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Mental Models of the Environment Particular to Weak Signal Analysis[1]

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Abstract. Perceived weakness of signals indicating change for companies are often subject to empirical investigation because this type of information is considered to be the basis for strategic decision-making and requires a particular process due to its ill-defined nature. However, studies rarely confirmed the presence of weakness in the perceptions of the samples in question, meaning that weakness of signals was assumed beforehand rather than checked to be present in the perception of subjects. This lack of validation can raise severe doubts about results and conclusions of previous work on weak signals. This study redid earlier investigations of managerial weak signal analysis, where top-managers were asked to recall critical incidents and the signals leading up to these incidents. Grounded theory guidelines were used to explore process characteristics and to enable the emergence of new insights. We established the presence of perceived weakness in the narratives and thus were able to validate and add to earlier findings on weak signal analysis. General process findings were validated. New results were found on underlying mental models and their ties to signal perceptions, search criteria, and strategy. Findings led to theoretical contributions in the shape of a mental model framework and to suggestions for the further development of managerial tools to explore weak signals and increase reflective capability in order to reduce weak signal myopia.

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1. Introduction

The company environment holds unfamiliar, ambiguous signals of emerging change that are difficult to perceive and interpret unequivocally. For instance, in its early years, the Internet was seen as a toy, a weapon, a sales technology, a thought framework, and many things in between (Schulte 2013). We now know that the Internet transformed entire industries, but it took decades for managers to make sense of this technology (Glowniak 1998; Leiner et al. 2009). The need to uncover technologies such as the Internet early is rising due to the increasing scope of technological change and its consequences for companies (Ahlqvist and Kohl 2016).

The early identification of emerging developments may give companies precious time to adapt to and profit from change (Heinonen and Hiltunen 2012; Hiltunen 2008). Ergo, successful managers are likely to be better versed in early identification; a process also called weak signal analysis. Weak signals are unfamiliar and ambiguous fragments of information on emerging trends that may impact the company in the future (Aguilar 1967).

In the last fifty years, how managers sense or search for weak signals has been thoroughly documented (Aguilar 1967; Auster and Choo 1994; Garg et al. 2003; Loza-Aguirre et al. 2016), but researchers rarely made explicit in what sense signals were weak. Weakness could have many meanings, such as non-salience, ambiguity, novelty or ridiculousness, as well as perspectives, such as objective trend data or subjective pressures. Here, weakness is not an inherent trait of information on emerging developments, but a perception of information that may vary per individual and situation. Indeed, managers can perceive different levels of weakness based on the same signal, depending on their familiarity with a signal. A well-developed trend can be perceived as very weak when an assessor does not know enough about it. Similarly, an ambiguous, unfamiliar trend can be perceived as very strong when an assessor can easily match it to existing knowledge. Thus, researchers must somehow verify signal weakness in the eyes of the sample, before any conclusion

can be reached on weak signal analysis. The existence of perceptions of weakness has been established (Seidl 2004), so now the field needs to validate initial results with studies based on verified perceived weakness. This paper serves as one of such checks because we redid studies on the ways top-managers perceive weak signals (Aguilar 1967; Auster and Choo 1993). Contrary to those studies, we did not set out to investigate where, how, and what signals were identified, but we explored underlying perceptions about the source, character, and interpretations of weak signals. Hence, our general research question was:

What underlying perceptions do outperforming top-managers have that may determine the process of weak signal analysis?

Outperforming top-managers of 13 companies were asked to recall the ways they have perceived emerging change. Based on their narratives on successes and failures, deductions were made about underlying perceptions about the environment, weak signals, and their interpretations.

In the next section, relevant literature is presented. The method used is described in section 3, and the results are in section 4. The article ends with the discussion and conclusions.

2. Theory

This study focuses on the perception and interpretation of weak signals and as such views the environment as a system of signals (El Akrouchi and Kassou 2015; Emery and Trist 1965; Lesca et al. 2012).

In the last fifty years, growing scientific interest in the strategic environment has led to the proliferation of studies on its many aspects, as well as to fragmentation of findings. New insights remained behind the boundaries of research disciplines, instead of advancing the overall theoretical frameworks. Research on signals in the environment started off in the late 1960s with a study on managerial scanning.

Strategic decisions were divided into routine and innovatory ones. Both involved scanning, but for innovatory decisions only unfamiliar, ambiguous signals would be available. Ambiguity required a distinct scanning process with vague goals and informal approaches. (Aguilar 1967). Unfamiliar, ambiguous signals, also called weak signals, came from unanticipated sources and the change they indicated would develop quicker than expected. Managers should detect weak signals as early as possible and respond fast, independent of the yearly routine strategy cycles. (Ansoff 1975, 1980; Molitor 1977).

