requiring an extensive mapping of the K-space with many overlaps between the combined pieces of knowledge, in order to consider the decision-making process as a closed one, where all the possible events are anticipated.

The effectuation principles are presented in rows seven through eleven inTable 1. The first principle states that one should star with the set of means readily available, which in a C-K diagram involves explicitly mapping the existent knowledge around the initial idea. A C-K diagram including effectuation develops in the C-space to displaymultiple partitions leading to several alternative paths which are achievable based upon collected knowledge, without predeterminingwhich path should be selected as the outcome of the process.

Focusing on affordable loss(row eight in Table 1) can be seen as evaluating multiple paths, as well as the ability to shift from one path to another. In a C-K diagram this is illustrated through links between the C-space and the K-space when one path appears as a dead end. Referencing back to the knowledge and expertise associated with the dead-end path can allow for identifying new value for another partition(new pathway). The first two effectuation principles underline possible gains from experimenting with as many strategies as possible within the given limited meansavailable (Read et al., 2011).

Strategic alliances (row nine in Table 1) can be traced through expansion in both the C-space and the K-space relative to the competencies and resources of associated stakeholders, including interpretation of value propositions not only for the entrepreneur him/her-self, but also for the network of stakeholders. This increases value options across the network of actors and grants robustness to the design process of the entrepreneur.Leveraging the environmental contingencies (row ten in Table 1) can be understood as exploring but also exploiting surprisesin the C-space. Typically, unexpected disruptive concepts that challenge

existing representations of the given problem are appreciated (rather than problematic), as they are seen as opportunities to explore further unpredicted value. Reaction to this unpredictability, throughapplication of C-K theory, addresses building alternatives that are able to accommodate variations of context.As a result, such alternatives can be seen to be adaptable within a dynamic environment, and thus are not predeterminedbased on a need to execute planning.

The framework to identity use ofcausal and effectualdecision-makingthrough C-K diagrams is exemplifiedin Figure 2 and 3.

Insert Figures 2 & 3 about here

Figure 2 illustrates path trajectories built mainly on use of causal logic would appear in a C-K diagram. Existent knowledge is used to establish a concept in the C-space which is to follow a predetermined goal. The singular partition and expansion shows development of the concept along the predetermined path. New knowledge to be acquired in the K-space is based upon the set goal.

Figure 3 shows how a C-K diagram may look if effectual logic is utilized while developing a new idea. The existing knowledge in the K-space is used to develop a concept that has multiple partitions. Some partitions are more obvious while others are more surprising, but all generate the need to determine new knowledge in the K-space. The new knowledge may be expansion of the initial existing knowledge, or it may be knowledge or resources associated to stakeholders. The final path for development of the idea is not pre-determined, but rather emerges from the options generated through linking the C and K spaces.

Method and Material

Nascent Technology Entrepreneurs at Chalmers University of Technology

Our present study is based on the analysis of 13 teamsof nascent technology entrepreneurs during their first year at Chalmers School of Entrepreneurship (Gothenburg, Sweden). As the program is based at a technical university, the majority of nascent technology entrepreneurs have a background in engineering or bioscience, with the remaining having expertise in business, law, economics, etc.(Lundqvist and Williams-Middleton, 2008).The two yearinternational master of science program at Chalmers School of Entrepreneurship mainly attracts individualsthat aim to have entrepreneurial careers in technology- or bioscience-based start-up firms, or alternatively in established technology-based organizations. The program is action-based(Rasmussen and Sørheim, 2006), emphasizing learning-by-doing (Cope and Watts, 2000), with more than half of the participantsentering into a venture creation approach (Ollila and Williams Middleton, 2011). This approachrequires participants to directly engage in bringing to market technology transfer inventions(Lackéus and Williams Middleton, 2015)through a nine month incubation period in the final year of the two year-long program. We argue that participants attending the program are nascent technology entrepreneurs, having entrepreneurial intention (particularly those who will enter the venture creation in the second year) based on their application and admission to the program. They are also well trained in the use of scientific methodology and engineering science, based on their previous education.Historically, 15 to 20 percent of the participantscontinue as entrepreneurs in the technology ventures initiated through the program(Williams Middleton and Donnellon, 2014). A vast majority of the graduates engage professionally in technology-based business development at start-ups or in established firms(Berggren et al., 2010, Lundqvist, 2014).

