Delft University of Technology

Compensating for perceptual filters in weak signal assessments

van Veen, Barbara; Ortt, J. Roland; Badke-Schaub, Petra

Citation (APA)

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Compensating for Perceptual Filters in Weak Signal Assessments

First and Corresponding Author

Barbara L. van Veen[1]

Industrial Design and Engineering

Delft University of Technology

Mekelweg 2

2628 CD Delft

Netherlands

b.l.vanveen@tudelft.nl; barbara@contexts.nl

+31611871413

Co-Authors

J. Roland Ortt

Technology, Policy, and Management

Delft University of Technology

Jaffalaan 5

2628 BX Delft

Netherlands

j.r.ortt@tudelft.nl

P.G. Badke-Schaub

Industrial Design and Engineering

Delft University of Technology

Mekelweg 2

2628 CD Delft

Netherlands

P.G.Badke-Schaub@tudelft.nl

---

[1] Present address: Jisperweg 5, 1463 ND Noordbeemster, Netherlands

Abstract:

The effect of ambiguous and non-salient information on the managerial interpretive process is rarely investigated, although this information is considered to be the basis for strategic decision-making and requires a different process due to its ill-defined nature. This paper explores the process that outperforming managers used to detect and interpret weak signals. Interviews with 13 top-managers were analyzed using a grounded theory approach to allow the process to emerge. The findings confirmed earlier conclusions on perceptual filters that reduce the number and type of signals assessed. Contrary to earlier findings, the process was significantly altered to compensate for this loss in two ways. First, managers deliberately postponed their assessment of a weak signal by discussing it with people with distinct and second, some managers deliberately searched for signals that were unfamiliar and not fitting their mental model. The sample consisted of outperforming top managers, which raised questions about the generalizability of the findings in specific directions: are the alterations in the weak signal process exemplary for outperformers only, and how does its success compare to formal foresight methods. Finally, the findings have managerial relevance since they indicate how to detect and bring weak signals into the company before impact.

1.   Introduction

Anticipating environmental change early is essential to the survival of companies. It gives top-managers time to assess possible future impact and to take measures if necessary (Heinonen & Hiltunen, 2012; Hiltunen, 2008; Rossel, 2011). Emerging change is perceived through novel, complex, rapid, or otherwise ill-defined signals. These signals progressively materialize into perception, amplifying from weak to strong with each consideration (Ansoff & Sullivan, 1993; Holopainen & Toivonen, 2012; Rossel, 2012; von Groddeck & Schwarz, 2013).

The first detection of a weak signal is difficult, not only because of its ill-defined nature but also because it is hard to detect. Weak signals can easily remain hidden in the noise of other data (Aguilar, 1967; Menon & Tomkins, 2004). The current exponential data growth will progressively trouble signal detection (Boyd & Fulk, 1996; Ebrahimi, 2000b; Elenkov, 1997;

Yasai-Ardekani & Nystrom, 1996; Zhang, Majid, & Foo, 2010). Cognitive limits also cap signal detection. Human minds simply cannot take all signals in (Hambrick, 1982; March, 1978; Simon, 1976), so our minds have to make-do with selective perception. The combination of noise and cognitive limits turns the detection of signals into a formidable managerial challenge. Insight in aspects of signal detection may help to ease that burden (Dutton, Fahey, & Narayanan, 1983; Jackson & Dutton, 1988; Murphy, 1989).

Research into weak signal detection took off with the work of Aguilar. He was one of the first to differentiate between two distinct detection processes: one for the gathering of information for familiar or routine decisions, and another for innovatory decisions. The latter process fitted the decisions based on weak signals. Both processes would involve signal detection, but the perception of signals differed considerably due to the presence or lack of precise and abundant information. (Aguilar, 1967).

Many researchers have since endorsed the existence of these two processes (Anderson & Nichols, 2007; Ansoff, 1975; Blanco & Lesca, 1997; Dutton et al., 1983; Lyles & Mitroff, 1980; Mintzberg, Raisinghani, & Theoret, 1976). Several dimensions of the process have been described, such as process patterns (Lyles & Mitroff, 1980; Lyles & Thomas, 1988; Mintzberg & Waters, 1982), scanning modes (Aguilar, 1967; Auster & Choo, 1993; Daft, Sormunen, & Parks, 1988; Dutton, 1993; Fahey & King, 1977; McEwen, 2008; Murphy, 2011; Nutt, 1984), scope and frequency (Beal, 2000; Boyd & Fulk, 1996; Ebrahimi, 2000a; Elenkov, 1997; Yasai-Ardekani & Nystrom, 1996; Zhang et al., 2010), and the role of perceptual filters (Ansoff, 1979; Hahn, Preuss, Pinkse, & Figge, 2014; Hambrick & Mason, 1984; Ilmola & Kuusi, 2006; Nadkarni & Barr, 2008; Weick, 1995), but the body of research within the strategy field looking into the effects of a weak signal on the process is very small. Section 2 will discuss this research.

Although the promising field of futures studies has reignited the interest in weak signals, the field is characterized by the lack of analytical frameworks, unclear signal definitions, and capped by wide descriptive perceptual processes (Holopainen & Toivonen, 2012; Liebl & Schwarz, 2010). This state of theoretical development impedes the comparison and generalization of findings, rendering insights fragmented at best. Although the research results are often tantalizing, top-managers need straight answers about signal perception if they want to improve the resilience of their company.

Aguilar's field research took place in an era in which automatization had just begun, and the Internet was still confined to university laboratories. The top-managers of today face a

radically different information landscape. Consequently, a better insight into the role of signals in the detection process has to start with the question if Aguilar's unchallenged observations on the innovatory process still hold, rather than building on top of fragmented fundaments. Therefore, senior Dutch top managers of outperforming companies were interviewed to explore how they perceive signals of emerging change in the environment.

A grounded approach was used to see which signals and signal detection patterns would emerge, leaving as much room as possible for new and contradictory findings in comparison to Aguilar.

In the next section, an overview of the literature on the topic of the perception signals of emerging change illustrates the blind spot for the intricacies of perception as described above. The grounded approach will be detailed in section 3; data analysis in section 4. The discussion in section 5 considers the results against the backdrop of existing perceptions. In the conclusion, practical applications and avenues for further research are described.

2. Background

Investigations of managerial perceptions of signals of emerging change in the environment started with the seminal field study on signal detection by Aguilar (1967) when the Internet as we know it was not yet invented. The Internet has changed the information landscape drastically, but Aguilar's findings have not been challenged.

2.1. Original Findings

Aguilar focused on the strategic decisions in the higher levels of organizations for which only fragmented and ambiguous information was available. This process was contrasted to the routine scans mostly taking place in the lower levels of organizations. As such, Aguilar was one of the first to discriminate between processes for weak and strong signals. The process for weak signals was described as a feedback loop with several information filters (see Figure 1. Aguilar's Process).

