Organization Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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Organization Science
Vol. 21, No. 2, March–April 2010, pp. 413–431
ISSN 1047-7039 | EISSN 1526-5455 | 10 | 2102 | 0413

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DOI 10.1287/orsc.1090.0462

Cognitive Processes of Opportunity Recognition: The Role of Structural Alignment

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Substantial gains can be made by individuals and organizations adept at detecting new opportunities. But how do business leaders do that concretely? Organization research shows that managers are more inclined to identify threats than opportunities, but it is still not clear why this is the case. Likewise, research points to several factors that may facilitate the recognition of opportunities. Yet empirical observations have been limited by retrospective biases and other conceptual challenges. As a result, key questions remain not only about *what* factors facilitate the recognition of opportunities, but also about *why* these factors play such a role. To further understanding of these issues, we study the reasoning strategies that individuals mobilize for recognizing opportunities. We develop a model of opportunity recognition as a cognitive process of structural alignment, and analyze the think-aloud verbalizations of executive entrepreneurs as they try to recognize opportunities for new technologies. In contrast to prior research, the qualitative and quantitative data do not provide evidence that individuals use prototypes to recognize opportunities. Instead, we find that different kinds of mental connections play different roles in the process of recognizing opportunities, with different consequences. We also document why and how prior knowledge may facilitate this process. By drawing attention to the cognitive underpinnings of opportunity recognition, we cast light on why it constitutes such a challenging task for individuals and organizations. In turn, this provides a useful basis for exploring the factors that explain why some individuals/organizations are able to recognize opportunities that others simply fail to see.

Key words: opportunity recognition; issue interpretation; cognitive processes; entrepreneurship; verbal protocols
History: Published online in *Articles in Advance* July 21, 2009.

Organizations operate in complex and dynamic environments that are increasingly characterized by rapid, substantial, and discontinuous change (Brown and Eisenhardt 1997, Hitt 2000). To sustain a competitive advantage, managers must respond strategically to these changes (Ireland and Hitt 1999, Pérez-Nordtvedt et al. 2008). Indeed, significant gains in profit, growth, and/or competitive positioning can be made by those individuals and organizations adept at exploiting the opportunities that arise in such changing environments (Eisenhardt 1989, Eisenhardt and Martin 2000, Sirmon et al. 2007). From the perspective of individual actors, however, uncertainty about the origin, extent, and consequences of environmental changes makes the task of recognizing opportunities as challenging as it is relevant.

Past studies have shown that the perception of inconsistencies between environmental signals and prior assumptions acts as a "trigger" that focuses attention upon interpreting the signal—and ultimately motivates the formulation and implementation of an organizational response (Corner et al. 1994, Dutton and Duncan 1987, Dutton and Jackson 1987). Though much may be known about the factors that influence managers' perception of signals in their organizations' environments (Dutton 1993, Kaplan 2008, Ocasio 1997), a great deal remains to be learned about opportunity recognition. For instance, organization research has found that managers are more inclined to identify threats than opportunities, yet explanations for this "threat bias" have focused on threats, and in particular on understanding why the identification of threats is more prevalent than that of opportunities (Jackson and Dutton 1988, Schneider and De Meyer 1991). Comparatively less attention has been directed at the process(es) by which one recognizes opportunities. Baron (2006, p. 104) proposed that the identification of opportunities involves pattern recognition, or the ability to "'connect the dots' between changes in technology, demographics, markets, government policies, and other factors." Along this line, Baron and Ensley (2006) showed that the opportunity prototypes of experts are more complex than those of novices.

These studies represent significant steps toward understanding opportunity recognition. Yet a number of conceptual issues and empirical challenges continue to impede research in this area. For instance, several studies ask about opportunities that were recognized in some distant past and are thus limited by retrospective and success biases (Golden 1992, Huber and Power 1985). As a result, it remains difficult to determine exactly how opportunity recognition is fostered by the attention allocated toward environmental signals (Ocasio 1997, Shepherd et al. 2007), the perceived characteristics of those signals (Jackson and Dutton 1988, Julian and Ofori-Dankwa 2008), abilities to process information (Kuvaas 2002, Milliken 1990), the unique resources, organizational slack, or strategy of a firm (Chattopadhyay et al. 2001, Thomas and McDaniel 1990), or the use of prior knowledge (Dimov 2007b, Shane 2000, Shepherd and DeTienne 2005) and other individual or organizational resources and abilities (Barnett 2008, Cattani and Ferriani 2008). In short, key questions remain not only about *what* factors facilitate the recognition of opportunities, but also about *why* these factors play such a fundamental role.

To further our understanding of these issues, we study the reasoning strategies that individuals mobilize for recognizing opportunities. More concretely, we explore two hitherto unanswered questions: *What cognitive process(es) supports individual efforts to recognize opportunities*? *What is the specific role of prior knowledge in this process(es)*? To investigate these questions, we develop a model of opportunity recognition as a cognitive process of structural alignment (Gentner 1983, 1989). We then conduct a series of exercises with executive entrepreneurs to record their think-aloud verbalizations as they try to recognize opportunities for new technologies. By analyzing these verbalizations, we document the extent to which executive entrepreneurs use structural alignment processes in their efforts to recognize opportunities for new technologies. We also investigate the role of prior knowledge in this process.

Although our theoretical model, research design, and empirical results focus on individual processes, our study has wider implications for organizational research. As Crossan et al. (1999) showed with respect to organizational learning, recognizing opportunities involves dynamics that take shape at the interindividual, group, organization, and society levels (Davidsson 2003, Dimov 2007a); but at the root of this multilevel phenomenon, there remain individual processes that are poorly understood. Furthermore, opportunity recognition is a necessary precursor to individual and organizational efforts to evaluate opportunities, and to pursue them (McMullen and Shepherd 2006, Thomas et al. 1993). Seen in this light, individual processes for recognizing opportunities are not only important for the birth of new firms, they are important for organizational strategy, adaptation, learning, and renewal (Crossan and Berdrow 2003, Gavetti 2005, Mosakowski 1998, Zott and Amit 2007).

By investigating the cognitive processes of opportunity recognition, we make three primary contributions to the literature. First, our paper is among the first to develop and test a model that *specifies* the cognitive processes involved in recognizing opportunities. In contrast to the suggestions of prior research (Baron 2006, Baron and Ensley 2006), the executives in our research did not use opportunity prototypes and their attributes. We find instead that entrepreneurs' efforts to recognize opportunities rested on their cognitive alignment of new technologies and markets. By showing that different kinds of "mental connections" play different roles, with different consequences, we contribute a better understanding of the cognitive mechanics that underpin the process of recognizing opportunities. Second, we further understanding of the specific role that prior knowledge plays in this process. Numerous studies have linked prior knowledge to opportunity recognition (Corbett 2005, Dimov 2007b, Fiet 1996, Shane 2000, Shepherd and DeTienne 2005), but few have explored the mechanism by which this occurs. By focusing on this mechanism, we help explain why, when, and how prior knowledge may facilitate—or hinder—efforts to recognize opportunities. Third, our findings provide new insights into equivocal findings regarding opportunity recognition in organizations. Prior research has identified a "threat bias" in managers: they are quick to identify issues as potential threats, but are less likely to identify opportunities (Jackson and Dutton 1988, Schneider and De Meyer 1991). By focusing on the cognitive process(es) supporting opportunity recognition, our research offers new avenues for explaining potential differences between how threats and opportunities are recognized in organizations.

Defining Opportunity Recognition

There is an ongoing debate about the ontological nature of opportunities: do opportunities arise as objective artifacts waiting to be "discovered" by predisposed individuals, or do they arise out of the subjective interpretations and creative actions of these individuals? The debate has generated considerable attention (cf. Davidsson 2003, Gartner et al. 2003, McMullen et al. 2007). Yet we believe that in its current articulation, it leads to an impasse that hinders research on the phenomena most directly relevant for organization scholars: the process(es) by which individuals and organizations recognize opportunities.

We take the position that instead of emphasizing the objective or subjective nature of opportunities, it is useful to articulate our research on the notion that opportunities arise from changes—whether the development of new knowledge by individuals and organizations, changes in the behavior of relevant actors in the economy (e.g., competitors, consumers, suppliers, institutions, etc.), or wide-ranging changes in the macroenvironment (e.g., market saturation, deregulation, business cycles, etc.). But though these changes may make current practices suboptimal, they do not form opportunities in and of themselves. For example, an inventor who comes up with a new technology may introduce an objectively identifiable change to the environment, but he or she does not yet "have" an opportunity, no more than the new technology itself represents the opportunity. Opportunities are courses of action that seek to derive benefits from these changes. In the case of entrepreneurship, for instance, opportunities for a new technology would thus lie in *applying* the technology in a particular market (cf. Venkatarman and Sarasvathy 2001, p. 652; but see also Drucker 1985, Eckhardt and Shane 2003).