After being given instruction in innovative design theory, 60 nascent technology entrepreneurs, grouped into 13 teams, were given four days to apply C-K theory and make C-K diagrams arounda technology platform. They were first introduced to C-K theoryand the C-K diagram methodology, both conceptually and through a basic example, in a lecture format supported by complementary reading material. They then worked in their teams over the four days and interacted with an instructor who provided feedback and support. Each team was asked to produce a C-K diagram. C-K theory and C-K diagramswere not communicated in relation to either mindful deviation, or decision-making logics; nor were the nascent technology entrepreneurs provided specific training in mindful deviation or decision-making logics (causation and effectuation).

C-K theory was applied to a real-life but shelved innovation called Samba Sensor (Figure 4 provides an example C-K diagram created by one of the teams). The basic technology behind Samba Sensor is a pressure sensor in whichfiber optics allow for pressure measurement, applicable to a variety of interesting areas: for example monitoring hearts and other body organs, measuring car combustion; ormeasuring difficult-to-access production environments, such as oil extraction and telecom monitoring. Samba Sensor can be described as a technology platform consisting of eight patents covering basic functions of the sensor as well as different areas of use.

Prior to introduction of C-K theory, the 13 teams had assessed the feasibility of the shelved innovation – Samba Sensor.To complete this, the teams were required to delve into the specifics of the patents and make initial choices regarding value and utility of the technology platform. While none of the nascent technology entrepreneurs had previous experience withinthe particular innovation area, the assessment provided a baseline knowledge of the technology that facilitated exploring possible future opportunities based (to some extent) upon the given technology platform when applying the C-K theory. For 11 of

the 13 teams, C-K theory was utilized towards developing product concepts and new applications. For the remaining two teams, C-K theory was instead used to explore market opportunities. Figure 4 is an example of the C-K diagrams produced by one of the teams, utilizing C-K theory towards developing a project concept. Figure 4 shows the expansion of both knowledge in the K-space, and pathways in the C-space, as well as the links between the C and K spaces.

Insert Figure 4 about here

Data collection

We collected our data in two ways: firstly, we analyzed the resulting C-K diagrams from the application of C-K theory through the framework described in relation to Table 1.Secondly, we distributed a questionnaire to all of the nascent technology entrepreneurs,asking questions about theirexperience of applying the C-K theory. The questionnaire had a 45% (27 of 60) response rate.

Data analysis: a combined quantitative and qualitative approach

Each team provided a C-K diagram. The 13 C-K diagrams were then scored by two raters independently. To do so, the raters used the interpretation of the five principles of the causationand effectuationbased upon theanalyticalframework presented in Table 1. For each C-K diagram, the raters had to score the C-K diagram according to the format presented in Table 2. Therefore, each diagram received a coupled score, one reflecting the use of causal logic, one reflecting the use of effectual logic. For example, if a team was seen to map both spaces (=1 effectual score), explore different alternatives and build on value of the link between C and K (=1 effectual score), map the unknown missing knowledge and the unknown paths (=1 effectual score), have no disruptive concept (=1 causal score), and present

extensive K mapping (=1 causal score), they would receive a coupled score of (2,3): a causation score of 2 and an effectuation score of 3.The ratings displayed satisfactory inter-rater correlation (r = .92).There is considerable co-variation among both five factors determining causation and the five factors capturing effectuation but arguably not between the two groups of factors. The factors are thus only helping to detect occurrence of a logic are only indicative as regards the magnitude of a logic used.

Insert Table 2 about here

An example scoring based on the team example C-K diagram provided in Figure 4 is presented in Table 3.