The distinction between the two scanning types has become widely accepted and now includes other phenomena such as cognition and perception (Anderson and Nichols 2007; Blanco and Lesca 1997; Dutton et al. 1983). Studies of weak signals can be found in loosely related research disciplines, such as sense-making (Maitlis and Christianson 2014), strategic choice (Child 1997), and foresight (Bell 2001; Rossel 2012). Sense-making focused on the perceptual side of the analysis, strategic choice on how the environment determined the analysis, and foresight specialized in methodologies to improve the analysis.

Sense-making was the process described for the interpretation of ambiguous signals of strategic problems (Daft and Weick 1984; Maitlis and Christianson 2014; Weick 1979). Definitions of signals were by no means clear and uniform, but referred foremost to unanticipated strategic challenges (Daft and Weick 1984; Kiesler and Sproull 1982; Starbuck and Milliken 1988). Perceptions would originate from individual belief systems because that system determined what signals got noticed and interpreted. Thus, different managers had acted differently to the same change in the environment (Brozovic 2016; Palich and Bagby 1995). Consequently, anticipating change was mainly relying on personal perceptions and interpretations (Blanco and Lesca 1997; Lesca, Caron-Fasan, and Falcy 2012; Lyles and Thomas 1988; Wang and Chan 1995), and cognitive limitations were seen as a major cause of failure (Garg et al. 2003; Kiesler and Sproull 1982; Yasai-Ardekani and Nystrom 1996). Anticipatory skills, such as knowing where to look and what signals to detect, were developed through experience with unanticipated challenges (Kiss and Barr 2015; Lyles and Thomas 1988). The limitation to challenges has brought many

interesting insights but has also become a challenge of its own. Challenges were found to be interpreted differently, led to a different sense-making process, and resided in a different mental schema (Anderson and Nichols 2007; Jackson and Dutton 1988; Jennings and Lumpkin 1992).

Strategic choice looked into environmental conditions such as the change rate, heterogeneity, and predictability of signals and signal clusters. Signals were foremost elicited from the samples and would consist of information on events and trends. Environmental conditions were determined by ratings of signals to calculate the level of uncertainty perceived in the environment (Auster and Choo 1993; Duncan 1972; Ebrahimi 2000; Milliken 1987; Zhang et al. 2012). The level of perceived uncertainty and the need to scan for signals were found to be positively related (Gordon and Narayanan 1984; Kattan et al. 2007). Research was meant to include weak signals, but whether or not samples perceived weakness was never confirmed.

Foresight viewed the sense-making process as a series of perceptual filters that decreased the number of signals processed. Some signals remained unseen, and others were ignored or rejected when they did not match the belief system of the observers (Ghanizadeh Poshtekooh 2014; Goosen 2014; Holopainen and Toivonen 2012; Ilmola and Kuusi 2006). Foresight contributed significantly to developing formal methods to overcome these filters (Carbonell et al. 2017; Dhami et al. 2016; Fritzsche 2017; Li 2017; Smith et al. 2017) but did not focus on the process itself or environmental conditions. Foresight did concentrate on weak signals, but despite several observations on the abundance of weak signal definitions (Hiltunen 2008; Holopainen and Toivonen 2012; Rossel 2012) neglected to ensure generalizability of their work. Definitions were so diverse that researchers may have measured entirely different constructs.

In short, sense-making was limited to challenges, strategic choice did not verify if signals were perceived as weak, and foresight omitted to generate comparable results and to establish what weakness entailed. This left the authors with the

uneasy feeling that results were difficult to compare at best, and not describing weak signal analysis at worst.

3. Sample and Approach

The goal of this study was to explore, not to confirm, the variety of underlying perceptions of outperforming top-managers that may determine the process of weak signal analysis. Variety was ensured by sample composition, data collection method, and process of analysis. The sample was restricted to outperforming top-level managers, but heterogeneous in terms of industry and firm size. The open interview was the data collection method of choice, allowing diverse input. Inductive interview reports were subjected to a thorough comparative, iterative analysis, under generally accepted grounded theory guidelines. We will discuss the specifics of the sample composition, data collection and analytic process below.

3.1. Sample Composition

A heterogeneous sample of outperforming Dutch top-managers was interviewed during the period October 2014 to February 2015 (see Table 1 Sample). The primary task of top-managers is to locate and exploit markets to maintain a healthy company with a well-defined domain (Miles et al. 1978), which makes them the most likely official to be well versed in perceiving weak signals.