Six years after the publication of Aguilar's book, in 1973, the world was faced with sudden oil shortages when the OPEC countries proclaimed an oil embargo. The oil crisis triggered the need to find approaches to the management of unexpected, high impact events. One of the results was the introduction of the notion of the emergence of weak signals by (Ansoff, 1975).
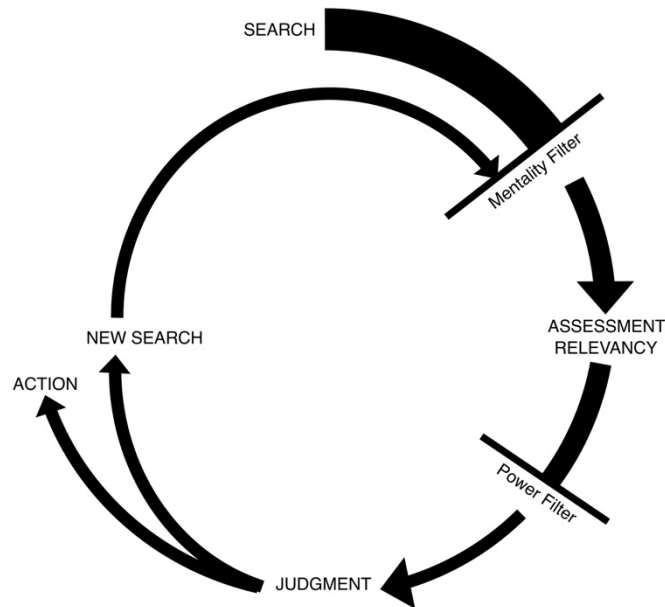
Figure 1: Aguilar's Interpretive Process (based on Aguilar, 1967)

When a change seemed to happen suddenly, preceding information usually went unnoticed by the majority of observers. Weak signals remained unseen amidst the abundance of information or were ignored in extrapolations of historical data series. Only through several iterations over time would a weak signal break through perceptual filters as more knowledge would be accumulated, clarifying its meaning and impact (see Figure 2. Ansoff's Process).

Figure 2: Ansoff's Interpretive Process (based on Ansoff, 1984)

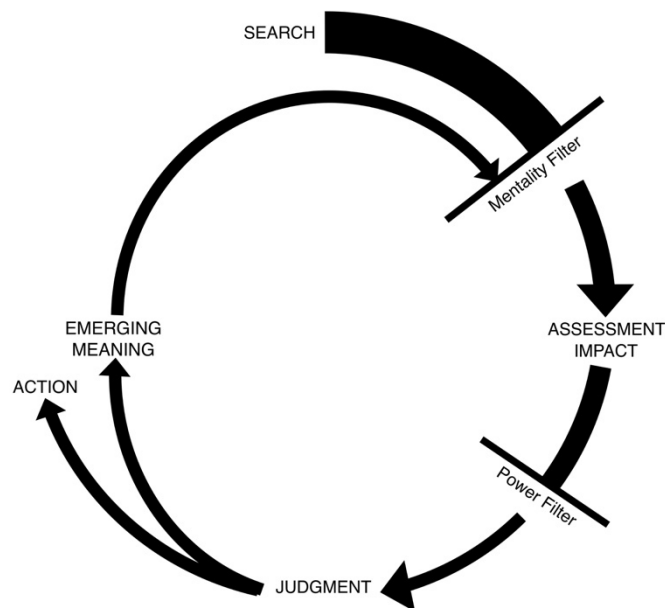Like Aguilar, Ansoff thought that two different approaches to environmental interpretation could and should be set apart to be effective. Aguilar's and Ansoff's process have in common that judgment and decision-making could be deferred when inconclusive signal assessments would leave too much room for doubt. In Aguilar's case, a new, specific search would commence, to gain new insights into the problem at hand. In Ansoff's case, it would take iterations of the same search parameters over time. Extra iterations would increase familiarity with the signal. With familiarity came openness to extra information that previously would have been discarded.

2.2.   Recent Findings
Recent field studies have recognized the existence of a special managerial process for weak signals, as well as the limiting role of perceptual filters (Ansoff, 1979; Hahn et al., 2014; Hambrick & Mason, 1984; Ilmola & Kuusi, 2006; Nadkarni & Barr, 2008; Weick, 1995), but the process itself has rarely been reinvestigated. Instead, research focused on methodologies to reduce the limiting effects of perceptual filters (Kayser & Bierwisch, 2016; MacKay & McKiernan, 2004; Mayer, Steinecke, & Quick, 2011; Rossel, 2011; Rossel, 2012; Schoemaker, Day, & Snyder, 2013; Thorleuchter & Van den Poel, 2015), the correct assessment of emerging signals (Battistella & De Toni, 2011; Carbonell, Sánchez-Esguevillas, & Carro, 2015; Derbyshire, 2017; Kuosa, 2011; Kuosa, 2010; von Groddeck & Schwarz, 2013; Warnke & Schirrmeister, 2016), and the adequacy of strategic response (Buyl, Boone, & Matthyssens, 2011; Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Reeves & Deimler, 2011).

The scholars who did study the managerial process corroborated and expanded the ideas of Aguilar and Ansoff. Different scanning modes for weak and strong signals were found (Auster & Choo, 1994; Daft et al., 1988; Lesca, Caron-Fasan, & Falcy, 2012). When managers were in the midst of decision-making, a focused search was used. When they were not involved in a specific decision process, unguided scanning was adopted. When uncertainty was high, managers scanned more and used more personal information sources. Multiple iterations were needed for meaning to emerge (Tapinos & Pyper, 2017). The shape of perceptual filters influenced the process output: narrow, deep filters led to focused output, and wide, flat filters to a diverse range of concrete issues from various sources (Ilmola & Kuusi, 2006).

2.3.   Research Techniques
Scholars have used both quantitative and qualitative techniques to research the managerial weak signal process. Among the quantitative techniques, surveys contrasted the internal

versus the external environment (Battistella & De Toni, 2011), threats versus opportunities (Jackson & Dutton, 1988b), or types of search activities (Beal, 2000; Fahey & King, 1977; Yasai-Ardekani & Nystrom, 1996). Surveys were also used to collect ratings of environmental conditions and subsequent search activity (Daft et al., 1988; Ebrahimi, 2000a; Elenkov, 1997; Gordon & Narayanan, 1984; Mitroff & Mason, 1981; Zhang et al., 2010).

Longitudinal qualitative research examined the variety of search activities (Anderson & Nichols, 2007) or process patterns (Mintzberg & Waters, 1982). Case studies investigated the workings and methodologies to overcome perceptual filters (Ilmola & Kuusi, 2006; Kayser & Bierwisch, 2016; Kim & Lee, 2017; Kuosa, 2010; Thorleuchter, Scheja, & Van Den Poel, 2014). Explorations of the cognitive process were done using action research (Blanco & Lesca, 1997), text analysis (Nadkarni & Barr, 2008), or process recall in interviews (Aguilar, 1967; Auster & Choo, 1994; Leitner, 2015; Tapinos & Pyper, 2017; Zach, 2005).

Mixed methods were used to quantitatively assess aspects that had emerged from qualitative methods on heuristics (Lesca et al., 2012) or teams (Büchel, Nieminen, Armbruster-Domeyer, & Denison, 2013).