However, because of the asymmetric diffusion of knowledge (Hayek 1945) and limits to individual rationality (Simon 1957), the appropriateness of applying a new technology to a particular market is uncertain ex ante (Knight 1921, McMullen and Shepherd 2006); it may only be determined post hoc. It follows that the process of recognizing opportunities involves both objective and subjective dimensions: the objective reality of one's context and the subjective interpretations that one makes of this context and of one's position in it—before the facts can be objectively known.

Accordingly, recent theorizing on entrepreneurial action has emphasized the distinction between two nested phases of entrepreneurial action (McMullen and Shepherd 2006). The first phase concerns the formation of subjective beliefs that an opportunity exists for those with the relevant abilities and means to exploit it (2006, p. 137). The second concerns the evaluation of the opportunity for oneself (or for one's organization), that is, whether one has the means and motivations to act on the opportunity. To date, most studies of opportunity recognition have either not made the distinction between the two phases of opportunity processes (e.g., Baron and Ensley 2006), or have focused on the evaluation phase (e.g., Chattopadhyay et al. 2001, Krueger and Brazeal 1994, Sarasvathy 2001, Thomas and McDaniel 1990). To further knowledge on the dynamics that lead to individual and organizational efforts to pursue opportunities, our paper focuses specifically on the first phase: the process of recognizing opportunities.

Building on these considerations, we define the *process of recognizing opportunities* as efforts to make sense of signals of change (e.g., new information about new conditions) to form beliefs regarding whether or not enacting a course of action to address this change could lead to net benefits (for instance, in terms of profits, growth, competitive jockeying, and/or other forms of individual or organizational gains). The *outcome* of this process lies in those subjective ex ante beliefs that an opportunity exists—or not—for the willing and able (Shepherd et al. 2007). Thus, it is possible to complete the process of recognizing opportunity and still come to believe that enacting a course of action to address this change does not constitute an opportunity for yourself or your firm.

Structural Alignment and the Recognition of Opportunities

Baron (2006, p. 109) proposed that "individuals notice various events in the external world…and then utilize cognitive frameworks they have developed through experience to determine whether these events are related in any way—whether, in short, they form a discernible pattern." Along this line, Baron and Ensley (2006, p. 1339) showed that the opportunity prototypes of expert entrepreneurs are richer than those of novices and place greater emphasis on desirable attributes, such as "solving a customer's problems, the ability to generate positive cash flow, the speed of revenue generation, manageable risk, and (the presence of) others in their network with whom to develop the venture" the ability to generate positive cash flow, manageable risk, superiority of the product/service, potential to change the industry, a favorable financial model, positive assessments or advice from others, the existence of a large untapped market, and intuition or gut feeling. But this raises an interesting conundrum. Given the retrospective nature of their study, it is still not clear whether novices and experts alike effectively use these desirable attributes in their efforts to recognize opportunities.

We advance that a key to this conundrum lies in considering the cognitive processes by which individuals make sense of new information, and more specifically, of information that is new to them. It is commonly accepted that people will mentally compare this new information with what they already know. This is how we make sense of new information. Seen in this light, the "discernment" of opportunity-relevant patterns involves cognitive efforts to consider the "resemblance" between events in the outside world (including signals of potential changes in this environment) and mental models of situations and contexts that are relevant not only for making sense of the new information, but, in the case of recognizing opportunities, for identifying a course of action to potentially profit from these changes.

But how is this done concretely? What are the cognitive processes by which individuals assess resemblance between new information and what they already know? The question of "resemblance" has been at the center of cognitive research on the perception of similarity, and on the use and consequences of similarity considerations in a wide range of reasoning tasks (cf. Holyoak and Thagard 1995). This literature highlights that perceptions of similarity between two or more objects of interest rest on the cognitive alignment of the mental representations that individuals make of these objects

(Day and Gentner 2007, Keane et al. 1994, Markman and Gentner 1993). Building on this literature, we propose that the cognitive process of *structural alignment* (Gentner 1983, 1989) provides a useful basis to investigate the process of recognizing of opportunities. At its most fundamental level, structural alignment is a cognitive tool that people use to compare things—and to draw implications from the comparison. For instance, when people encounter a new object, their first instinct is to ask whether anything in this new object resembles anything they have seen before. In turn, people build on the similarities they observe to better understand the new object. Cognitive scientists have shown that similarity comparisons and the underlying mechanism of structural alignment play an important role in how people make sense of new information, learn new concepts, and develop categories (cf. Holland et al. 1986, Vosniadou and Ortony 1989). More importantly, the same preocesses of structural alignment were shown to influence the performance of activities that demand high levels of abstract reasoning such as in scientific innovation, new product ideation, and other creative endeavors (cf. Dahl and Moreau 2002, Dunbar 1993, Ward 1995)—and including strategy making (Gavetti and Rivkin 2005, 2007).

One of the primary findings of this research is that alignment proceeds at two distinct levels: one centered on the *superficial features* and the other on *structural relationships* (Gentner 1983, 1989). Superficial features relate to the basic "parts" of a mental representation, along with their attributes and characteristics (Gentner et al. 1995, p. 271). By contrast, structural relationships refer to the links that unite different superficial features within a mental representation. Research distinguishes two types of structural relationships: first-order and higher-order structural relationships. The former consists of one-to-one functional relationships between superficial features (e.g., action verbs, direct effects). Higher-order relationships include more abstract "relationships between relationships," such as causal chains, goal statements, and conditional rules (cf. Gentner 1989, Gentner et al. 1993, Holyoak 1985).

We use the example of a new technology developed at MIT—the 3DP™ documented in Shane (2000)—to illustrate the distinctions between superficial features and structural relationships. Examples of superficial features of the technology include who developed the technology (mechanical engineers at MIT), the components of the technology (mechanical arm, print head), the material it uses (ceramic powders), and what the technology produced in the lab (e.g., ceramic filters, casting molds, etc.). Examples of first-order structural relationships include how the technology operates (e.g., [mechanical arm (moves) print head]; [print head (deposits) powder]). Higher-order structural relationships include more abstract capabilities of the technology (e.g., [how the technology operates] causes [fabrication of tridimensional objects with high level of automation and precision]).

Structural alignment processes play an important role in efforts to make sense of new information: faced with a new target stimulus, individuals consider the alignment of its features and relationships with that of a relevant "source" (Gentner 1989, Holland et al. 1986). This "source" can be a relevant object, a more abstract framework (such as a category or a theoretical model), or more generally, a mental representation of a situation that is relevant to understanding the new information target. By comparing the new information with a relevant object, model, or situation—that is, by considering whether or not the superficial features and structural relationships of target and source are aligned—people are able to perceive meaningful patterns and draw relevant conclusions. This leads to the following guiding proposition:

Proposition 1. *In their efforts to recognize opportunities, individuals will mentally compare the superficial features and structural relationships of signals from their environment with the features and relationships of contexts where this information could be meaningful.*

Preponderant Role of Aligning Structural Relationships

Research on structural alignment indicates that the processing of superficial features and of structural relationships involves different sets of cognitive structures and dynamics (Gentner 1989, Gentner et al. 1993, Keane et al. 1994). As a result, the two are likely to play different roles in efforts to recognize opportunities. On the one hand, research has shown that superficial features influence the search and retrieval of information from memory (Gentner 1989, Gentner et al. 1993). Accordingly, the superficial features of a new stimulus (say, the features of a new technology such as the material it works with) may lead one to recall corresponding features of a relevant source from memory (in this case, a market associated with this material). The source that is recalled from memory is often influenced by one's prior experiences or familiarity with particular features, or by one's context or situation (for instance, a feature that is made salient because of particular events). This may narrow the range of superficially related domains that are spontaneously accessed (Keane et al. 1994) and where one scans for relevant bases for alignment. On the other hand, structural relationships are more directly involved in higher-order reasoning processes (Holland et al. 1986, Keane et al. 1994). For instance, the processing and alignment of structural relationships influence category formation (Namy and Gentner 2002), learning (Loewenstein and Gentner 2005), and problem solving (Catrambone and Holyoak 1989, 1990).