The top-managers were recruited from our personal network, so we could count on active, robust partners, who would grant us the benefit of their extensive experience and expertise, both in the richness of initial data as in the development of theory. This way, participants were directed by the interviewer, while in turn, the interviewer was also directed by the participants. Together, we constructed a perceptual view of weak signal analysis (Charmaz and Belgrave 2012; Charmaz and Mitchell 1996).

Top-managers can be considered outperformers in this task when their companies' profile demonstrates long-term profitability (Buyl et al. 2011; Finkelstein and Hambrick 1996; Rutherford and Holt 2007). Here, outperformance was ensured by setting three restrictions on participation: the top-managers should be at the helm of companies leading in their industry, they should be the person highest in the

hierarchy responsible for overall strategy, and they must have over ten years of experience at this level. In most cases, this role was taken up by the CEO or the chairman of the board. In all, 13 top-managers were interviewed. Ages varied from 40 to 65 as a result of these requirements.

Sample Composition				
Case	**Seniority**	**Annual sales in million euro in 2013**	**Company Type**	**Industry (main)**
1	Advisory Board	17,600	Conglomerate	Energy
2	Advisory Board	963	Diversified	Software
3	Board of Directors	40	Single industry	Consulting
4	Board of Directors	2,500	Single industry	Retail Non-food
5	Board of Directors	120	Diversified	High-Tech
6	Board of Directors	4	Single industry	Finance
7	Board of Directors	19	Single industry	Destination/Retail
8	Board of Directors	2,498	Diversified	Wholesale/Retail Food
9	Board of Directors	595	Diversified	Audit/Consultancy
10	Board of Directors	4,345	Single industry	Mail/Logistics
11	Advisory Board	958	Diversified	Chemical
12	Board of Directors	59,256	Conglomerate	Space/Defense
13	Board of Directors	289	Single industry	Legal

Table 1 *Sample*

Heterogeneity was ensured by the variety of industries and firm sizes included in the sample.

Managerial perceptions are influenced by age and expertise (Carpenter and Westphal 2001; McKenzie et al. 2009; Rodenbach and Brettel 2012), thus caution is needed when interpreting the results of the very experienced participants in this sample.

3.2. Data Collection

The study into the underlying perceptions of weak signal analysis was set-up as an in-depth discourse on the best and worst practices of weak signal analysis processes, in which these perceptions would surface in between the lines. The emergent character required distinct interview guidelines because it entailed comparison of inductive data over multiple iterations; each iteration more directed than before. Instead of a pre-developed set of interview questions, we started interviewing with a more general area of interest, and questions and guidelines were developed continuously during data gathering, resulting in increasingly more focused interviews.

We went this route because, in earlier work, researchers had not verified the level of perceived weakness of the signals, rendering their conclusions on the effect of weak signals unvalidated. Thus, we could not identify the most significant process and had to let it emerge from data instead. Interviews commenced with a specific prompt to initiate the recall of relevant experiences. This method, called the Critical Incident Technique (Flanagan 1954), was adopted from earlier studies into managerial scanning (Auster and Choo 1994, 1993). The 'incident' referred to a complete, recent event of domain discussions and the environmental assessments leading up to the discourse. We copied the prompt from these studies verbatim:

"Please try to recall a recent instance in which you received important information about a specific event or trend in the external environment information that led you or your company to a new initiative, a change of direction, or some significant action. Would you please describe that incident for me in enough detail so that I can visualize the situation?" (Auster and Choo 1994, p 609)

When the account was told without interruption, subsequent probing questions first invited participants to clarify and to explore weak signal process characteristics, then to explore uncertainties and failures in contrast to certainties and successes, and finally to build on earlier interviews by the request to review lists of findings therein (adapted from Glaser 1978; Glaser and Holton 2004; Scheibelhofer 2008). As such, narratives were not merely an instance of hindsight bias and justifications, but also of

new reflections and insights (Charmaz and McMullen 2011; Charmaz and Mitchell 1996).

It soon became apparent that the initial prompt led to the spontaneous and detailed recall of multiple critical incidents per participant, and further interview guidelines were not developed. Narratives all took around one and a half hour each and took place at the offices or home address of the participant. A single researcher had the role of interviewer, to enable comparable narratives. Her role was primarily to prompt narration, take notes in keyword format, using the expressions and analogies of the participant, and to instigate reflection. Participants did not want to be taped, so we had to resort to written reports. A joint production of notes by the interviewer and task experts in a heterogeneous sample could lead to sound results (Clausen 2012). Therefore, the final text was checked by each participant to be a correct record of the conversation. Joint production helped us to reach the most reliable, valid, and transparent record possible without taping.