In short, during the five decades following Aguilar's exploration into scanning, authors have agreed on the existence of a separate investigation and interpretation process for weak signals, that it takes several iterations for emerging signals to become clear, and that perceptual filters remove signals from the process.

During that same fifty years, the Internet was launched. Online information proliferated exponentially, as well as data mining software packages and artificial intelligence to interpret its findings. The first studies into the new information and automated analysis have been published already (Kayser & Bierwisch, 2016; Kim & Lee, 2017; Mayer et al., 2011; Yoon, 2012). However, the possible effects of digitalization on the process are unknown.

Huge quantities readily available information on the web may have affected the way managers search for weak signals. For example: does more available information mean a continuous urge to scan or to a foremost non-scanning state only interrupted when prompted by an external trigger? Do top-managers leave the process to technology, or do they still use the informal sources that Aguilar described? Are the limiting effects of Ansoff's perceptual filters compensated by more available information or process technologies? The next section presents the details of the method used to reexamine the process of the detection and perception of emerging environmental change.

3.   Method

The purpose of this paper was to explore the current cognitive process and to compare the findings to the original findings of Aguilar and theoretical principles of Ansoff. Hence, we adopted his interview method including the critical incident technique and analyzed the interviews with a grounded theory approach to let possible new findings emerge.

3.1.   Sample

A sample of 13 top-managers of leading companies in the Netherlands was interviewed from October 2014 to February 2015, to determine the role of weak signals in their perception of the environment. The sample was not limited to one industry or one job title, but as heterogeneous as possible (see Table 1).

The responsibility for the detection of weak signals resides predominantly with top managers, because finding such signals may lead to a reconsideration of the company's domain and strategy (Buyl et al., 2011; Hambrick, 2007; Hambrick & Mason, 1984; Leitner, 2015). Of the participating companies, the person highest in the hierarchy responsible for overall strategy participated. In several companies, this role was taken up by the CEO and in others by the chairman of the board. Since the interviewees' primary task was to locate and exploit markets to maintain a healthy company with a clear domain, they were likely to be well versed in assessing emerging change (Buyl et al., 2011; Hambrick, 2007; Hambrick & Mason, 1984; Miles, Snow, Meyer, & Coleman, 1978).

Interview	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

Top managers of leading companies have successfully asserted their power in the domain choices they made: the proof is in their companies' profitability and ability to deal with change (Miles et al., 1978). Furthermore, their wisdom is pivotal to the detection process (Simmons & Sower, 2012).

The composition and size of our sample were driven by the grounded theory approach. The sample composition was deliberately heterogeneous to generate a full range of variation of the phenomenon. The participants had three aspects in common: they were the highest responsible officer for weak signal analysis, in a Dutch company, which was leading in its industry. The sample size was not set a priori but was established by theoretical saturation (Sim, Saunders, Waterfield, & Kingstone, 2018). Saturation would be reached when no new themes would arise from the data. We used a stopping criterion of five interviews not generating new themes and verified saturation with a CEO of an industry association. In our study, saturation was reached at interview eight. Such early saturation is not uncommon. Empirical investigation has shown that theoretical saturation can occur between six and twelve interviews (Francis et al., 2010; Guest, Bunce, & Johnson, 2006), and similar weak signal studies did reach saturation within twelve interviews (Tapinos & Pyper, 2017; Zach, 2005).

3.2. Interview approach

The focus of the study was secured by the critical incident technique (Flanagan, 1954). The technique has proven its worth in similar studies (Aguilar, 1967; Auster & Choo, 1994; Zach, 2005). This paper copied the set-up of Auster & Choo, (1994). The 'incident' to be studied was a complete, recent event of domain discussions and the perception of signals leading up to the discourse. Auster and Choo's phrasing of the lead question was left intact:

"Please try to recall a recent instance in which you received important information about a specific event and 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)

Prompts were used to invite subjects to describe task characteristics (when, how, where), to explore attributes assessed and assessment criteria, and to contrast certainties in the reasoning with uncertainties and failures. The prompts covered the questions asked by Aguilar in his phrasing of the critical incident (Aguilar, 1967).

At the end of the interview, a list compiled from literature and interviews with preceding participants were discussed to decrease the interview bias for successful perception and focus of attention.

The set-up allowed for the use of monologues, started by the initial question, helped along with the incidental prompt, and checked for completeness with a cross-reference list. Thinking-out-loud as the method to elicit data was rejected because it performs best in tasks where experts are requested to make immediate inferences. In situations like the set-up in this paper, the pressure of the presence of the interviewer is likely to reduce the quality of results to the same level as after-the-fact descriptions (Olson & Biolsi, 1991).

In each interview, the interview technique was thoroughly introduced. The role of the interviewer was primarily to ask questions and to take notes in keyword format, using the expressions and analogies of the subject. The final text was checked by each subject to be a correct record of the conversation. Audio recording was not used, to ensure the cooperation of the top managers.

The careful composition of the sample and the interview set-up enabled a focused interview without audio recording, while still have reliable, valid, and transparent results. The sample and set-up were created according to the criteria of Clausen (2012), who showed that a joint production of notes by the interview and strong individual subjects in a heterogeneous sample could lead to sound results.

3.3. Grounded Theory Approach

The absence of recent research on the relationship between weak signals and the process to perceive these encouraged the researcher to use a grounded approach to enable theory building.

At first glance, a grounded approach may seem to clash with our approach. Classic grounded theory research demands as little interference by the researcher as possible, to prevent framing and other biases influencing analysis. It stipulates that a literature review is done post-experiment, and an absent researcher during data collection. However, amongst grounded theory scholars, a lively debate about the objectivity of data and the role of the researcher has led to other approaches. The constructivist approach treats previously acquired knowledge as if it were another informant (Ramalho, Adams, Huggard, & Hoare,

2015). In this study, the simultaneous data collection and analysis occurred on the interview reports in conjunction with the literature review findings.

The professional expertise of the interviewer as a futurologist played a role in the analysis in an engaging way. Data was used to critically challenge insights from practice and led to surprising outcomes to the researcher (Charmaz & Mitchell, 1996).

The analysis followed the steps as listed by O'Reilly (2012). It began with line by line coding of the interview notes. Guiding questions for open coding were used as posed by Glaser and Holton (2004), like "What category does this incident indicate?" and "What is the main concern being faced by the subject?" This approach forced the analyst to verify and saturate code categories, minimized missing codes and ensured the grounding of categories beyond impressionism.

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 they had the same meaning. Other codes moved to different parent-codes. New codes and categorizations led to reassessing previous interviews, to log all occurrences. The process stopped after interview eight when following data incidents did no longer lead to category refinement (Eisenhardt, 1989; Glaser & Holton, 2004; Glaser & Strauss, 2009; O'Reilly, 2012).

Whenever a particular line in the data, code or categorization lead to theoretical questions, a memo was attached to record the incident. After seven interviews, hardly any new codes were added, but the number of memo's increased.