Insert Table 3 about here

To identifyhow the nascent technology entrepreneursperceived their use of causation and effectuation more in hindsight, thequestionnaire included both open-ended questions, as well as one multiple-part Likert-scale question (see Appendix A). The first three open-ended questions addressedhow the nascent technology entrepreneur generally comprehendedC-K theory related to the Samba Sensor case, in order to qualify that the response to the final questions were not impeded by the use of C-K theory itself. The fourth question addressed the nascent technology entrepreneur's own interpretation of their performance in applying C-K theory towards exploring the potential pathways of the technology.The fifth and final questionutilized a Likert-scale format, designed to investigate perceived use of C-K theory in terms of six different orientations: action-orientation (a.), goal-orientation (b.), process-orientation (c.), product-orientation (d.), actor-orientation (e.), and reflexively (f.). Items (a.),

(c.), and (e.)are seen to align with effectuation principles while the (b.), (d.), and (f.)align with causation principles.Previous studies have applied similar data collection methods in order to assess the use of causal and effectual logics in decision-making towards new venture or technological development (Brettel et al., 2012, Chandler et al., 2011, Harms and Schiele, 2012). Furthermore, the Likert-scale question mirrors a study conducted by Brettel et al. (2012), addressing the use of causal and effectual logics relative to R&D project performance, as our respondents are, like the Brettel et al. study, asked to evaluate preference towards causal or effectual logics through a Likert scale format, as well as subjective performance evaluation. As for the first part of the data analysis, this resulted in coding each participant responses based on the Likert-scale questions. Indeed, the responses to the parts (a.) through (f.) of the final question in the questionnaire were utilized to establish a coupled score (effectual score, causal score), where theeffectual score was the mean of the answered given in items (a.), (c.), and (e.)while themean of the score given in(b.), (d.), and (f.)align allowed for a causal score.

Results

Coding C-K diagrams and evaluating causation and effectuation

The 13 teams delivered analyses utilizing C-K diagrams. For each team/C-K diagram, a coordinate is generatedfromthecoupled score (effectual score, causal score), with minimum possible score of zero and maximum possible score of five (using the scoring system from Table 2). The 13 coupled scores were then compiled to illustrate the overall causal and effectual distribution across all 13 teams (Figure 5). In Figure 5, the x-axis represents the effectual score and the y-axis represents the causal score. The axes range from zero to five to illustrate the score generated for each team through the analytical framework (Table 2), with the coupled score establishing a coordinate relative to the x and y axes. The size of the dots is

correlated with the number of teamsthat generated the same coupled score, such that a smaller circle would represent fewer teams with the same score, and a larger circle would represent a larger number of teams with the same score.

Insert Figure 5 about here

Figure 5 shows that in applying a C-K diagrams on the sensor technology, the actions of the nascent technology entrepreneurs can be interpreted as combiningcausation and effectuation, but with a greater emphasis on the use of effectual decision-making.

Perception of use

The responses to the final question in the questionnaire establish a coupled score (effectual score, causal score), generating a coordinate, positioned on Figure 6. Figure 6 compares the respondent's own perceived use of causal and effectual decision-making, as determined by the coupled score. The same representation applied in Figure 5 is also used in Figure 6; thus, again the x-axis represents the effectual score and the y-axis represents the causal score, with the coupled score of each respondent generating a coordinate presented in the figure. Again, similar to the format of Figure 5, the size of the dots in Figure 6is correlated with the number of respondents that were coded with the same coupled score.

Figure 6illustrates that respondents tended to interpret their perceived use of C-K diagrams towards decision-making as causally oriented more than effectually oriented.

Insert Figure 6 about here

In comparison, Figure 5 and Figure 6differ as regards occurrence of causation and effectuation. The questionnaire results, which occurs in hindsight,(Figure 6) detect mainly use

of causal logic, whereas use of effectual logic is seen to occur more extensively when interpreting the use of C-K diagrams(Figure 5). These results thus suggest a gap between the decision-making actually done (being more effectual) and how the nascent technology entrepreneurs in hindsight perceive their own decision-making (stated in more causal terms).

Discussion and conclusions

The purpose of this article is to explore mindful deviation in technology entrepreneurship as decision-making combining causal and effectual logics. First, the discussion will investigate the relevance of a decision-making approach. Following this, four aspects related to the occurrence of effectual and causal logic will be analyzed.

Previous studies into technology entrepreneurship basically have understood early-stage deviation into new opportunities as a discrete creative event and not as a decision-making process. Prior knowledge into an area (Shane, 2000) as well strong pattern-recognition capabilities (Baron, 2006) are identified factors behind successful opportunity recognition. Through C-K design theory applied by 13 teams of nascent technology entrepreneurs upon the same innovation, a method for detecting decision-making is introduced. Even though prior knowledge among the 13 teams can be considered moderate, the majority are still able to deviate substantially from their original platform technology into a variety of different product concepts. This deviation is also clearly traceable through the C-K diagrams, in which different concepts are logically interrelated in the C-space while knowledge expansions occur in the K-space. It can thus be concluded that deviation in early-stage technology entrepreneurship can be characterized as a decision-making process engaging a team (thus being collective) with moderate prior knowledge, rather than as something singular, individualistic and depending upon prior knowledge.