Both superficial features and structural relationships can influence interpretation. Yet, research has shown that structural relationships are particularly important when making inferences about a new and/or ambiguous stimulus (Day and Gentner 2007, Gentner 1989). Accordingly, we postulate that efforts to recognize opportunities will emphasize the consideration and alignment of structural relationships. Two further reasons motivate this emphasis. First, reasoning based on structural relationships is fostered when stimuli are encoded in a rich and deep manner, such as in cognitively demanding tasks or when facing an emotionally important challenge (cf. Blanchette and Dunbar 2001, Catrambone and Holyoak 1989). These conditions characterize most efforts to recognize opportunities. The relevant information for such tasks is often complex and ambiguous, making its interpretation challenging. Likewise, these tasks are emotionally engaging, in large part because of the potential consequences they have for individuals and their firm (cf. Cardon et al. 2009, Ireland et al. 2003).

Second, research has shown that from a neurocognitive standpoint, noticing the alignment of structural relationships generates more "brain activation" than does noticing the alignment of superficial features (Holland et al. 1986, Keane et al. 1994). This preference for structural matches allows for comparing and recognizing meaningful patterns that may not include superficial similarities. Indeed, the use of structurally based "mental leaps" (Holyoak and Thagard 1995) has been observed in several fields, and notably in scientific and creative thinking (e.g., Dahl and Moreau 2002, Dunbar 1993, Ward 1995). In strategic decision making for instance, Gavetti and Rivkin (2005) showed that former Intel CEO Andrew Grove figured out the danger of abandoning the low-end microprocessor segment not by thinking about the situation in computer or electronic products, but by comparing Intel's situation with what had happened in the steel industry with the advent of Nucor and the minimills. Microprocessors and reinforcing bars have few features in common, but Nucor's entry and growth in the steel industry was highly similar to the Advanced Micro Devices, Inc. (AMD) entry and growth in the microprocessor industry. Knowing what happened to large U.S. steel foundries, Grove devised a strategy to avoid a similar fate. The above considerations suggest that in their efforts to recognize opportunities, individuals will pay particular attention to the alignment of structural relationships, relative to their alignment of superficial features. Thus, the following applies.

Hypothesis 1. *The process of recognizing opportunities will involve greater cognitive effort* (*attention*) *to align structural relationships than to align superficial features.*

Role of Prior Knowledge

Extant research has shown that because the distribution of knowledge in society is not uniform, prior knowledge helps to explain why some individuals are able to recognize particular opportunities that others simply fail to see (e.g., Corbett 2005, Dimov 2007b, Fiet 1996, Shane 2000, Shepherd and DeTienne 2005). In general, these studies infer that prior knowledge provides a basis from which to interpret—and use—new information. However, because of the indirect and retrospective nature of the empirical evidence (cf. Davidsson 2006, Dimov 2007b), most of these studies do not specify the cognitive mechanism by which prior knowledge effectively influences efforts to recognize opportunities.

Cognitive research indicates that prior knowledge fosters the consideration of structural relationships. For example, experts in a domain find it naturally easier to reason in terms of structural relationships, in large part because they have richer mental representations with which to work (Chi et al. 1981). Knowledgeable experts are more readily able to solve problems with low superficial similarity but high structural similarity (Gick and Holyoak 1983, Keane 1988). In parallel, research on insight has shown that one's failure to solve a particular problem often leaves "failure indices" in long-term memory. According to the "opportunistic-assimilation hypothesis" of Seifert et al. (1995), such indices lay dormant until a chance encounter with a stimulus relevant to solving the problem, at which time these indices "serve as signposts that guide subsequent retrieval processes back to stored aspects of the problematic situation" (Seifert et al. 1995, p. 87). In other words, prior exposure to a problem can increase alertness to solution-relevant stimuli (Dimov 2004). The implications of the "richer mental representations" and "opportunistic-assimilation" perspectives are that prior knowledge facilitates the noticing of structural parallels between new information and a relevant context, even in the absence of superficial correspondence between the two. Thus, the following applies.

Hypothesis 2. *In the process of recognizing opportunities, reliance on higher levels of prior knowledge will be associated with greater cognitive effort* (*attention*) *to align structural relationships than to align superficial features.*

Research Methodology

In developing the model and hypotheses above, our purpose is not to document the particular sequence of thoughts that one follows to recognize opportunities, but rather to test whether the process of recognizing opportunities involves discrete forms of reasoning. To this aim, we conduct a verbal protocol study (Ericsson and Simon 1993). Specifically, we met with senior executives that had new-venture founding experience, presented them with short descriptions of new technologies, and asked them to "think out loud" as they considered what possible opportunities could be pursued with these new technologies (if any). Participants completed two exercises, using two different technologies. In turn, we content analyzed the transcriptions of participants' verbalized thoughts for evidence that in their efforts to recognize opportunities they used cognitive processes of alignment.

Verbal protocol analysis allows one to observe the thought processes of executives *in real time* while they attempt to recognize opportunities, as opposed to relying on retrospective recollections of such efforts. In organization research, the technique has been used to study the reasoning strategies of managers and corporate officers (e.g., Isenberg 1986, Melone 1994), the decision processes of investors (e.g., Hall and Hofer 1993, Sarasvathy et al. 1998), the thinking that supports new product ideation (e.g., Dahl and Moreau 2002), and the decision modes of entrepreneurs (e.g., Sarasvathy 2001).

Research Material

We derived the research material from publicly available descriptions of two new technologies already exploited in niche markets. The first stimulus was based on NASA's Extended Attention Span Training (EAST™) (NASA 2003). The second was based on MIT's three-dimensional printing (3DP™), the same technology studied in Shane (2000). We present the research material in the appendix.

We acknowledge that opportunities for new technologies are only a subset of the types of opportunities that individuals and organizations may pursue. We chose to anchor our research on the well-documented context of technology transfer (Mowery et al. 2004; Shane 2001a, b) to control for dynamics that may be associated with different forms of opportunity in different situations and contexts. We designed the study to be consistent with prior accounts of technology transfer—where entrepreneurs learn of technologies that are offered for licensing and subsequently identify opportunities for these (Shane 2000). Furthermore, our design makes use of real-life technologies for which opportunities were already exploited, thereby augmenting the external validity of our task and material.

Sample

We conducted the study with senior executives with new-venture founding and managing experience in two industries: life-science technologies and marketing services. We chose executives with new-venture experience because the task of recognizing opportunities is one with which they are familiar. Consistent with Ericsson and Simon (1993), this ensures that participants' verbalizations will not be affected by their need to cope with a new or incongruous task. In addition, the selection of participants from two distinct groups with markedly different backgrounds allowed us to broaden the generalizability of our findings.

Because our research exercise drew from authentic cases of technology transfer, however, it was important to select participants who were unlikely to have prior knowledge of the current exploitation of these technologies. To minimize this possibility, we focused on executives who do not operate technology-related businesses and who are unlikely to have engineering backgrounds. As a post-experimental control, we asked participants to report the prior knowledge they had of the specific technologies we presented them, as well as the scientific principles underpinning these techonologies.

To identify potential participants, we consulted a list of 152 entrepreneurs operating businesses in a U.S. mountain state, and who had professional relationships with a university's entrepreneurship center. We identified five executives with experience in marketing services, and one with experience in life sciences. A second executive with experience in life sciences was identified from a personal contact and that person suggested three additional names. All 10 executives were contacted via e-mail with a detailed message explaining the study's purpose and procedures. Nine agreed to take part. The one who refused (female, 35–44 years old) cited "lack of time to meet for such an extensive procedure."

Participants include two males and two females heading marketing services firms, and four males and one female executives from life-science businesses. All had decades of work experience, including several years as an entrepreneur (mean = 18.6 years): all had founded and managed at least one new venture. All but two were the founders (and lead executive) of the current firm in which they work. The exceptions had previous founding experience and were members of their current firm's executive team (vice president and chief financial officer (CFO)). By and large, participants stated that they had low levels of prior knowledge for the technologies we presented (mean of 2.39 and 1.50 for the two technologies (EAST™ and 3DP™), respectively, on a nine-point scale anchored 1 = "minimal knowledge," with standard deviations of 1.9 and 0.8). By contrast, they expressed having more knowledge of the markets they discussed (mean = 5.03; std. dev. = 2.7).