At interview 13, the coding tree was checked for characterizations of environmental change found in the literature review. All characterizations were present and were clustered in separate parent codes. Re-examination of the entire code tree led to new additions to these parent codes, thus enriching existing analysis.

Finally, a fourteenth interview was used to verify theoretical saturation. As the narratives of different player types may yield new insights, an interview with a general manager of a large industry association was used. No mutations were needed to code the report.

The written coded interview report was offered to the subjects for feedback on accuracy by the subject to gain interpretive validity on the perspective of the interviewer. Some edits were made, but these were all related to the narrative and did not influence the coding.

Dedoose software was chosen to manage the data. Dedoose is comparable to other software dedicated to qualitative data analysis and prepared for grounded theory research.

4. Data Analysis

We began data analysis by establishing the presence of weak signals and distinct weak signal processes, as described in section 4.1. Data was then sorted in categories following Aguilar's breakdown of findings.

4.1. Establishing Weakness and Weak Signal Processes

Weak signals have the shape of inconspicuous communications about the future impact of recent developments (Ansoff, 1979). By their nature, these signals are hard to detect because they drop out of sight in the vast amount of information that surrounds managers every day.

Before managers can detect and interpret these signals, two conditions need to be met. Firstly, the top manager has to have access to or must be exposed to the signal to receive it. Secondly, the top manager's mind should be open to the signal and consciously receive it rather than unconsciously discard or ignore it. The deliberate dealing with signals means that the top manager could perceive and recall it.

It is important to notice that multiple signals were discussed with each top-manager and that certain signals were reported by more managers. This made the number of signals higher than the number of interviewees, and the number of interpretations higher than the number of signals. The total of signals discussed was 47, and the total of interpretations was 96. The count data was not used for statistical analysis but to show that findings were not based on a single incident.

Signals could fall in several behavioral categories, such as not seen, not included or included, which indicated that weak signals were discussed. In seven interviews, managers pointed out that they had not seen the signals that signified the emergence of crucial changes in their business environment. It is important to note that this figure is most probably an underestimation: managers will often be unable to recall what they did not see.

Not included signals could be discarded, neglected or ignored in further considerations or actions. Sometimes it was felt that not including a signal was the correct decision and other times it was to the regret of the interviewee. Several reasons were given for non-inclusion. A signal could be too far removed from a company's domain to justify further attention, or the actions needed to exploit or counter its effects were deemed outside the power of the company.

In total, 19 out of 47 signals were explicitly labeled as signals of emerging change, two of which originated from observations within the company. From the 13 interviewees, two did talk about routine signals exclusively. Both top managers were active in the high-tech industry and rated themselves very open to their environments. Considering their curiosity and their capacity to discuss environmental complexity and predictability, it is unlikely that weak signals remained unseen; they were simply not labeled as such.

Perhaps their shared familiarity with emerging technologies contributed to the lack of discrimination between the two signal types, but another possible explanation also surfaced. Both experienced two dynamics in their various markets: fast, short sales cycles and slow, long cycles. In each case, signals were swapped between cycles: signals that were routine in one cycle were innovatory in the other.

Top-managers only to a certain extent included other management layers in the detection of weak signals. Rather than merely receiving an assessment of signals done by others, they wanted to observe environmental change directly, and if necessary interpret and discuss a signal on the spot. They seemed to imply that the visioning of new options required a degree of involvement in observations and interpretation that is not provided by the tools and methods for data gathering and analysis of routine signals and decisions.

4.2. Modes of Scanning

Aguilar distinguished four scanning modes: undirected or directed exposure, and informal or formal search. In the first two modes, the scanner is not searching for weak signals but stumbles upon them unawares. During directed exposure, the environmental segment to which a scanner is exposed is defined. Informal and formal search are delineated by the absence or presence of systematic action. Both search modes have a specific information goal.

All modes were found in the data, but a hybrid mode was dominant. All but one top manager indicated that they actively searched for signals of specific changes and scanned the

environment for new, unfamiliar signals. The interviewees expressed that their investigations were driven by a feeling of curiosity, fear that competitors would beat them to innovations and new markets, or the experience and belief that signals could always lead to significant opportunities.

Search did not mean that top managers knew what exact signals they were searching for. Most signals mentioned were stumbled upon during the search. This accidental stumble was precisely the goal of search and was secured by knowing where to look: all subjects scrutinized a broad but specific selection of sources already listed by Aguilar.

All interviewees used an informal and active approach to the gathering of signals. Personal meetings with various types of stakeholders such as competitors and start-ups were supplemented with site inspections and informal conversations at conferences, trade-shows, and industry laboratories. The search was not limited to the industries or regions within their organization's domain at all. Surprisingly, the Internet and other general news sources hardly made it into the conversations.

The gathering of information was predominantly ad-hoc but frequent, informal, interactive, and on the spot. Formal methods to gather data, such as market analysis were rarely mentioned, and almost always belonged to strong signal procedures done by specialized departments in the organization.

4.3. Information Typologies
Aguilar classified weak signals into environmental segments. In our study, the interviewees classified signals in strengths/weaknesses and opportunity/threats. It is unclear if this classification happened once a signal was received and perceived as something needing interpretation, or that it is a byproduct of recall.

Aguilar distinguished between outside and inside sources, and both were found in our study. Most signals were seen as external to the company in the shape of threats and opportunities. Seventeen times a signal was deemed a threat and 20 times an opportunity. Internal signals were mentioned ten times: three times as a strength and seven times as a weakness. A simple explanation for the prevalence of external signals may be that signals heralding change often originate outside the company.

4.4. Triggers and Barriers

Once top managers started to interpret signals deliberately, several barriers were encountered impeding further analysis and action. Aguilar also noted problems, but mainly concentrated on the ambiguity of information and the small information flow from the top-manager to the company. Here, barriers were sometimes linked to signal detection, but foremost to its perception and dispersion within the company.

Barriers were grouped into three categories: factors in the company's environment, obstacles within the company, and personal limitations of the top managers themselves.

Environmental barriers for detection were divided into environmental characteristics (seven counts) and stakeholder issues (three). The characteristics were all perceptions of high uncertainty or ambiguity of the environment as a whole. One manager described this as the big picture being too abstract and uncertain to grasp (interview 1). Stakeholder issues varied between risk aversion of shareholders and interdependence between stakeholders that lead to inertia.

Barriers that restricted the process of freely and creatively analyzing and interpreting the organization's environment and the subsequent strategy formation were mentioned by all interviewees. The majority of the barriers (37 out of 63) were internal to the organization and included a lack of curiosity, groupthink, a lack of sharing available information in the organization, a lack of mechanisms to combine the information, and so on.

Sixteen occurrences of personal barriers were counted. The two types of barriers were mentioned most seemed to refer to Ansoff's perceptual filters: a tight focus and personal preferences. A tight focus did not allow signals to pass the surveillance filter. Among the discarded signals were tech giants entering the market (interview 2) and changing consumer needs (interview 7). Personal preferences comparable to a mentality filter varied from resistance to consider data or long-term effects to the absence of a do-mentality. One of the most precise descriptions of resistance was given by a manager who relayed an example of a recent reputation crisis based on fake facts escalating in social media. He said that he had to learn that feelings are also facts, and even when based on fake data (interview 11).