3.3. Data Analysis

The analysis began with the open coding of fragments of the case reports (O'Reilly 2012). Guiding questions for coding were used like 'What category does this incident indicate?' and 'What is the main concern being faced by the subject?' (Glaser and Holton 2004). Resulting codes first took the shape of gerunds to describe process characteristics and then of focused codes to describe underlying perceptions. Gerunds express actions taking place and thus help to move from static text to interpretation of process. Focused codes use significant or frequent initial codes to reduce and conceptualize the data. This approach forced the analyst to verify and saturate code categories, minimized missing codes and ensured the grounding of categories beyond impressionism (Charmaz 2006; Charmaz and Belgrave 2012; Glaser 1978; Glaser and Strauss 2009).

Resulting theoretical implications were the prime mover for collecting data and codes. When codes became abundant, these were categorized per common denominator, thus forming a code tree. No codes were deleted. Several codes were merged when interview data indicated that these codes had the same meaning. For

instance, ignoring, neglecting, and discarding signals were merged into not-enacted. Other codes moved to different parent-codes. New codes and categorizations led to reassessing previous case reports, to log all occurrences. The process stopped when new data did no longer lead to code generation or category refinement (Eisenhardt 1989; Glaser and Holton 2004; O'Reilly 2012).

Codes were grouped into tentative categories, then categories were refined and completed using literature, and finally, the case reports were reread for the occurrence of new or changed category items. Analysis of codes, categories, and empirical evidence often led to theoretical questions or meta observations, and a memo was attached to record the question or observation. For instance, participants often used words such as complex, continuous change, and dynamic to describe the environment. After seven cases had been reviewed, a memo was written comparing and contrasting these words with environmental dimensions found in literature. The memo ended with two questions: what other dimensions are verbalized, and, can dimensions form an index of some type? Memos like these were used to ask more focused questions and to make the researcher's process explicit. This way, theoretical sampling enriched data and played a self-correcting role.

After seven interviews, hardly any new codes were added, but the number of memos increased temporarily until interview eleven, and it seemed theoretical saturation was reached when lines could easily be coded without having to create new codes, categories, or memos for interview twelve and thirteen. We verified this through of a fourteenth interview with the top-manager of an industry association, assuming that this specific position would have led to a distinct expert frame. However, existing codes were sufficient to code the complete report adequately. Coding reliability was checked by another researcher, who, without training, was able to code the same text fragments with the same codes.

Codes, categories, and memos were sorted and integrated into insights on stages in the process of weak signal perception and assessment, environmental models, and perceptions. We will present the insights in the next section.

4. Results

The coding and categorization of both successful and erroneous weak signal analysis narratives were assumed to lead to the finding of a variety of processes and underlying perceptions, that would help the validation of earlier findings and extend insights into the perceptual view. Hence, we will first concisely point out the similarities between our findings and literature and proceed with a more detailed discussion of new findings. Since we critiqued the absence of perceived weakness verifications, we will establish the presence of weakness in our data. After that, we will address underlying perspectives: we will present the various mental models of the environment and their implications for weak signal analysis.

4.1. Validation of Weak Signal Process Patterns

The weak signal process is usually described in contrast with its strong signal counterpart. The strong process is the formal, systematic gathering and assessing of routine management information, and the weak process is its opposite (Aguilar 1967; Ansoff 1975; Mintzberg et al. 1976). It is usually described as the informal, incremental approach to notice and construct meaning about emerging change. Researchers describing the observed process have noted many variants at company level (Blanco and Lesca 1997; Mintzberg et al. 1976). However, over the years, the consensus is that the personal perceptual process does follow a particular pattern (see Figure 1).

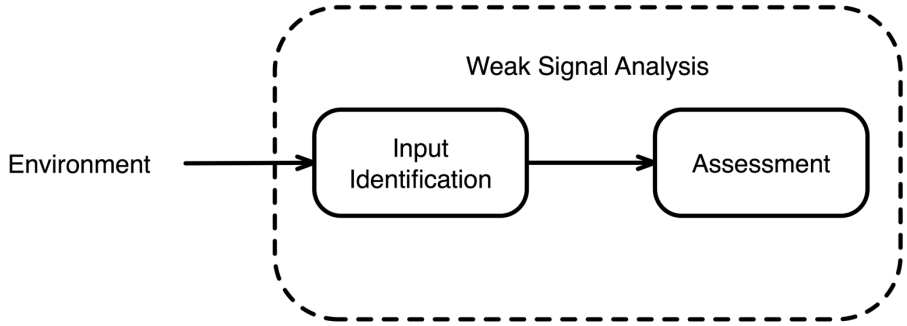

Figure 1 *Weak Signal Assessment (adapted from Ansoff, 1975)*

First, a signal must enter the field of vision and be recognized as such. If its meaning is somehow deemed relevant for the company's future, its possible impact is assessed (Ilmola and Kuusi 2006; Lesca and Caron-Fasan 2008; Regan 2012; Starbuck and Milliken 1988).