Given the demanding nature of the procedures, verbal protocol studies tend to trade large sample sizes that would warrant statistical validity for methodological strategies that emphasize the internal, construct, and external validity of the observations. In this regard, our sample size of nine executives is directly comparable to that of other verbal protocol studies in management research, including Isenberg's (1986) sample of 12 general managers from six corporations, Melone's (1994) sample of eight corporate development VPs and CFOs (five and three, respectively), and Sarasvathy et al.'s (1998) sample of eight entrepreneurs and bankers (four and four, respectively). All participants completed two exercises for two different technology stimuli, generating a total of 18 analyzable protocols.

Data Collection and Research Procedures

Each executive in our study completed the exercises at a scheduled meeting, which lasted 40 to 50 minutes. Our research procedures follow those set forth in Ericsson and Simon (1993). We first presented the participants with two practice problems. We then asked whether they were comfortable with the procedures, including the recording of their think-aloud verbalizations. After confirmation, we presented them the written description of a first technology (randomly assigned). Participants read the description out loud and proceeded with the exercise. Although some participants voiced comments as they were reading the description, others read the description in its entirety without pausing. All participants then described what possible opportunity(ies) could be pursued with the new technology (if any). At any time, they could ask questions or interrupt the study. Participant's verbalizations (including reading the stimulus) ranged from two and a half to 10 minutes. Once they had finished describing their thoughts, they were asked to indicate on one to nine scale the extent to which they had prior knowledge of the technology presented, of the market(s) they discussed, and of the problems affecting individuals in those market(s). We then asked participants whether they could do a second exercise. All agreed. After completing the two exercises, participants completed a questionnaire that asked for information about themselves and their current firm. The first author transcribed each recording in the days following each interview, and sent a verification copy to each respondent.

Data Analysis and Coding Schemes

We analyzed participants' verbalization using content analysis techniques (Krippendorff 2004, Neuendorf 2002). In line with Crutcher (1994) and Ericsson and Simon (1993), the coding schemes we introduce below focus on the occurrence of discrete forms of reasoning across participants' verbalizations, and not on idiosyncratic variations that would be specific to the particular thoughts of each participant. Consistent with other prior verbal protocol studies (e.g., Isenberg 1986, Melone 1994, Sarasvathy 2001, Sarasvathy et al. 1998), evidence for our hypotheses comes from the number, length, and relative proportion of participants' verbalizations that reflect their use of alignment processes and prior knowledge. We use logistic regression techniques to assess the predominance of structural alignment reasoning and the role of prior knowledge in supporting this process.

Following Ericsson and Simon (1993, p. 205), our unit of analysis consists of meaningful blocks of texts, generally a sentence or groups of related clauses that "flowed" together in participants' verbalizations and that were separated from other statements by short pauses. We identified these statements as we transcribed the audio recordings, and verified them after all protocols had been transcribed. The 18 protocols generated 396 statements, each averaging 12.65 seconds (std. dev. = 9.7s).

We coded the verbal protocols on three dimensions: (1) the *attention focus* (i.e., the "topic" of each statement); (2) the *level of structural reasoning* (i.e., superficial versus structural); and (3) the *level of prior knowledge anchoring different statements*. Table 1 describes how we operationalized each dimension. We used subdimensions to translate the analytical categories into concrete terms.

The first dimension identifies the particular aspect of the problem space that captured participants' attention. Because we focus on the process(es) of recognizing opportunities for new technologies, the relevant problem space consists of information about the specific technologies we present participants, and whatever objects, models, situations, or contexts participants use to "make sense" of these technologies. We coded each statement according to whether it referred to something about the technology (the supply side), about the market (the demand side), about both, or about neither (something else). Evidence of cognitive alignment comes from statements that attend to features/relationships of *both* technology and market. Yet we note that our research design does not ask participants to align technology and markets: whether they do so is an empirical question, one that we investigate in this paper.

The second dimension of our coding scheme captures the level of reasoning expressed in each statement. More specifically, we coded each statement according to whether it made an explicit reference to superficial features or to one of two types of structural relationships: first or high order. Please note that we combine the two forms of structural relationships for the quantitative analyses.[1]

The third dimension captures the level of prior knowledge that anchors the thoughts and reasoning strategies evidenced in each statement. We distinguished between three levels of prior knowledge: high, medium, and low. Because participants were unlikely to have extensive knowledge of the technologies but were free to use any other knowledge base in their efforts to recognize opportunities, the high levels of prior knowledge we observed were mostly concerned with prior knowledge of markets.

For control purposes, we also noted the point in time within each protocol before which participants were "searching" for an application of the new technology, and after which they had "identified" a specific opportunity for that technology. This allows us to assess the relative distribution of content categories before and after participants explicitly identified an opportunity.

Dependent Measures

To document the absolute and relative occurrence of structural alignment processes in participants' efforts to recognize opportunities, we calculated three dependent measures consistent with prior use of verbal protocols in management research (cf. Isenberg 1986, Melone 1994,

Table 1 Coding Schemes

Analytical categories	Subcategories	Operationalization
Attention focus		
Technology		The statement consists primarily of comments, observations, questions, issues (etc.) about the technology presented
Market		The statement consists primarily of comments, observations, questions, issues (etc.) about a market context
Neither/other		The statement refers to neither the technology presented, nor to a particular market context.

Analytical categories	Subcategories	Operationalization: The statement consists primarily of comments, observations, questions, issues (etc.) about…
Level of structural reasoning		
Superficial, technology	Techno characteristics	…the "objects" of a technology, such as the parts of the technology, its elements, the materials/inputs it uses, the objects/output it produces, the individuals who developed that technology, the general field of origin of that technology, along with all the characteristics of these objects, individuals, etc.
Superficial, market	Market characteristics	…the objects in a context, and/or their attributes/characteristics/features. This includes individuals in that market context, their characteristics, the products/services they use, the characteristics of these products/services, the characteristics of the market context as a whole, etc.
First-order relationships, technology	T-how: How technology operates	…the operation of a technology, how it works, what it does, what it does with what, and how.
	T-why: Aims and purposes of technology	…the current aims and purposes of the technology in the specific context of its development, e.g., why its developers have the technology do what it does (in the lab), with what effects.
First order relationships, market	M-how: How a market "works"	…the activities in a context, i.e. what individuals in that context do with current products/services they use, how they interact with these products/services, how the products/services themselves function, etc.
	M-why: Aims and purposes of market actors	…the current and immediate purposes of individuals in that market context, i.e., why they do the things they do.
High-order relationships, technology	T-ben: Ultimate benefits of technology and their causes	…the potential benefits/advantages/implications of the technology, e.g., the ultimate capabilities/effects of the technology, along with the causes/reasons why it has such capabilities.
	T-prob: Problems of technology and causes	…the particular problems/limitations of the technology, along with the reasons/causes of such capabilities.
High-order relationships, market	M-ben: Benefits of market activities and causes	…the larger implications/advantages/implications that actions and activities in a market may have—such as using products/services for a particular purpose.
	M-prob: Problems of market activities and causes	…the problems individuals have in a market context, the limitations of an activity and/or product/service they use in that market. This also extends to the goals, motives and needs that individuals have that are poorly satisfied under current conditions, and/or the reasons why these problems and limitations exist.
Implicit, technology Implicit, market		Although the statement discusses something else, a preposition in the statement refers implicitly to something about a market context. Because the reference is implicit however, it is impossible to determine the level of structural alignment that is emphasized.

Table 1 (cont'd.)

Analytical categories	Subcategories	Operationalization
Anchoring of reasoning on different levels of prior knowledge		
Low	Minimum knowledge	The statement is not explicitly or implicitly anchored on any particular domain of knowledge for which the individual claims to be, or could be said to be knowledgeable.
Medium	Some familiarity	The statement refers to a knowledge domain for which the individual claims to be vaguely familiar, to know something about, without necessarily being an expert or being directly interest in that domain (e.g., a domain that has never been experienced directly by the individual himself/herself).
	Distant knowledge	The statement refers to a knowledge domain that is obviously and explicitly distant, such as a past memory, a distant event, and event that is not particularly significant and/or emotionally charged.
High	Self-experience	The statement refers to a knowledge domain that is explicitly and directly related to a profoundly marking personal experience, an experience that was salient and meaningful.
	Family experience	The statement refers to a knowledge domain that is explicitly and directly related to and/or involving close family members (e.g., spouse, children, parents, etc.).
	Personal interest	The statement refers to a knowledge domain for which the individual claims or can be said to have a high personal interest, such as a personal hobby, sports, etc.
	Professional expertise	The statement refers to a knowledge domain that corresponds to the individual area of professional expertise.