These results seem to support the counts for external and internal signals. Taken together, they imply that signals of emerging change mostly originate outside the company and that mostly internal barriers prevent their absorption. The interviewees gave the impression that they deliberately compensated for this phenomenon. Their choice of sources, diverging and

advocating processes, and immediate actions seem to have the effect of increasing the exposure of the company to signals and raising the number of signals surviving until the moment of absorption into strategy.

4.5. *Flow of Information*

Top managers always brought signals of perceived importance into the company for further assessment and interpretation, mostly in the shape of dedicated meetings.
The meetings were often arranged away from the organization's offices and deliberately kept separate from daily operations. Sessions to analyze, discuss and turn signals into strategy, took place twice or more per year. These sessions typically lasted between one to three days. In addition to management team members, several other management levels, and outsiders were invited to share their opinions. Scenario analysis was explicitly mentioned by several top managers. Some of the organizations involved in scenario sessions had implemented distinct processes to communicate the information from the session to the entire organization (within 24 hours) and to turn the analysis into strategies that were applied directly.

In the majority of interpretations (76 cases), a collective process was started to consider the signal's significance to the company. These processes could include an exploratory phase (30 cases) to find as many takes on the possible meanings and effects of the signal concerned, a converging phase (21 cases) to limit the number of signals to either assess or manage, and a phase to find advocates for further company involvement (25 cases). The various phases could take place simultaneously or separately, in different sequences and combinations.

The descriptions of both the exploratory and the advocates finding phase were framed with comments hinting at perceptual filters. For example, one manager said that scanning was not hard, but that many "images" and intensive discussions were needed to get co-workers curious and have them think outside the box (interview 10). Another one conveyed that scanning is a must for survival, but that the company's understanding of signals comes only after a cascade of goal-oriented discussions (interview 8).

Collective interpretation, in contrast with the individual detecting, perceiving, and interpreting was often organized explicitly and more formally. Apparently, management teams needed to break away from daily operations to be able to think freely. This finding is in line with the indication of several interviewees that they do think about strategy during daily operations but that it happens under extreme time pressure.

5.   Discussion

Readily available online information may have affected the weak signal search and interpretation process as described by Aguilar and Ansoff. We explored the current process using Aguilar's interview method including the critical incident technique. Data analysis confirmed the existence of a distinct process for weak signals, as well as Aguilar's findings on scanning modes and sources and the presence of Ansoff's perceptual filters.

In line with accepted scholarly opinions, the top-managers mentioned the use of different processes for routine and weak signals (Aguilar, 1967; Anderson & Nichols, 2007; Ansoff, 1975; Blanco & Lesca, 1997; Dutton et al., 1983; Lyles & Mitroff, 1980; Mintzberg et al., 1976).

Remarkably, top managers compensated for Ansoff's perceptual filters (see Figure 3. Managerial Weak Signal Process). To compensate for the loss of signals caused by their filter, the interviewees made sure that the number of signals included in their surveillance would be as large and broad as possible. Two measures stood out. Firstly, they took particular care to include a wide range of sources, without search limits based on their company's domain. This compares to findings on wide filter effects (Ilmola & Kuusi, 2006). Secondly, they deliberately looked for unfamiliar information that somehow did not fit their mental model or experience. These unfamiliar dissonants would trigger inclusion rather than removal.

The power filter (i.e., the filter caused by unintentional distortion or intentional distortion because of self-interest) was explicitly mentioned and its damage repaired by a specific part of the interpretive process. Judgment would be deferred until many other perspectives on a signal's meaning, urgency and relevancy were collected and discussed. Interviewees deliberately looked for different perspectives by ensuring as much variation in the background of their discussion partners as they could manage. A synthesis of these perspectives would then form the basis for judgment and decision-making. This compares to findings on deep filter effects (Ilmola & Kuusi, 2006).
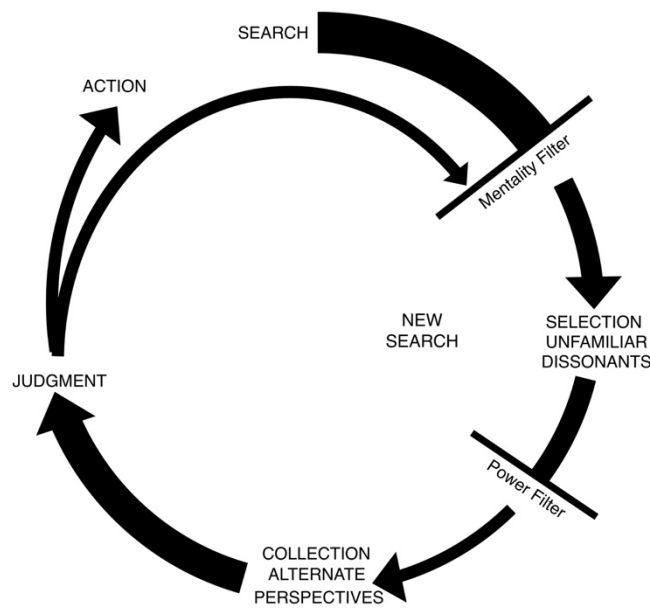
Figure 3: Managerial Weak Signal Process

In the literature on environmental uncertainty, several indications were given for a positive relationship between uncertainty and frequency of scanning (Gordon & Narayanan, 1984). Contrary to those findings, the top managers gathered weak signals irrespective of the uncertainty they perceived in their business environment. Uncertainty indications ranged over the full continuum of certain to uncertain, but in every instance, uncertainty was seen as a fact of life and deemed manageable. Some top managers explicitly said that uncertainty spiced up their job. Instead, the top managers pointed towards other drivers of search, such as feelings of curiosity and competitiveness. The deliberate collection of diversified perspectives also seems to have the effect of turning weak signals into more familiar ones (Ansoff, 1980). This effect may help companies to embrace change more easily as it decreases feelings of aversion and anxiety related to unfamiliar signals.

Familiarization with weak signals seems to reduce uncertainty at lower-levels and increase commitment to decisions and actions following the interpretation of those signals. One manager characterized this as fervor, positive energy and a willingness to act generated by cascading discussions (interview 9). The success of this communication strategy is in line with the knowledge links and trust networks that successful teams in new product development used to spur innovation (Büchel et al., 2013).

That levels of uncertainty differ per organizational unit has already been established (Lawrence & Lorsch, 1967). The difference was attributed to the subsets of information that for example marketing and operations examine, as well as the different time-span of

performance reviews within the units. Some top managers specified that they would sometimes delegate weak signal collection to a staff member, or that they experienced great variability in the eagerness of employees to get involved with change. Time-span orientation and curiosity were mentioned as the discriminating characteristics of lower-level managers concerning weak signal noticing, interpreting, and enacting.