In line with the literature, our sample also described as many variants as there were participants for the process at company level, and referred to a similar process pattern for individual perception.

4.2. Confirmation of Perceived Weakness

We defined weak signals as unfamiliar, ambiguous fragments of information on emerging trends that may impact the company in the future. Prompted to recall the situation that led up to critical incidents, participants would refer to several attributes of unfamiliarity or ambiguity, such as distance to the business environment, unawareness of information, perceived ridiculousness of information, opposition to information, complexity or unstructuredness of information, unpredictability or extreme speed of a trend's emergence, first time connections between trends, or information limited to the presence of a gut feeling. References to one or more of these attributes would lead to the gerund code "Perceiving as weak." Thus established, eleven of the thirteen participants referred to weakness attributes explicitly, and among them, 23 weak signals were discussed. The two participants who did not refer to weakness managed high-tech companies at the forefront of technological innovation. To them, emerging trends were inside the frame of reference and weakness was expressed in terms of originality rather than unfamiliarity and ambiguity. The difference could be illustrated by the lack of uncertainty or surprise that weak signals usually evoke, and the presence of a formalized, systematic, and frequent process to monitor and evaluate new developments. Nonetheless, we concluded that our findings did reflect weak signal analysis.

4.3. Unusual Mental Models of the Environment

Aguilar was not only the author of the first field study into scanning of weak signals, but also the father of the assessment tool that compartmentalized the business

environment in a political, economic, societal, and technological segment (Aguilar 1967). The tool has become widely adopted in business environment analysis. It has made it into the handbooks for marketing most used in graduate schools around the world and survived until the present edition (Kotler 2002; Kotler and Armstrong 2018). It is so universally accepted, that researchers of the business environment rarely explain their choice for this model in their studies. Considering the commonality of this model among educators, marketers, and scientists, it is quite surprising that top-managers hardly referred to it. In two cases, a simplification was mentioned (case 2 and 4), but most models of the environment were of a very different nature (see Table 2).

Textures of Mental Models		
Case	**Texture**	**Summarized Descriptions of Environmental Models**
1.	Fog	The environment is foggy, and navigating it is done by sensing and reflecting, rather than scanning
2.	Layers	The environment is layered: “the company” (inner circle), “substitutes” (first layer) and “related technology” (second layer)
3.	Loops	The environment consists of linked and looped conditions and pressures over time that hold some type of power over the company, such as relevant negotiations or the governmental climate
4.	Segments	The environment consists of classic segments such as regulation and technology, mixed with parts of other text-book models such as supply chain links
5.	Silos (sole)	The environment holds various, unlinked systems with their own change rate, adoption curve, and needs. Each system is represented by a separate mental model that the narrator would explicitly keep apart
6.	Silos (linked)	The environment holds distinct, financially unlinked systems, with the top-manager as linking pin
7.	Web	The environment is a web of interlinked cultures, each with their own time-span orientation, change rates, needs, and biases, with the top manager as linking pin

8.	Silos (sole)	The environment holds stand-alone conditions, pressures, and stakeholders, such as inflation, level of consumer confidence, stock market fluctuations, actions of competitors, and social media developments
9.	Web	The environment is a web of perspectives on causal relationships, which considers the various starting position of the perceivers in the web, concerning hierarchy, regions, and industries
10.	Zones	The environment is layered in domains and competencies of various spatial and temporal distances to the company's present core business and competencies
11.	Matrix	The environment is described in emerging themes like demography and digitalization, that overlay siloed markets and departments
12.	Horizons	The environment is a sequence of time horizons: the customer orders six years in advance, it takes twenty years to develop new technologies, and so on
13.	Puzzle piece	The environment is a puzzle: the assembling of piecemeal "a-ha erlebnissen" from a myriad of sources

Table 2 *Textures of Mental Models*

The environment was described using metaphorical concepts describing its perceived structure (Lakoff and Johnson 2008), like weather, realms of influence, containers, or webbed perspectives. These metaphors convey more than imagery, they also communicate an understanding of the relevant environmental components and their relationships, in literature called environmental texture (Emery and Trist 1965).

After naming textures on the basis of the descriptions, we attempted to group all textures in dimensions related to the weak signal definition, which were unfamiliarity, ambiguity, and emergence. Unfamiliarity could be expressed in spatial distance away from the knowns, such as layers (case 2) and zones (case 10). Ambiguity could be expressed in vagueness such as fog (case 1), pressures (case 3). Models with higher unfamiliarity and ambiguity consisted of more nodes and links than those with lower unfamiliarity and ambiguity. For instance, a web described causal

relationships of several types (many links and nodes), while sole silos described unrelated systems (no links, few nodes). We summarized this progression in a composite dimension called linkage.