Sarasvathy 2001, Sarasvathy et al. 1998). The first measure builds on the distribution of statements within each protocol to report the number of participants who made at least one statement corresponding to our coding categories. We also report the number of participants who made two statements or more. Similar in spirit to the Borda-count method used by Sarasvathy (2001), this approach allowed us to assess whether the importance given to each category is generalized across our participants. The second measure focuses on the total length of time (in seconds) devoted to different categories of statements within each protocol. The third measure captures the relative importance of each category of statements over the duration of the "average" protocol. To construct this measure, we first calculated the relative importance of each category of statement with respect to the length of each participant's protocols (in percentage of total time). We then calculated the weighted average of these measures controlling for the length of individual protocols. This measure provides a conservative estimate of the importance that particular forms of reasoning have within participants' verbalizations, net of whether some individuals were more or less loquacious.

Coding Procedures and Assessment of Validity and Reliability

To assess whether participants effectively verbalized their thoughts as they were trying to recognize opportunities, we asked and recorded what they remembered having said and thought during the first exercise. Although space limitations prevent us from reporting the results here, participants' retrospective verbalizations were highly convergent with what they had said in the think-aloud protocols. This observation supports the internal validity of the protocols (Ericsson and Simon 1993, Chapter 3).

Consistent with the standards of verbal protocol and content analysis (cf. Krippendorff 2004, Neuendorf 2002), two coders independently coded the raw data: the first author and a graduate student who was blind to both the theoretical rationales and particular hypotheses of the study. The coders began by coding a single protocol together and discussed every aspect of the coding procedure. They then coded two protocols independently, and met back to discuss the objectivity and meaning of each coding category. Having agreed, the two coded all 396 statements independently.

We calculated two indices of interrater reliability for all coding dimensions: percentage of agreement and Cohen's κ. We reached the following levels of reliability: 95.9% agreement ($\kappa = 0.935$) for the attention focus dimension, 83.4% agreement ($\kappa = 0.801$) for the level of structural reasoning dimension, and 92.5% agreement ($\kappa = 0.816$) for the prior knowledge dimension. These results indicate acceptable levels of interrater reliability (cf. Lombard et al. 2002, Neuendorf 2002). The coders discussed discrepancies and reached agreement on all statements before conducting the final analyses.

Results

The 18 protocols reveal a wide diversity in the sequence of thoughts and reasoning strategies mobilized by participating executives in their efforts to recognize opportunities. Some had an idea right away and proceeded to expand upon it. Some spent time considering various possibilities before they settled on a particular one. Still others voiced hypotheses that they continued to develop until they found an opportunity they felt confident to defend. And three participants did not identify an opportunity for the 3DP™ technology—an observation to which we will return.

Several participants indicated that although they would need more information to assess whether they should try exploiting the opportunity(ies) they had described, they were confident that they had identified an opportunity that could work.

> Now I would have to do a lot of due diligence to convince myself, as I would go forward in that analysis of whether [the opportunity I described above] would work, but I am prepared to say: "all right, let's go to the next step, let's assume it works, now let's figure out what commercial opportunity that could be associated with this." (M45bio EAST™)[2]

This indicates that the participant made an explicit distinction between efforts to recognize an opportunity and the decision whether to exploit an opportunity. Interestingly, some of the applications they discussed proved very similar to opportunities that are actually being pursued. Yet, participants discussed other applications that appeared just as plausible.

The apparent diversity in reasoning strategies across executives masks a number of regularities that are important for understanding the cognitive processes that are used for recognizing opportunity. Table 1 reports the results of our content analysis of the verbal protocols. An initial look at this data points to several observations that are consistent with structural alignment processes.

First, we observe that participants spent less time talking about the presented technologies than they spent describing markets for these technologies. For the average protocol regarding NASA's EAST™ technology, verbalizations for the technology alone accounted for 9.1% (2.8% for superficial and 6.3% for structural) of the total time, whereas verbalizations about markets accounted for 29.1% (7.6% for superficial and 21.5% for structural). Similarly, for the average protocol regarding MIT's 3DP™ technology, verbalizations for the technology alone accounted for 9.5% (2.3% for superficial and 7.2% for structural) of the total time, whereas verbalizations about markets accounted for 43.7% (4.0% for superficial and 39.7% for structural). We note that for both technology-alone and market-alone statements, in both sets of protocols, verbalizations about structural relationships systematically accounted for larger proportions of the average protocol than verbalizations about superficial features (see Figure 1). Interestingly, larger proportions of verbalizations focusing on superficial features were made before a specific opportunity was recognized than for verbalizations focusing on structural relationships. This suggests that the consideration of superficial features may be an initial reaction that triggers the search for technology–market combinations on which to focus greater structural attention.

Second, we observe that though we never asked them to do so, all participants spontaneously made statements where the focus of attention is on *both* technology and market—that is, statements whose meaning rest on the parallels and similarities between a technology that was presented and one or more market(s) in which to apply this technology. For example:

> And, so, for me to pursue a technology like this, and try to understand if there is an opportunity (would be) to apply the technology to create a new way to give athletes or weekend athletes, or weekend warriors, or people who just care about physical activity, feedback on their level of concentration and (whether) it correlated to their performance so that they can see that when they were concentrating and focused, what their performance did and give them feedback on that. (F45mkt, EAST™)

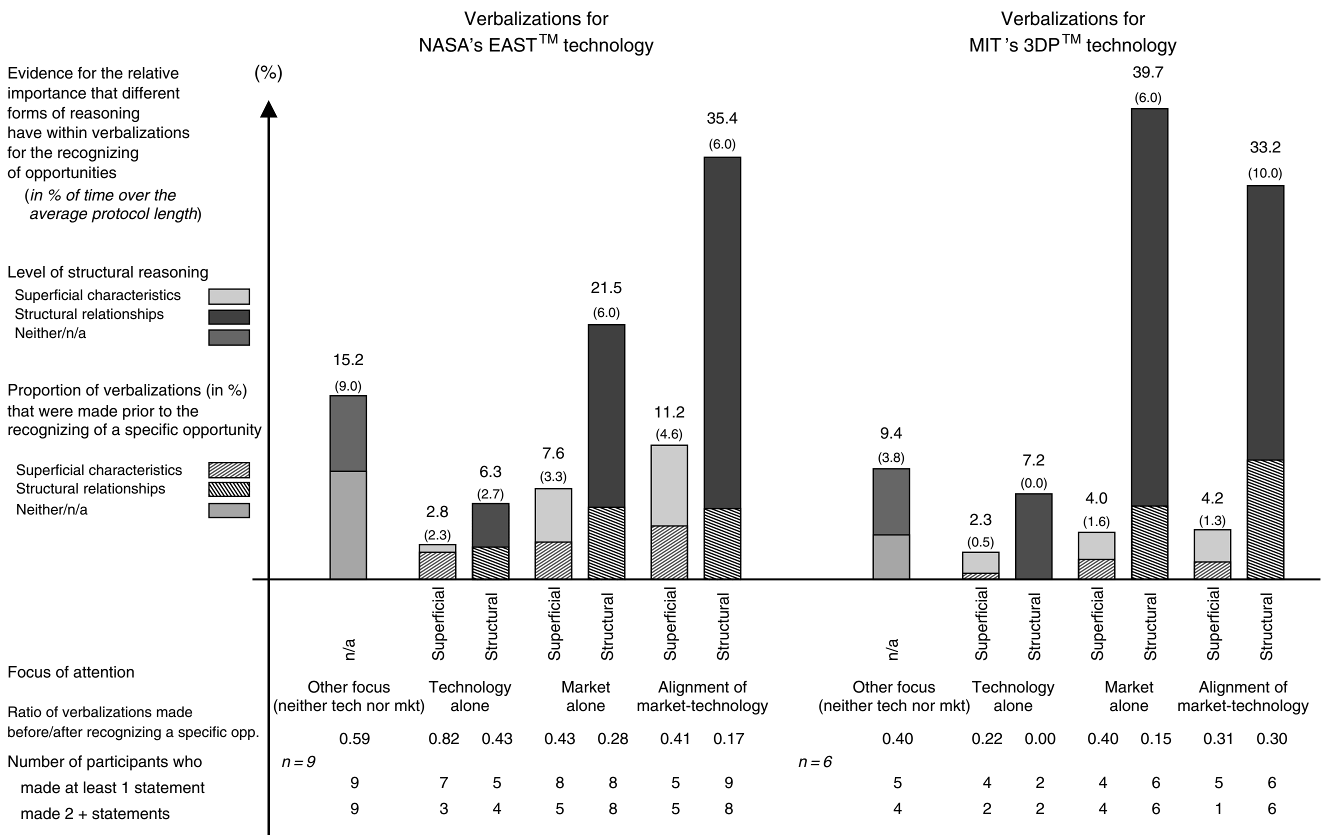
> In manufacturing, you have people building things, and if you can go from computer digital design straight to 3D objects, with the use of a robotic type machine, then you've just eliminated a lot of labor involved in having to do that through some manual means. (M45mkt, 3DP™)

Third, we observe that although most participants made statements denoting the alignment of superficial features (five of nine executives in the first case, five of six in the second), superficial alignment accounted for only a moderate proportion of the average protocol length (11.2% for the EAST™ technology and 4.2% for the 3DP™ technology).