However, the difference in perceptions between management levels may also stem from other causes. Top managers indicated to thoroughly enjoy complexity. That they could not fully oversee the company's environment and how emerging changes would develop seemed to inspire them. In uncertain situations, they could put their minds and experience to good use. Top managers also indicated that lower-level management usually favors the safest option. Lower-level managers were willing to look beyond routine and improve, but they also wanted to minimize risk. Top managers found that understandable since the salary and careers of lower-level managers depended on their performance. Why take a risk with only a probable high gain and high costs involved if one has access to a process with a certain but moderate gain and low costs involved?

6.   Conclusion

Digitization has altered the information landscape completely, but the scanning process for weak signals has not been revisited by scholars since the first comprehensive field study, the work of Aguilar in 1967. Surprisingly, many of Aguilar's observations still hold.

In line with all authors who discerned separate perceptual processes for routine and weak signals, the top managers referred to the two processes within their companies. The interviewees also acknowledged the existence of perceptual filters.

In contrast with the accepted model, the top managers were able to compensate for the loss of signals caused by the filters. Instead of assessing urgency and relevancy of incoming signals, they rated signals on unfamiliarity and lack of fit with their mental model. Instead of iterations over time, they collected and synthesized alternate perspectives before judging and deciding.

The shift from urgency and relevancy assessments to unfamiliarity and lack of fit is significant. It suggests that the earlier models may represent a sub-variant of the strong signal process instead of a true weak signal process, which may have several consequences. At best, it would leave the topic even further under-researched. Considering

the composition of our sample, it could also mean that only the best managers are actively compensating for their mentality filter and that lesser achievers fail to do so.

The deliberate compensation for the power filter with the search for diversified perspectives may also be symptomatic for our sample of outperformers. This measure would enable them to avoid time-intensive iterations and reach judgment and strategic action quicker than lesser competitors.

One cannot help but wonder how the interviewees have developed their process. Was it embedded in the company culture or does this process reflect their level of task expertise? Further research is needed to uncover the formation of this process.

Foresight research is oriented towards the investigation of methodologies, such as scenario planning or road mapping. These methods have the compensation of filters as a common feature. By systematic scanning and reasoning, previously ignored signals are allowed to pass perceptual filters. Scenario planning is a formal approach to envision a world different from the current mental model and hence can be considered as a formal approach to compensate for a perceptual filter. Road mapping allows to envision possible technology developments and hence could also be used to envision technological changes without the current restrictions of our mental model. If so, the capacity to overcome the effects of filters can enable categorization and assessments of the success of foresight methods. A clear and testable definition of filters is already developed, and a subsequent case study has explained the effects of filter width and depth (Ilmola & Kuusi, 2006). Besides normative studies of filter width and depth, the concept may also help to move away from case studies into quantitative research on the effects of these methodologies.

Finally, a word on the intricacies of perceptual research. This study's set-up left the objective phenomenon out of the equation and tried to separate signal and perception as best as human memory allowed. It was done by deep diving into the signal detection process and its sources. The interviewees were asked to recall signals leading up to recent critical incidents and were prompted to provide as much detail as they could remember. The weak or routine nature of the signal and its perception was induced from their stories. Verbalizations of surprise, unfamiliarity, uncertainty and direct utterings during recall were used to label signals. The interviewer did not mention the difference between the two types and processes until the very end of the interview when tentative inductions were verified by direct questions.

Recall is not the best method to investigate perceptions, but this study was done to explore the managerial process, not their perceptions. However, the next step in unraveling the details of weak signal perception should focus on perception and use a method befitting of the disaggregation between signal and signal perception.

While concrete steps for future research are opening up, the results thus far have four important practical managerial implications already. Firstly, to notice emerging change, top managers indicate that search into areas outside the industry and outside regularly monitored market developments are required.

Secondly, to notice these disruptions, specific types of sources need to be scanned regularly. Among those are the feelings of known critics and opinion makers, customer behavior next to the domain of the company, and the research and development projects of very valuable companies in comparable industries, with comparable positions in supply chains, comparable business models, or with comparable customer needs.

Thirdly, detection of weak signals of emerging change entails more than observation by designated employees. Noticing these signals is seen as a top management activity, requiring curiosity and eagerness to interpret and discuss unfamiliar and dissonant signals.

Fourthly and finally, the collective analysis of selected weak signals and their translation into strategies should involve stakeholders with profoundly distinct backgrounds and perspectives from inside and outside the company.

The need for further research steps is driven by the increasing digitization of companies and their environments and the subsequent data growth. It is the hope of the authors that these steps will be taken soon, rather than in another fifty years from the original work of Aguilar (Aguilar, 1967).

7.   References

Aguilar, F. J. (1967). *Scanning the Business Environment*. New York: Macmillan.

Anderson, M. H., & Nichols, M. L. (2007). Information gathering and changes in threat and opportunity perceptions. *Journal of Management Studies*, *44*(3), 367–387.

Ansoff, H. I. (1975). Managing strategic surprise by response to weak signals. *California Management Review*, *18*(000002), 21–33.

Ansoff, H. I. (1979). *Strategic Management*. London: Palgrave Macmillan UK. http://doi.org/10.1007/978-1-349-02971-6

Ansoff, H. I. (1980). Strategic issue management. *Strategic Management Journal*, *1*(2), 131–148.

Ansoff, H. I., & Sullivan, P. A. (1993). Optimizing profitability in turbulent environments: A formula for strategic success. *Long Range Planning*, *26*(5), 11–23. http://doi.org/10.1016/0024-6301(93)90073-O

Auster, E., & Choo, C. W. (1993). Environmental Scanning by CEO's in Two Canadian Industries. *Journal of the American Society for Information Science*, *44*(4), 194–203. http://doi.org/10.1002/(sici)1097-4571(199305)44:4<194::aid-asi2>3.0.co;2-1

Auster, E., & Choo, C. W. (1994). How senior managers acquire and use information in environmental scanning. *Information Processing & Management*, *30*(5), 607–618.

Battistella, C., & De Toni, A. F. (2011). A methodology of technological foresight: A proposal and field study. *Technological Forecasting and Social Change*, *78*(6), 1029–1048. http://doi.org/10.1016/j.techfore.2011.01.006

Beal, R. M. (2000). Competing effectively: Environmental scanning, competitive strategy, and organizational performance in small manufacturing firms. *Journal of Small Business Management*, *38*(1), 27.

Blanco, S., & Lesca, H. (1997). *Environmental scanning: Designing a collective learning process to track down weak signals.* (J. N. D. Gupta, Ed.)*Association for Information Systems Proceeding of the Americas Conference on Information Systems*.

Boyd, B. K., & Fulk, J. (1996). Executive Scanning and Perceived Uncertainty: A Multidimensional Model. *Journal of Management*, *22*(1), 1–21. http://doi.org/10.1177/014920639602200101

Büchel, B., Nieminen, L., Armbruster-Domeyer, H., & Denison, D. (2013). Managing stakeholders in team-based innovation: The dynamics of knowledge and trust networks. *European Journal of Innovation Management*, *16*(1), 22–49. http://doi.org/doi:10.1108/14601061311292841

Buyl, T., Boone, C., & Matthyssens, P. (2011). Upper echelons research and managerial cognition. *Strategic Organization*, *9*(3), 240–246. http://doi.org/10.1177/1476127011417345

Carbonell, J., Sánchez-Esguevillas, A., & Carro, B. (2015). Assessing emerging issues. The external and internal approach. *Futures*, *73*, 12–21. http://doi.org/10.1016/J.FUTURES.2015.07.015

Charmaz, K., & Mitchell, R. G. (1996). The myth of silent authorship: Self, substance, and style in ethnographic writing. *Symbolic Interaction*, *19*(4), 285–302.