Emergence could be expressed in references to future states, such as horizons (case 12) and zones (case 10). Horizons and zones had explicit references to future states, contrary to models that would remain the same no matter what, such as the puzzle piece (case 13) and fog (case 1). Some models would not accommodate emergence but could be modified in accordance with environmental change. Such models would capture the environment at a certain point in time, and remain stable until an evaluation was done at a later point in time. We likened this to a sequence of snapshots of the environment. Models like silos (case 5, 6, and 8) and segments (case 4) fell in this category. We summarized the three categories (static, snapshot, and emergent) in a dimension called dynamism.

All models were plotted in a matrix created with the dimensions links and dynamism (see Figure 2).

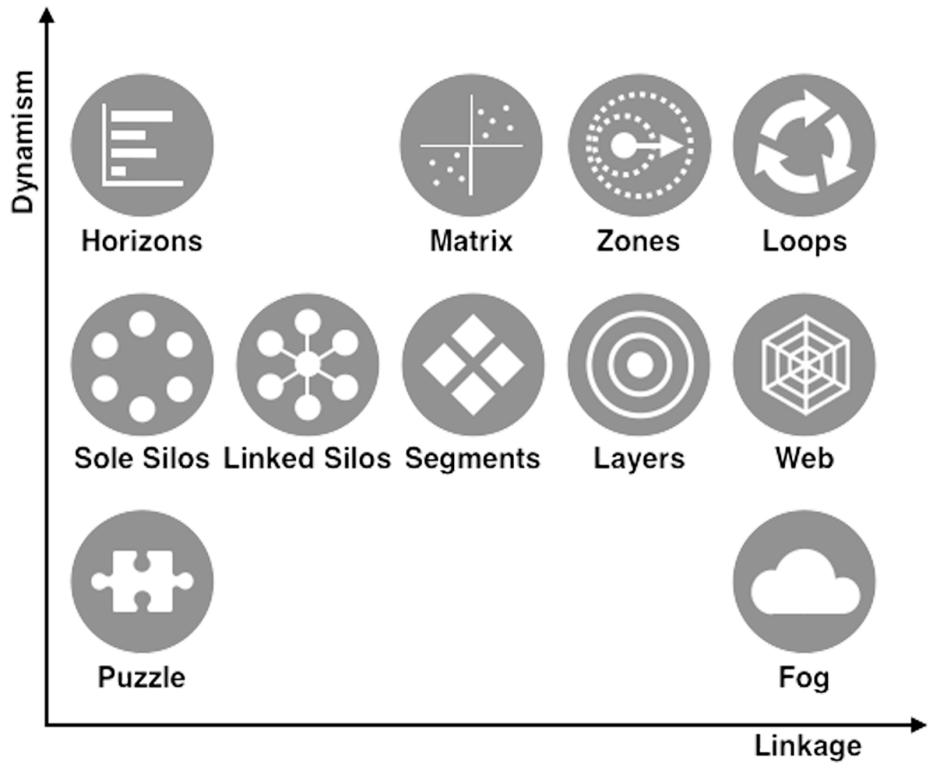

Figure 2 *Mental models in a framework of increasing number of links and dynamism*

Linkage progressed from a single unrelated element to very many connections. For instance, the environment as a collection of silos that the top-manager treats as unrelated has fewer links than when the top-manager views himself as the linking pin who brings elements from one to another. Similarly, silos linked by the top-manager have fewer links than segments that together form a whole. In turn, segments have fewer links than an environment that defines nodes and links, as a web does. Dynamism progressed from a static element to a snapshot of influences at a particular moment in time, to elements that would affect each other dynamically over time. For instance, a puzzle piece has a fixed shape that has fixed relationships with other puzzle pieces. A silo represents a system at a given time, and as such functions as a snapshot of the current situation. A horizon indicates development, and as such is a more dynamic view than a snapshot.

4.4. Coherence of Textures and Weak Signal Perceptions

Texture appeared to be consistent with the type of signals perceived and, not surprisingly, criteria for search. We will first explain how the coding of signal perception developed, and then we will present commonalities between specific model textures and the corresponding signal perceptions and search criteria. After that, we will zoom out to view the mental model framework as a whole.