Fourth, and by contrast, we observe that all executives made statements denoting the alignment of technologies and markets in terms of structural relationships (nine of nine and six of six for the two technologies, respectively). Figure 1 indicates that the alignment of structural relationships accounted for 35.4% and 33.2% of the average protocol length for the two technologies, respectively. These findings indicate that in the process of recognizing opportunities for new technologies, individuals pay attention to the structural alignment of technology and markets.

Consistent with the theory of structural alignment, qualitative analyses revealed that participants' alignment of structural relationships involved two kinds of relationships: first order and higher order. Participants' alignment of first-order relationships focused on how a technology operates, and how/why people in a market would use it.

Figure 1 Analysis of Entrepreneurs' Verbalizations



> A business-to-consumer, I can see it very much in the gaming worlds, but not even electronic gaming, like I can see it for people that are concentrating in world poker tournament, and who are really trying to get focused on that piece. (F35mkt EAST™)

> Like for instance, in a watch, there are little gears: well that gear had to be made by somebody, cutting it out of a piece of metal, and shaping it, and so I guess, this could be used for making stuff like that, if it were the right component. (M45mkt 3DP™)

Finer-grained analyses indicate that the alignment of first-order relationships accounted for 13.5% and 19.6% of the average protocol length for the EAST™ and 3DP™ technologies, respectively. For the two sets of protocols, this corresponds to 38% and 59% of the time spent on aligning structural relationships, respectively.

By contrast, participants' alignment of higher-order relationships was articulated in terms of the benefits/capabilities of a technology, and the needs and problems of individuals in a given market.

> Clearly, in technical surgical procedures, either done directly by a surgeon or increasingly used by robotics, which has a strong similarity to games, because they can be done remote, not just remotely within an operating suite but remotely in terms of big geographical differences, this whole sort of thing can be certainly utilized, and therefore, any company that's investing in imaging, or surgical technology would have an interest in utilizing an approach like this, to enhance the reproducibility, the predictability and the skills of the operator. (M55bio1 EAST™)

> And in terms of architectural design and filling it with space, I think that a lot of people don't have an idea of what that finished product is gonna look like, and whether, it's something you want to buy, and so, I think that for most high-end commercial construction projects, this would be definitely a big plus. It would also free you from sticks and pieces of paper that models are made of now. (F45bio 3DP™)

The alignment of higher-order relationships counted for 21.9% and 13.6% of the average protocol length for the EAST™ and 3DP™ technologies, respectively. This corresponds to 62% and 41% of the total time devoted to aligning structural relationships in the two sets of protocols.

Taken together, these results indicate that in their efforts to recognize opportunities for new technologies, individuals pay attention to aligning both types of structural relationships, that is, first-order relationships focused on the functional operation of technology and markets, and high-order relationships focused on the causal dynamics that underpin the benefits and capabilities of new technologies, and the needs and problems of individuals in a given market.

Table 2 Results of Logistic Regressions

	Structural (HI + 1st) vs. superficial alignment	
Predicted contrast	Model 1	Model 2
Intercept	2.249*	2.940**
Control variables		
Technology	0.204	−0.040
After vs. before opportunity found	0.246	0.771
Effects of prior knowledge		
Linear		2.105**
Curvilinear		−0.094
Model statistics		
Goodness of fit (X^2)	19.397*	28.791**
Hosmer and Lemeshow test (X^2)	4.514ns	3.212ns
Cox and Snell R^2	0.155	0.221
Nagelkerke R^2	0.219	0.313

Notes. $n = 115$ alignment statements. Each model includes dummy codes to control for differences between individual participants.

nsNot significant; $^{*}p \leq 0.05$; $^{**}p \leq 0.01$.

Hypotheses Testing

The columns in Figure 1 indicate that for both sets of protocols, the average participant devoted more time to align technology and market in terms of their first- and high-order structural relationships than in terms of their superficial features. Across protocols and technologies, participants spent on average 108.7 seconds aligning structural relationships compared to 25.7 seconds aligning superficial features ($t_{1:14}$; $p < 0.001$). These findings provide preliminary evidence for Hypothesis 1.

We used logistic regression to formally assess the relative attention devoted to aligning structural relationships over superficial features (Hypothesis 1) and the role of prior knowledge in this process (Hypothesis 2). The tests measure the odds that a randomly selected verbalization from an average protocol focused on aligning structural relationships as opposed to superficial features. In all of these tests, we controlled for differences between participants (eight dummy variables), between the two technologies scenarios (−0.5 for NASA's EAST™ and 0.5 for MIT's 3DP™), and for whether a statement was made before or after a first potential opportunity was identified within an exercise (−0.5 for before; 0.5 for after).

The results reported in Table 2 provide support for both Hypotheses 1 and 2. The results for Model 1 show that in their efforts to recognize opportunities, executive entrepreneurs are more likely to make verbalizations focusing on the alignment of structural relationships than on the alignment of superficial features (Model 1 intercept: likelihood coefficient $\beta_0 = 2.249$; $p = 0.033$). In other words, the odds that an average participant made a statement aligning structural relationships are more than nine times greater than the odds that she made a statement aligning superficial features ($\text{Exp}(\beta_0) = 9.483$).

Model 2 builds on these findings to assess the role of prior knowledge in participants' alignment of technology and market. Controlling for differences between individuals, technology, and whether a statement was made before or after a specific opportunity was identified, we find that the greater likelihood of aligning structural relationships as opposed to superficial features (Model 2: $\beta_0 = 2.940$; $p = 0.008$) augments significantly with linear increases in prior knowledge ($\beta_{\text{klin}} = 2.105$; $p = 0.007$). These results imply that, all else being equal, the odds of aligning structural relationships ($\text{Exp}(\beta_0) = 18.918$) are further augmented when participants rely on high levels of prior knowledge ($\text{Exp}(\beta_{\text{klin}}) = 8.204$). These findings suggest that in the process of recognizing opportunities, reliance on higher levels of prior knowledge is associated with greater cognitive effort (attention) to align structural relationships than to align superficial features. These results support Hypothesis 2.

Additional Observations

Three executives in our study did not identify an opportunity for the 3DP™ technology. Although our research was not meant to explain why some individuals may fail to recognize opportunities, examination of these participants' verbalizations suggests that the sole reliance on superficial features may impede efforts to recognize opportunities (one participant). Likewise, time constraints (one participant) or prior experiences with superficially similar technologies (in this case prior difficulties one participant had in obtaining intellectual property protection for a superficially similar technology) may prevent one from attending to structural relationships (such as the structurally relevant reasons why the capabilities of a new technology are unique and/or different from older ones). Although limited, these observations point to promising avenues of future research on when and why the process of recognizing opportunities may prove particularly challenging. We return to these questions below.

Discussion

Through this study, we sought to develop a better understanding of the cognitive process(es) that individuals use in their efforts to recognize opportunities. The results from analyzing 18 verbal protocols from nine executive entrepreneurs as they sought to recognize opportunities for two different technological innovations provide evidence that recognizing opportunities involves cognitive processes of structural alignment. We also demonstrate that drawing on prior knowledge facilitates these processes. Prior to discussing these results, it is important to emphasize that the significance of our findings lies not in observing that executive entrepreneurs find opportunities by *matching* technology with market, but rather that their *matching* of technology and market involves their *aligning* the superficial features and structural relationships of technology and market to one another. Furthermore, we find evidence that aligning superficial features plays a different role in the process of recognizing opportunities than aligning structural relationships, with different consequences.