Clausen, A. S. (2012). The individually focused interview: Methodological quality without transcription of audio recordings. *The Qualitative Report*, *17*(19), 1.

Daft, R. L., Sormunen, J., & Parks, D. (1988). Chief executive scanning, environmental characteristics, and company performance: an empirical study. *Strategic Management Journal*, *9*(2), 123–139.

Derbyshire, J. (2017). The siren call of probability: Dangers associated with using probability for consideration of the future. *Futures*, *88*, 43–54. http://doi.org/10.1016/J.FUTURES.2017.03.011

Dutton, J. E. (1993). Interpretations on Automatic - a Different View of Strategic Issue Diagnosis. *Journal of Management Studies*, *30*(3), 339–357. http://doi.org/DOI 10.1111/j.1467-6486.1993.tb00308.x

Dutton, J. E., Fahey, L., & Narayanan, V. K. (1983). Toward Understanding Strategic Issue Diagnosis. *Strategic Management Journal*, *4*(4), 307–323. http://doi.org/DOI 10.1002/smj.4250040403

Ebrahimi, B. P. (2000a). Environmental complexity, importance, variability and scanning behavior of Hong Kong executives. *International Business Review*, *9*(2), 253–270.

Ebrahimi, B. P. (2000b). Perceived strategic uncertainty and environmental scanning behavior of Hong Kong Chinese executives. *Journal of Business Research*, *49*(1), 67–77. http://doi.org/10.1016/s0148-2963(98)00120-9

Eisenhardt, K. M. (1989). Making fast strategic decisions in high-velocity environments. *Academy of Management Journal*, *32*(3), 543–576.

Elenkov, D. S. (1997). Strategic uncertainty and environmental scanning: The case for institutional influences on scanning behavior. *Strategic Management Journal*, *18*(4), 287–302.

Fahey, L., & King, W. R. (1977). Environmental scanning for corporate planning. *Business Horizons*, *20*(4), 61–71.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin*, *51*(4), 327.

Francis, J. J., Johnston, M., Robertson, C., Glidewell, L., Entwistle, V., Eccles, M. P., & Grimshaw, J. M. (2010). What is an adequate sample size? Operationalising data saturation for theory-based interview studies. *Psychology and Health*, *25*(10), 1229–1245.

Glaser, B. G., & Holton, J. (2004). Remodeling Grounded Theory. *Forum Qualitative*

Sozialforschung / Forum: Qualitative Social Research; Vol 5, No 2 (2004): Qualitative Market, Media and Opinion Research. Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/607/1315

Glaser, B. G., & Strauss, A. L. (2009). *The discovery of grounded theory: Strategies for qualitative research*. Transaction Publishers.

Gordon, L. A., & Narayanan, V. K. (1984). Managent Accounting Systems, Perceived Environmental Uncertainty and Organization Structure - An Empirical Investigation. *Accounting Organizations and Society*, *9*(1), 33–47. http://doi.org/10.1016/0361-3682(84)90028-x

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, *18*(1), 59–82.

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, *23*(2), 485–498.

Hahn, T., Preuss, L., Pinkse, J., & Figge, F. (2014). Cognitive Frames in Corporate Sustainability: Managerial Sensemaking with Paradoxical and Business Case Frames. *Academy of Management Review*. http://doi.org/10.5465/amr.2012.0341

Hambrick, D. C. (1982). Environmental Scanning and Organizational Strategy. *Strategic Management Journal*, *3*(2), 159–174. http://doi.org/DOI 10.1002/smj.4250030207

Hambrick, D. C. (2007). Upper echelons theory: An update. *Academy of Management Review*, *32*(2), 334–343. http://doi.org/10.2307/20159303

Hambrick, D. C., & Mason, P. A. (1984). Upper Echelons: The Organization as a Reflection of Its Top Managers. *Academy of Management Review*, *9*(2), 193–206. http://doi.org/10.5465/amr.1984.4277628

Heinonen, S., & Hiltunen, E. (2012). Creative Foresight Space and the Futures Window: Using visual weak signals to enhance anticipation and innovation. *Futures*, *44*(3), 248–256. http://doi.org/10.1016/j.futures.2011.10.007

Hiltunen, E. (2008). The future sign and its three dimensions. *Futures*, *40*(3), 247–260.

Holopainen, M., & Toivonen, M. (2012). Weak signals: Ansoff today. *Futures*, *44*(3), 198–205. http://doi.org/http://dx.doi.org/10.1016/j.futures.2011.10.002

Ilmola, L., & Kuusi, O. (2006). Filters of weak signals hinder foresight: Monitoring weak signals efficiently in corporate decision-making. *Futures*, *38*(8), 908–924. http://doi.org/10.1016/j.futures.2005.12.019

Jackson, S. E., & Dutton, J. E. (1988a). Discerning threats and opportunities. *Administrative Science Quarterly*, *33*(3), 370–387. http://doi.org/10.2307/2392714

Jackson, S. E., & Dutton, J. E. (1988b). Discerning Threats and Opportunities. *Administrative Science Quarterly*, *33*(3), 370–387. http://doi.org/10.2307/2392714

Kayser, V., & Bierwisch, A. (2016). Using Twitter for foresight: An opportunity? *Futures*, *84*, 50–63. http://doi.org/10.1016/J.FUTURES.2016.09.006

Kim, J., & Lee, C. (2017). Novelty-focused weak signal detection in futuristic data: Assessing the rarity and paradigm unrelatedness of signals. *Technological Forecasting and Social Change*.

Kuosa, T. (2010). Futures signals sense-making framework (FSSF): A start-up tool to analyse and categorise weak signals, wild cards, drivers, trends and other types of information. *Futures*, *42*(1), 42–48. http://doi.org/10.1016/j.futures.2009.08.003

Kuosa, T. (2011). Different approaches of pattern management and strategic intelligence. *Technological Forecasting and Social Change*, *78*(3), 458–467. http://doi.org/10.1016/j.techfore.2010.06.004

Lawrence, P. R., & Lorsch, J. W. (1967). Differentiation and integration in complex organizations. *Administrative Science Quarterly*, 1–47.

Leitner, K.-H. (2015). Pathways for the co-evolution of new product development and strategy formation processes: Empirical evidence from major Austrian innovations. *European Journal of Innovation Management*, *18*(2), 172–194. http://doi.org/doi:10.1108/EJIM-01-2014-0002

Lesca, N., Caron-Fasan, M. L., & Falcy, S. (2012). How managers interpret scanning information. *Information & Management*, *49*(2), 126–134. http://doi.org/10.1016/j.im.2012.01.004

Liebl, F., & Schwarz, J. O. (2010). Normality of the future: Trend diagnosis for strategic foresight. *Futures*, *42*(4), 313–327. http://doi.org/10.1016/j.futures.2009.11.017

Lyles, M. A., & Mitroff, I. (1980). Organizational problem formulation: An empirical study. *Administrative Science Quarterly*, 102–119.