Coding of signals was not restricted to a signal definition. Anything and everything that a participant labeled as a signal were included and coded as a signal. Signal weakness was coded unconnectedly as described in paragraph 4.2. When signals were coded, and weakness was established, we returned to the text fragments around a signal and induced how weak signals were perceived. Signal perceptions were closely tied to environmental texture. For instance, in the siloed model of case 6 (see Table 2), texture consisted of financial systems, and the recalled weak signals consisted of revenue models that were likely to spark a change in the silo formation. In the looped model of case 3, unfamiliar signals on existing conditions were seen as precursors of new loops. This finding has a parallel in the cases without weak signals. For instance, in the horizon environment of case 12, signals were not sought

but created from current technological impossibilities. These self-made signals were not used to recognize emerging change, but to stretch horizons.

Top-managers positioned themselves as outside the textured environment, which is consistent with the task to recall a sequence of events. Nevertheless, an overview is also needed for the early detection of textural change. In contrast, sensing a textural change from within an environment would be much harder, as the spread of change would not be visible. This notion led us to induce that texture may be indicative of search criteria, and we returned to the data to see if this was the case. Observations of change was combined with signals specific to the texture. For instance, it is useless to peer into a fog for specific signals (case 1). Having classifications of signals and action repertoires at hand for the moment that signals start looming makes more sense. Indeed, this participant stated: “I know that I can’t know it all”, and: “I know what type of signals to look out for.” In case 10, the environment was layered, but not in the classical Kotlerian sense. Layers, in this instance called zones for the purpose of contrast, had the shape of spatial and temporal distances to the current domain of the company. As such, this was the mental model that came closest to a literal weak signal capturing framework. Like case 1, search was not directed to specific signals. Unlike case 1, the top-manager did not wait until signals started looming. Instead, she actively scouted unfamiliar but scalable developments in domains that were one or two steps removed.

Close ties between texture, signal perceptions, and search criteria, seemed to suggest a strong link between texture and strategic planning. Indeed, both weak signal analysis and belief structures have already been defined as pervasive and central to strategy (Dutton 1993; Kiss and Barr 2015; Nadkarni and Barr 2008). Links were found between the position of the mental model in the framework depicted in Figure 2 and the strategy to reduce weakness of information and environmental uncertainty. Simple, static models mirror the notion that the environment is fundamentally knowable and that uncertainty can be eliminated by more search. Simple, dynamic models mirror a transparent, changing environment. Uncertainty can be reduced by forecasting. Complex, static models mirror a more permanent state of high uncertainty. Here, uncertainty is a given and can be managed by

systematic probing. Complex, dynamic models mirror turbulence, and its management requires more a complex strategy.

Organized by the dimensions of complexity and dynamism, the model framework seems akin to modern strategy paradigms that recognize multiple levels of uncertainty and corresponding strategies (Makridakis et al. 2009; Walker et al. 2010). Although these paradigms emerged from observations of the external world and the model framework from verbalized cognitions, they share the assumption that environmental conditions such as uncertainty or perceived weakness require specific action, and that these conditions and actions should be proportional to the amount of uncertainty or weakness, to avoid costly mistakes of under- or overestimations.

Implications of the findings for theory and practice will be discussed in the next section.

5. Discussion, Conclusions, and Future Research

The goal of this study was to explore underlying perceptions on weak signal analysis of outperforming top-managers that may determine the process. In-depth recollections of thirteen top-managers from diverse industries and company sizes on critical incidents and the weak signals leading up to them were analyzed along the guidelines of grounded theory. Perceived weakness was established for the majority of cases, and a pervasive underlying perception was found in the form of the texture of the mental model of the environment. Textures were closely tied to signal perception, search criteria, and strategies to reduce weakness.

5.1. Weak Signal Verification

Recent contributions to a theory on weak signal analysis have been focused on the process and its integration into strategy and practice (Haeckel 2004; Kuosa 2010; Mendonça et al. 2012), despite appeals to qualify and quantify perceived weakness and weak signal definitions first (Hiltunen 2008; Holopainen and Toivonen 2012; Rossel 2012). We defined weak signals as unfamiliar, ambiguous fragments of

information on emerging trends that may impact the company in the future, and confirmed perceived weakness by counting the occurrence of verbalized attributes of weakness. Attributes were expressions of unfamiliarity or ambiguity, such as distance to the business environment, unawareness of information, perceived ridiculousness of information, opposition to information, complexity or unstructuredness of information, unpredictability or extreme speed of a trend's emergence, first-time connections between trends, or information limited to the presence of a gut feeling. The variety and characterization of the attributes are in line with aspects of many different weak signal definitions. We interpreted the sheer number of attributes as another call for a more well-defined construct and measurements, and we consider this a primary issue in urgent need of addressing. Further theoretical contributions are depending on agreements on what the theory is supposed to be on and on comparable, generalizable, thus quantified results. A starting point could be the development of a unified definition that would include the principal attributes used in literature.