Cognitive Processes of Recognizing Opportunities

Prior research has argued that the identification of opportunities involves pattern recognition (Baron 2006, Baron and Ensley 2006). Although these studies have made important advances, the particular processes used in recognizing opportunities have not been sufficiently developed theoretically, nor have they been directly investigated empirically. Our study is among the first to develop and test a model that focuses specifically on the cognitive processes involved in recognizing opportunities.

Our results contribute direct evidence about the kind of mental connections that are involved in the process of recognizing opportunities. More specifically, the pattern of qualitative and quantitative findings from our study is consistent with a structural alignment model of opportunity recognition and suggests that these cognitive processes are critical to recognizing opportunity. In general terms, we found that when executive entrepreneurs encountered information about a new technology, they considered the "similarities" between this information and context(s) where this information might be meaningful. Furthermore, different types of similarities were involved in the process, each with different consequences. Some similarity comparisons concern the superficial features of markets and technologies. Consistent with research in cognitive psychology (cf. Gentner 1989, Keane et al. 1994), our results suggest that these features serve to guide initial efforts to search for domains and situations that provide relevant bases for evaluating the meaning of the stimulus (in this case, finding market domains that could be aligned with the technology). In this regard, however, and still consistent with psychology research, our results indicate that the bulk of efforts to make sense of new information and interpret whether a technology–market match constitutes a potential opportunity relied predominantly on the consideration and alignment of structural relationships. In other words, we found that in their efforts to recognize opportunities, participants considered the alignment between how a technology operates and the cause–effect principles explaining the benefits and advantages of a technology, with what individuals in a market do, why they do it, and the cause–effect relationships accounting for the unsatisfied needs and problems in that market.

Most importantly, we found that noticing parallels between higher-order relationships appears to be a critical step in the process of recognizing opportunities. Three lines of evidence support this observation. First, we observed that if participants made some verbalizations emphasizing the parallels between the superficial features of markets and technologies, they devoted considerably more cognitive attention to aligning the structural relationships between markets and technologies, and particularly the aligning of high-order structural relationships. Second, we found that, in several cases, executives thought of opportunities where the markets and technologies shared high levels of structural relationships but low levels of superficial features. In other words, executives' reliance on the alignment of structural relationships allowed them to "transfer" the technologies "across domains" and think of opportunities that were not "superficially obvious." Third, we observed that when more emphasis was placed on the superficial elements of a stimulus than on its structural relationships, it became more difficult to think of potential opportunities. The same difficulties arose when other matters interfered with the consideration of these structurally relevant capabilities (such as when a participant focused on evaluating the feasibility of intellectual property protection for the technology and when another became concerned with time constraints). Taken together, these lines of evidence converge on the notion that, although superficial elements may guide initial reasoning about new information, reasoning about the alignment of structural relationships plays a critical role in efforts to recognize opportunities.

Our results regarding the importance of higher-order structural similarities provides a cognitive explanation for why the detection of opportunity-relevant patterns has been found to be a challenging task (cf. Chattopadhyay et al. 2001, Dutton 1993, Julian and Ofori-Dankwa 2008). Research has documented that the processing of structurally relevant information is cognitively more demanding than the processing of superficial features (Keane et al. 1994). To begin with, one needs to attend to a variety of potentially relevant signals from the environment (Ocasio 1997). But more critically, one needs to have the necessary energy to encode and process these signals at the deeper level of structural relationships. At the same time, the complexity of the task, particularly in dynamic industries, may make it quite challenging for managers to find the cognitive energy to process relevant signals at a deeper level. By drawing attention to the underlying mechanisms that underpin the recognition of opportunities, we contribute a framework for investigating the factors that facilitate (or inhibit) the process.

Our results also contribute a better specification of the cognitive processes involved in efforts to recognize opportunities. It has been advanced that entrepreneurs use prototypes and exemplars of "ideal" opportunities to detect relevant patterns between seemingly unconnected changes (Baron 2006). Contrary to the suggestions of prototype-based models, however, it is telling that the executives in our study did not refer to other opportunities they knew about. Likewise, their verbalizations only refer to one desirable attributes of opportunity prototypes (cf. Baron and Ensley 2006, pp. 1337–8).[3] To explain this difference in findings, we advance that the attributes highlighted in Baron and Ensley (2006) may be more directly involved in the *evaluation* of whether a recognized opportunity is personally worth acting on, rather than on the antecedent process of recognizing opportunities. We also observe that this explanation is methodologically more in line with the design of Baron and Ensley's (2006) study, which asked novice and experienced entrepreneurs to describe opportunities they have recognized *in the past*.

Recognition of Opportunities and Prior Knowledge

Our results also provide important insights into the role of prior knowledge in opportunity recognition. In line with past research, we observe that the executives in our study used their prior knowledge of markets to search for and think of opportunities for new technologies. But most importantly, our results document that this prior knowledge is systematically associated with executives' considerations and alignment of structural relationships. As they drew on their prior knowledge of particular markets, the executives in our study came to emphasize not the superficial features of those markets, but the difficulties and challenges that these markets face. In doing so, they made statements highlighting the causes and effects of these difficulties, and then drew parallels between these and the advantages and benefits of the new technologies. In other words, they used their prior knowledge of markets to "connect the dots" and draw meaningful parallels between the causes and effects of the problems they knew in some markets and the structurally relevant capabilities of new technologies.

By providing direct evidence for the role of prior knowledge in efforts to recognize opportunities, we contribute a conceptual explanation and empirical evidence for *why* prior knowledge is so important. Not only is it a relevant resource that provides one person with idiosyncratic advantages over other individuals (Fiet 1996), prior knowledge is a cognitive resource that enables individuals to focus on key structural parallels and to think of opportunities in markets that share few superficial features with the original context where the technology was originally developed. In other words, our results show *how* and *why* prior knowledge enables some entrepreneurs and managers to transcend the nonobviousness that may characterize some opportunities (Shane 2000). This complements recent research on the imprinting effect of founder knowledge (functional experience) on organizational structure (Beckman and Burton 2008) by focusing on a preceding step in the entrepreneurial process.

One highly relevant implication of this finding is to provide cognitive grounds to explore when and why it is important to have deep technical knowledge in certain areas—a question that is not only relevant for managers and entrepreneurs, but also for any investor or executive who sponsors the pursuit of new opportunities. For instance, nonexperts might come to overvalue some opportunities because the strong superficial similarities that they perceive may not prove all that important. Likewise, they might undervalue less obvious opportunities because they do not perceive strong superficial connections between a new technology and its application. By contrast, experts with deep technical knowledge are better placed to think of opportunities that call for making strong structural connections in the absence of superficial similarities—such as the transfer of new technologies across superficially distant domains.

Recognition of Opportunities in Organizations

Although we conducted our tests at the individual level of analysis and focused exclusively on the recognition of entrepreneurial opportunities for new technologies, our study has two important implications for future research on the recognition of opportunities in organizations.

First, we contribute a cognitive explanation for the equivocal findings of prior research on the categorization of ambiguous signals as threats or opportunities. The issue categorization literature has found convergent evidence that links the characteristics of negative valence, potential for loss, and uncontrollability to an automatic diagnosis of threat (Jackson and Dutton 1988). However, the same level of convergence has not been found for the diagnosis of opportunities (Julian and Ofori-Dankwa 2008). Building on our results, we speculate that opportunity diagnosis involves more complex—and less automatic—cognitive processes than research on threat diagnosis may imply. Opportunity diagnosis may require one to engage in the more demanding processes of encoding issues at a structural level, and of seeking to align the structural relationships of that issue with those of a relevant context. Faced with information about a shift in a competitor's behavior, for example, managers may need to align the structural relationships of this event with the structural relationships embedded in the mental representation they have of their firm's resources and capabilities. To the extent that there is sufficient alignment, managers can recognize whether this alignment points to a beneficial course of action for their firm. By contrast, the diagnosis of threats may rely more directly on considerations of superficial features, the processing of which is, by definition, less demanding and more automatic. The structural alignment perspective thus suggests that the diverging evidence regarding threat and opportunity diagnosis results from the different kinds of cognitive processes involved in the two activities.