Lyles, M. A., & Thomas, A. (1988). Strategic Problem Formulation - Biases and Assumptions Embedded in Alternative Decision-Making Models. *Journal of Management Studies*, *25*(2), 131–145. http://doi.org/DOI 10.1111/j.1467-6486.1988.tb00028.x

MacKay, R. B., & McKiernan, P. (2004). Exploring strategy context with foresight. *European Management Review*, *1*(1), 69–77. http://doi.org/10.1057/palgrave.emr.1500010

March, J. G. (1978). Bounded rationality, ambiguity, and the engineering of choice. *The Bell Journal of Economics*, 587–608.

Mayer, J. H., Steinecke, N., & Quick, R. (2011). Improving the Applicability of Environmental Scanning Systems: State of the Art and Future Research. In M. Nuttgens, A. Gadatsch, K. Kautz, I. Schirmer, & N. Blinn (Eds.), *Governance and Sustainability in Information Systems: Managing the Transfer and Diffusion of It* (Vol. 366, pp. 207–223).

McEwen, T. (2008). Environmental scanning and organizational learning in entrepreneurial ventures. *The Entrepreneurial Executive*, *13*, 1.

Menon, A., & Tomkins, A. (2004). Learning about the market's periphery: IBM's WebFountain. *Long Range Planning*, *37*(2), 153–162.

Miles, R. E., Snow, C. C., Meyer, A. D., & Coleman, H. J. (1978). Organizational strategy, structure, and process. *Academy of Management Review*, *3*(3), 546–562.

Mintzberg, H., Raisinghani, D., & Theoret, A. (1976). The structure of" unstructured" decision processes. *Administrative Science Quarterly*, 246–275.

Mintzberg, H., & Waters, J. A. (1982). Tracking Strategy in an Entrepreneurial Firm. *The Academy of Management Journal*, *25*(3), 465–499. http://doi.org/10.2307/256075

Mitroff, I. I., & Mason, R. O. (1981). *Creating a dialectical social science : concepts, methods, and models. Theory and decision library;vol. 25*. Dordrecht [etc.]: Reidel.

Murphy, J. J. (1989). Identifying strategic issues. *Long Range Planning*, *22*(2), 101–105. http://doi.org/10.1016/0024-6301(89)90128-3

Murphy, P. J. (2011). A 2× 2 conceptual foundation for entrepreneurial discovery theory. *Entrepreneurship Theory and Practice*, *35*(2), 359–374.

Nadkarni, S., & Barr, P. S. (2008). Environmental context, managerial cognition, and strategic action: an integrated view. *Strategic Management Journal*, *29*(13), 1395–1427. http://doi.org/10.1002/smj.717

Nutt, P. C. (1984). Types of Organizational Decision Processes. *Administrative Science Quarterly*, *29*(3), 414–450. http://doi.org/10.2307/2393033

O'Reilly, K. (2012). Paper, D., & Marx, S.(2012). Demystifying grounded theory for business research. *Organizational Research Methods*, *15*(2), 247–262.

Olson, J. R., & Biolsi, K. J. (1991). 10 Techniques for representing expert knowledge. *Toward a General Theory of Expertise: Prospects and Limits*, 240.

Ramalho, R., Adams, P., Huggard, P., & Hoare, K. (2015). Literature Review and Constructivist Grounded Theory Methodology. *2015*, *16*(3).

Reeves, M., & Deimler, M. (2011). Adaptability: The New Competitive Advantage. *Harvard Business Review*, *89*(7–8), 134–41.

Rossel, P. (2011). Beyond the obvious: Examining ways of consolidating early detection schemes. *Technological Forecasting and Social Change*, *78*(3), 375–385. http://doi.org/10.1016/j.techfore.2010.06.016

Rossel, P. (2012). Early detection, warnings, weak signals and seeds of change: A turbulent domain of futures studies. *Futures*, *44*(3), 229–239. http://doi.org/10.1016/j.futures.2011.10.005

Schoemaker, P. J. H., Day, G. S., & Snyder, S. A. (2013). Integrating organizational networks, weak signals, strategic radars and scenario planning. *Technological Forecasting and Social Change*, *80*(4), 815–824. http://doi.org/10.1016/j.techfore.2012.10.020

Sim, J., Saunders, B., Waterfield, J., & Kingstone, T. (2018). Can sample size in qualitative research be determined a priori? *International Journal of Social Research Methodology*, *21*(5), 619–634. http://doi.org/10.1080/13645579.2018.1454643

Simmons, A. L., & Sower, V. E. (2012). Leadership sagacity and its relationship with individual creative performance and innovation. *European Journal of Innovation Management*, *15*(3), 298–309. http://doi.org/doi:10.1108/14601061211243648

Simon, H. A. (1976). *Administrative behavior*. New York: Free Press.

Tapinos, E., & Pyper, N. (2017). Forward looking analysis: Investigating how individuals 'do' foresight and make sense of the future. *Technological Forecasting and Social Change*. http://doi.org/https://doi.org/10.1016/j.techfore.2017.04.025

Thorleuchter, D., Scheja, T., & Van Den Poel, D. (2014). Semantic weak signal tracing. *Expert Systems with Applications*, *41*(11). http://doi.org/10.1016/j.eswa.2014.02.046

Thorleuchter, D., & Van den Poel, D. (2015). Idea mining for web-based weak signal detection. *Futures*, *66*, 25–34. http://doi.org/10.1016/J.FUTURES.2014.12.007

von Groddeck, V., & Schwarz, J. O. (2013). Perceiving megatrends as empty signifiers: A discourse-theoretical interpretation of trend management. *Futures*, *47*, 28–37. http://doi.org/10.1016/j.futures.2013.01.004

Warnke, P., & Schirrmeister, E. (2016). Small seeds for grand challenges—Exploring disregarded seeds of change in a foresight process for RTI policy. *Futures*, *77*, 1–10. http://doi.org/10.1016/J.FUTURES.2015.12.001

Weick, K. E. (1995). *Sensemaking in organizations* (Vol. 3). Sage.

Yasai-Ardekani, M., & Nystrom, P. C. (1996). Designs for environmental scanning systems: Tests of a contingency theory. *Management Science*, *42*(2), 187–204.

Yoon, J. (2012). Detecting weak signals for long-term business opportunities using text mining of Web news. *Expert Systems with Applications*, *39*(16), 12543–12550.

Zach, L. (2005). When is "enough" enough? Modeling the information-seeking and stopping behavior of senior arts administrators. *Journal of the American Society for Information Science and Technology*, *56*(1), 23–35.

Zhang, X., Majid, S., & Foo, S. (2010). Environmental scanning: An application of information literacy skills at the workplace. *Journal of Information Science*, *36*(6), 719–732.