Given, the exploratory and experimental character of the study, there are some limitations to this main conclusion. Firstly, although the nascent entrepreneurs were asked for both for C-K maps and written accounts around the process, it is not possible to fully determine how much these delivered outputs actually represent the process and how much they are after-rationalizations of something that might have occurred more individualistically and singularly. Secondly, while the concept of mindful deviation comes from entrepreneurs arguing for andlegitimizing a path-breaking solution, the current study does nothave account of any subsequent progress and realization of a chosen opportunity. It merely reports that C-K diagramsindicates use of decision-making, during an early opportunity recognizing stage. However, given these limitations and the obvious need for further studies, the richness and variety found through applying C-K diagramsin early stage technology entrepreneurship does suggest that a more singular, individualistic and discovery-oriented (rather than a collective decision-making-oriented) view on technology entrepreneurship can be questioned.

Effectuation occurring among nascent entrepreneurs

Previous research into effectuation associateseffectual logic with experienced entrepreneurs(Dew et al., 2009, Read and Sarasvathy, 2005, Sarasvathy, 2001). This study show that nascent entrepreneurs also use effectual logic.Whether this is due to the applicationof C-K theory, or whether this would have been the case regardless of the method used, is difficult to say. However, our study suggests that effectual logic should subsequently not only be associated with experience and seniority. Rather, effectual logic can also occur – either naturally or induced through method – among individuals lacking entrepreneurial experience. This arguably widens“the population of effectuators” substantially, while demystifying this type of decision-making as not depending significantly upon expertise and certain experiences.

Hindsight bias disguises effectuation

Results from the questionnaire indicate that use of effectual logic is more difficult to detect in hindsight. Whether this due tothe nascent technology entrepreneur lacking sufficient skill, experience or language to appreciate an effectual logic, or whether such hindsight bias always would occur, is not possible to determine throughthe current study. Nevertheless, this differentiation between the application versus perceived use of effectual logic is not addressed in previous studies of effectuation (for example, Dew et al., 2009). There is, thus, strong reason to continue exploringmore interactive (rather than ex post) measurement of effectual logic if we want to capture its occurrence and relevance. Interactive measurement may also help to avoid a hindsight bias, through which humans simplify and rationalize in order to make sense of a more complex and fluid experience (Kahneman and Riepe, 1998). In conclusion, our study suggests that effectuation occurs much more in action than is possible to detect in hindsight, adding to the previous conclusion that this decision-making logic should be demystified and not solely associated to experts or previous experience.

Expanding mindful deviation into opportunity recognition

The tracing of decision-making through C-K diagrams adds to our understanding ofmindful deviation. The concept of mindful deviation has been associated to later stages of technology entrepreneurship, where the need to convince others to join or buy into a chosen novel path is essential(Garud and Karnoe, 2001). The current study expands mindfulness into the early concept-generative phase of technology entrepreneurship, where mindfulnesswasobserved aseffectual and causal decision-making.So, while mindful deviation has been more readily associated with individual technology entrepreneurs communicating to and convincing others, the current study instead emphasizes the inclusion of persons into a more collective and open-ended decision-making, which precedes any subsequent and perhaps more persuasive process. Although this is a shift in perspective (from convincing to making decisions) and includes earlier stages (opportunity recognition), we propose that the

concept of mindful deviation remains highly relevant and is even enriched through the current study. Future studies into technology entrepreneurship as a process ought to benefit from focusing more on process of collective and mindful articulation, whether for explorative (decision-making) or more exploitative (convincing and influencing) purposes.