Second, our emphasis on the cognitive processes used in efforts to recognize opportunities points to promising avenues to extend our work from the level of individual managers to the level of the organizations. As Dutton (1993, p. 351) pointed out, organizational routines and conditions may contribute to "put decision-makers on automatic in their interpretation of strategic issues." Organization routines, systems, and policies often focus the attention of organizational actors on discrete segments of the information environment (Gavetti and Rivkin 2007, Ocasio 1997). But are there organizational routines, systems, and policies that encourage (or inhibit) the encoding of information stimuli at the deeper level of structural relationships? What is the nature of these routines and how do they differ across organizations? And what are the consequences of these routines on the process of recognizing opportunities? Do they allow for the detection of opportunity-relevant patterns across superficially different contexts? Are more and better opportunities identified faster, with more certainty?

Like we did with the role of prior knowledge, we advance that the cognitive framework we develop in this research might be profitably leveraged to investigate the moderating roles of organizational factors for recognizing opportunities. For instance, it would be relevant to study whether organizational attributes like firm-level knowledge, structural flexibility, and/or dynamic capabilities (Eisenhardt and Martin 2000, Gavetti 2005) facilitate managers' efforts to consider and align structural relationships in their efforts to recognize opportunities. By the same token, it would be relevant to explore whether organizational abilities to process information (Kuvaas 2002, Milliken 1990), or the unique resources, organizational slack, or strategy of a firm (Chattopadhyay et al. 2001, Chen 2008, Thomas and McDaniel 1990), have similar effects on managers' reasoning about opportunity-relevant signals. In both cases, we propose that interesting advances could be gained by not only looking at the direct effects of organizational factors on opportunity identification, but also by considering the extent to which these factors facilitate or hinder the cognitive process of recognizing opportunities.

Limitations, Avenues for Future Research, and Conclusion

Though we took great care to conduct our analyses with rigor, important avenues for future research remain in exploring the boundary conditions of our model and in studying the factors that may facilitate (or limit) efforts to recognize opportunities. To expand the ecological validity of the findings, for instance, it would be relevant to test the model with different types of opportunity signals than the technologies used here, such as information about new market trends, or about new means of supply that are less "technological" in nature. By extension, one could investigate whether managers use structural alignment processes when interpreting ambiguous issues such as changes in their industry environment.

By its very design, our study focused managers' attention on the presented stimuli, and encouraged them to think creatively about potential opportunities. In practice, however, entrepreneurs and managers alike are bombarded with information signals—only a few of which they can reasonably attend to. Beyond the issue of whether a particular signal is attended to, the cognitive load of the task may influence the extent to which a manager uses structural alignment processes in his or her efforts for recognizing opportunities. Indeed, our study offered some evidence that when a manager was stressed (time pressure) or otherwise preoccupied, structural alignment processes were not activated, and the manager had a more difficult time thinking of opportunities. Experiments that manipulate time pressure or the number of competing tasks may be able to increase our understanding of these factors.

Last, our design was meant to investigate common patterns of thinking across executive entrepreneurs that were familiar with the task of recognizing opportunities for new technologies and for which the task was relevant. In this regard, it would be interesting to investigate whether individuals, teams, and/or organizations with different levels of entrepreneurial experience use different cognitive processes in their efforts to recognize opportunities, and with what consequences.

Successful efforts to recognize opportunities may lead to important benefits for individuals, organizations, and society. This study furthers our understanding of the cognitive processes used for recognizing opportunities. We show that efforts to connect the dots between new technologies and markets involve similarity comparison and structural alignment, and illustrate the role of knowledge in supporting these processes. By unpacking the cognitive processes that lead to the detection of relevant patterns and the formation of opportunity beliefs, we provide a basis to encourage further research on the factors that foster (and impede) this important activity for entrepreneurs and managers alike.

Acknowledgments

The authors thank L. Argote, T. Lumpkin, S. Matusik, P. Moreau, E. Mosakowski, J. Gimeno, and three anonymous reviewers for their insights and comments on prior versions of this work. Thanks also to David W. Williams for his assistance in analyzing the material. They also express gratitude to the individuals who generously agreed to take part in the study. A preliminary version of this paper was presented at the 2006 Academy of Management Conference in Atlanta, GA, and a summary was published in the 2006 *Best Paper Proceedings*. This research was funded in part by the Ewing Marion Kauffman Foundation. The contents of this publication are solely the responsibility of the authors.

Appendix. Research Material

NASA develops new training tool for improving people's concentration skills	MIT develops a method for the rapid fabrication of 3D objects
NASA has just announced the development of a new technology that could revolutionize the way all sorts of people could improve their attention and concentration skills. The SMART® (Self-Mastery and Regulation Training) works by making any computer game/simulation respond to changes in the player's pattern of brain activity. Electroencephalogram neurofeedback sensors are attached to the player's body and brain. These sensors monitor the player's neurophysiological activity and send these signals to a signal processing unit, which in turn is connected to the computer game controller. "In the program we designed," says NASA Computer Engineer Monica Rotner, "the simulation game becomes easier to control when the player's pattern of brain activity indicates that he/she is focused. But if the player gets bored, distracted, or unfocused, the computer makes the game much harder to play. Interestingly, our tests show that within weeks of repeated practice, this neurofeedback technology can significantly improve the player's concentration and attention skills." Initial tests have also shown that the SMART® technology was compatible with a number of off-the-shelf computer games and simulations. Building on these successful results, NASA's Technology Transfer Center is actively seeking partnerships and collaborations to commercialize its SMART® neurofeedback training system. The question is: *What business opportunity(ies) could you pursue with this technology?*	MIT has just announced the development of a new technology that could revolutionize the way all sorts of three-dimensional objects can be made rapidly, directly from a CAD drawing. The 3DP™ works by building parts in layers, and out of any material that can be obtained in powder (e.g., ceramics, metal, plasters, starch, some kinds of plastics, etc.). Working from a computer drawing of the desired object, a "slicing software" generates detailed information regarding the structure of each layer. The computer sends this information to the actual 3DP™ machine: the fabrication of the object takes place within an enclosed chamber where the building floor is supported on a piston, so that it can be moved up and down. The process begins by spreading and compressing a measured quantity of powder material at the surface of the building floor. Using a technology similar to ink-jet printing, a mechanical arm moves over the loose powder and deposits a binder material at specific points, effectively "gluing" the powder at the precise location where the object is to be formed. Once a layer is formed, the floor supporting the object is lowered a short distance, so that a new layer of powder can be spread, compressed, and glued. This layer-by-layer process repeats until the part is completed; unbound powder is then removed, thus revealing the finished object. Comparison with other technologies has shown that the 3DP™ process is relatively faster, quieter, cheaper to operate, and can allow for the fabrication of objects with complex internal shapes, as long as there is a hole for the powder to escape. Building on these initial results, MIT's Technological Transfer Office is actively seeking partnerships and collaborations to commercialize its 3DP™ technology. The question is: *What business opportunity(ies) could you pursue with this technology?*

Endnotes

[1]To heighten the rigor of our analysis, we also distinguished between explicit and implicit references, such as when a pronoun is used in lieu of a more complete description of this or that aspect of the technology or market. Taken in isolation, pronouns cannot indicate whether a statement expresses superficial or structural concerns. To the extent that a pronoun is used in the context of a larger statement, however, one can infer the kind of alignment that mobilizes attention. Results showed that the distribution of statements across explicit and implicit categories of alignment was similar, giving us a basis to combine the two in the results we provide below.

[2]Please note that we follow each direct quotation from our protocols with a label indicating the participant's gender (male (M)/female (F)), age range (35–44; 45–54; 55–64), sector (marketing services (mkt)/life sciences (bio)), and the particular exercise that the quote is taken from (given the technology stimulus: EAST™/3DP™).

[3]As a completely separate post hoc analysis, we content analyzed the verbal protocols in light of the attributes listed in Baron and Ensley (2006, pp. 1337–1338). Results indicate that participants used only one of the attribute categories associated with opportunity prototypes: solving customer problems. Verbalizations for this category counted for 49.8% and 41.4% of the average length of the two sets of protocols, respectively. By comparison, verbalizations for other attributes counted for 2.6% of the protocol length, on average. This importance of market considerations relative to other attributes of ideal pro-

totypes is consistent with our findings that participants' efforts to recognize opportunities rested on their structural alignment of the presented technologies with markets where it would be meaningful to use these technologies. A full description of the method, analysis, and results for these post hoc analyses is available from the first author.

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