5.2. Mental Models

The classic layered, segmented environmental model prevalent in strategic and marketing management was rarely mentioned. Instead of striving for such a complete model, top-managers claimed that their perspective was not, probably can never be, and even stronger: should not be complete. Complete models would provide a false sense of security, and may not be the best protection for the uncertainty perceived. Deliberately incomplete models allowed top-managers to remain sensitive and highly perceptive to unfamiliar, ambiguous signals.

The mental models were characterized by textural metaphors that could be organized along two dimensions: complexity and dynamism. Mental models are shaped by experience and learning (Garzón-Vico et al. 2016), and so it is not surprising that textures reflect precisely the dimensions typical to environmental turbulence (Duncan 1972; Emery and Trist 1965; Nadkarni and Barr 2008).

The mental model framework is an indication of the richness of the concepts still to explore within the field. It can be seen as a step towards a more detailed

representation of mental models and their role in weak signal analysis, clearly identifying textures and dimensions, which can be used to detail the phase prior to signal identification (Hutzschenreuter and Kleindienst 2006), examine its effect on perceptual filters (Barreto 2012; Nadkarni and Barr 2008), and the interpretation of the signal (Hahn et al. 2014).

5.3. Textural Pervasiveness

The pervasiveness of texture in signal perceptions, search criteria, and strategy, indicates that the mental model is a coherent framework used to guide decision-making. Research on decision-making has already established that experts rely on general constructs and less on detail (Kiesler and Sproull 1982; Westhead et al. 2005), making experts more effective. Our sample consisted of outperformers, and the question arises if the same coherent models exist in the minds of managers without extensive experience. Nevertheless, the close ties between mental model and signal perception implicate a significant role of texture during the recognition of weak signals in both academic and managerial endeavors. A few theoretical implications have already been noted in paragraph 5.2. We will explore a significant managerial implication here.

Managerial mental models are the antecedents of strategic change (Haleblian and Rajagopalan 2005; Nadkarni and Barr 2008), and their complexity promotes strategic flexibility (Nadkarni and Narayanan 2007). Models also frame search and the interpretive process on which strategic decision-making is based (Hodgkinson et al. 1999; Jackson and Dutton 1988; Schwenk 1988). Our findings suggest the same role for the mental model specific to weak signal analysis, and assumptions in the model on linkage and dynamism can be matched to levels of environmental turbulence. Awareness of the model's central role and of tangible model textures and dimensions may spark reflections on the dominant, shared mental model in organizations and evaluations of the match between the shared model and perceived turbulence. Such probes of the mental models of those responsible for weak signal analysis may already lead to more competent search and interpretations, because explication may reveal blind spots and mismatches leading to erroneous search and interpretations. For instance, if the CEO's mental model's

texture consists of zones and other management team members models of layers, they share compartmentalization but not the vision on the future state. This may remain hidden as long as environmental change is small or slow but may lead to serious unexpected oversights in measures for the resilience of the company at the same time.

5.4. Future Research

Although weak signal analysis has a clear empirical point of origin (Aguilar 1967; Ansoff 1975; Molitor 1977), research has diverged into various more or less separate lines of research, among which strategy and cognition. Exploring parallels, such as frameworks for strategies per level of uncertainty and our mental model framework, may enhance theory in each line and reduce myopia that comes from specialization. Specifically, weak signal research, severely limited through unverified weakness in studies, may benefit tremendously by cross-referencing uncertainty research. Not only does uncertainty research already have a fully developed perceptual view, it also has validated instruments to measure perceived uncertainty, and disaggregated the construct into meaningful types and levels (Daft and Weick 1984; Duncan 1972; Milliken 1987; Namiki 1989; Regan 2012). In our exploratory study, we were able to verify that data included perceived weakness and the parallel with uncertainty pointed towards the cost of leaving verifications on the binary level. More than just noting the absence or presence of perceived weakness, our field should also determine levels of perceived weakness, enabling investigations of the elements of competent proportional action and the corresponding mental models central to strategic action.

Remarkably, our field has been focusing on myopia of a different order. Tools to enhance managerial weak signal analysis, such as scenario planning, road mapping, or voroscoping aim to reduce weak signal myopia by widening the scope of scanning (Schoemaker et al. 2013; Van der Heijden 2011). These tools often employ (parts of) classical models of the environment. Much of the empirical effort resides in attempts to formalize tools and finding proof of their beneficial effect. Perhaps this work would benefit from reflection on the pervasiveness of the classical model and the

consequences thereof, as well as explorations of the effects of other model dimensions and textures on the tools.

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