Mindful deviation as combining effectuation and causation

Finally, the interpretation of the C-K diagrams relative to effectuation and causation can increase our understanding of how the two logics can be combined. The factors used to define effectuation and causation (Table 1),arguably imply that path deviation requires effectuation. Effectuation has much to do with starting with means while keeping ends open, as well as allowing contingencies to trigger imaginary rethinking. Causation, on the other hand, assumes ends and objectives to be fixed or predetermined. Hence, it is perhaps not surprising to find more effectuallogic occurring the C-K diagrams. However, without any causal logic illustrated in the C-K diagrams, the notion of mindfulness, including being able to make and communicateconscious decisions, would be hampereddue to lack of consequential reasoning and inability to compare different choices. Combining effectuation and causation then comes close to the type of strategic decision-making proposed as "the science of muddling through" (Lindblom, 1959, Lindblom, 1979) or "logical incrementalism" (Quinn, 1978). As far as we are aware, early stage opportunity recognition has not previously been associated to such strategy-making concepts. Rather early stage opportunity recognition has been said to be reliant upon appreciation of the insightfulness of experts with certain pattern-recognition capabilities.In essence, the combination of causal and effectual thinking displayed by all 13 teams helped create a more holistic map in which consequential paths as well as path deviations are included.

The variety of application ideas traced using C-K diagrams shouldthus not only be ascribed to the use of effectuation, but rather to the combination of both causation and

effectuation. For example, sometimes the teams converged ona goal, and then elaborated on the goal further. Other times, it is obvious that new concepts emerged through effectual decision-making and were then translated as a goal once identified. In conclusion, the combination of effectuation and causation reflects that(nascent) technology entrepreneurs are required to address both existing technological paths and novel entrepreneurial developments, and that they benefit from decision-making process more similar to strategy-making than to singular events of individual insightfulness.

Limitations and Next Steps

There are several limitations to our study.The current study is local and contextual and requires further validation to substantiate claims that effectual decision-making is used by early-stage technology entrepreneurs(Chandler et al., 2011, Perry et al., 2011). Our study of the decision-making behavior of (nascent) technology entrepreneurs is, through the first level of analysis, based on coding the outcome of four days of work on a design theory-basedinterpretation of the two types of decision-making (causal and effectual). This experimental setting is of course limited in time as well as in realism (the entrepreneurs knew this was a shelvedinnovation, and thus not completely 'real'). Nevertheless, the setting is illustrative of early-stage technology entrepreneurship, mirroringinitiation of venture creation. The interpretative means for determining causal and effectual logics, the second level of analysis, while based on previous work, could also benefit from further testing.

A second limitation is the lack of a control group (such asmore traditional engineers, consultants, etc.).The study could potentially benefit from having a control group to determine if the participants in the current study, as a population, have a specific mind-set which might bias their application and/or perception one way or another.The teams were mostly hybrids, with team-members having engineering or business degree backgrounds.

However, our study has traced mindful deviation in a population intending to (at least) become entrepreneurial (if not entrepreneurs). Studying groups lacking such ambition may not provide relevant insight into entrepreneurial decision-making processes, as these groups might lack the agency emphasized in existent literature.

Our study was conducted on technology entrepreneurship students due to the easy access to this specific population. However, such a selection in our data sample might not reflect both the actions and the perception of these actions of more mature and experienced technology entrepreneurs. Yet it allows elaboration on future hypotheses for the current understanding of nascent technology entrepreneurs. Facilitating traceable conscious decision-makingprocesses of technology entrepreneurs may also allow us to increase general understanding of entrepreneurial cognition, as explored in the work of Mitchell et al.(2007).

Finally, although the current study indicates behavioral preference towards effectuation and cognitive preference towards causation, this should not automatically favor one at the expense of the other.Rather, C-K theory, through C-K diagrams,seems to offer a valuable tool to further explore actual entrepreneurial behavior as well as entrepreneurial perception and identity. The current study shows that even a simulated setting can offer some insights. Further studies could look into use of C-K diagramsmore longitudinally as well as related to more real-life entrepreneurship situations.

Appendix A

Question 1. Was C-K theory useful for the Samba Sensor case?

Question 2. Was C-K theory easy to understand?

Question 3. Was the amount of introduction to C-K theory sufficient?

Question 4. Describe in your own words how you applied C-K theory.

Question 5. On a scale of 1(low) to 5 (high), how did you apply C-K theory, in terms of the following:

a. from an action-oriented perspective
b. from a goal-oriented perspective
c. from a process-oriented perspective
d. from a product/service oriented perspective
e. from an actor-oriented perspective
f. reflexively

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