Straws That Tell the Wind

Top-Manager Perception of Distant Signals of the Future

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Straws That Tell the Wind

Top-Manager Perception of Distant Signals of the Future

Dissertation

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Chair of the Board for Doctorates
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by

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De wind in het koren

Top-manager perceptie van verre toekomstsignalen

Proefschrift

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To George.

The future is uncertain and inescapably subjective:
it does not exist except in the minds of people attempting to anticipate it.
John Adams, Risk, p.30

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Summary

This dissertation was prompted by its author's amazement that only a handful of financial experts had read the arrival of the 2009 recession in the subprime mortgage problems in the American housing market. Despite hefty confrontations in the media between investment experts during the years leading up to the recession, it took the fall of Lehmann Brothers for the world to become aware of the effects of the subprime crisis. Such myopia is exemplary for weak signals: the strategic phenomena detected in the environment or created during interpretation, that are distant to the perceiving top-manager's frame of reference.

If top-managers perceive weak signals early enough and interpret them accurately, they can increase the resilience of their company. If they don't, their companies run high risks. In the case of the great recession, the correct perceiving top-managers betted against mortgage-backed securities, and the rest had to take drastic measures to survive a double-dip recession. Whether or not having insights into the effective perception of weak signals can make or break companies.

The dissertation explores what happened in the weak signal processes of the participating top-managers. Thirteen expert top-managers recalled the times that they missed or misinterpreted signals and the times that they saw it right. Thereafter, twenty top-managers participated in an experiment in which they interpreted multiple weak signals. Both studies resulted in actionable insights into the role of reference frames and expertise in the weak signal process.

In this dissertation, weakness refers to the distance of new information to the frame of reference of the perceiver. A large distance means that new information is not comparable to information already in the frame, which makes it difficult to detect and interpret. A very short distance refers to strong signals, of which much is already known, thus inside the frame. The same information can be weak in the eyes of one manager and strong in the other, depending on their prior knowledge. Hence, weakness was seen as a perception, not an inherent, objective trait of information.

The weak signal definition that concludes the first paragraph may seem like just another way of describing weak signals, but it is much more. In the reviewed literature, weakness was something different to almost every researcher who explored it. This made it difficult to connect and validate reviewed findings. Cluster analysis of 30 keywords from 68 weak signal descriptions led to an inclusive definition of weak signals. It turned weakness into a measurable concept (frame distance) as well as a means of connecting the findings for a wide variety of other descriptions (see section 2.3.).

Literature described the weak signal process in four stages: (1) identification of problems or search goals; (2) signal detection; (3) signal interpretation; and (4) action as a result from interpretation. Perception filtered the information at specific moments in the process to reduce the amount of information to process, and to increase its relevance. The perceptual filters were situated in between the process stages. The first filter contained a top-manager's conscious or subconscious decisions on what information to include in the process. The second filter consisted of a top-manager's reference frame of beliefs and knowledge on the environment. The third filter consisted of the loss of information through communication about possible interpretation and actions (see section 2.2.2.).

The field study found three striking adjustments to the process to compensate for undesired reducing effects of the filters. Top-managers stipulated that (1) search had to focus on distant information; (2) that a distinct, wide range of sources had to be consulted; (3) and that interpretation must be deferred until multiple viewpoints on the signal had been gathered. The adjustments were the first indication of the relevance of frame distance and cognitive diversity to the process (see section 3.4.2.).

The reviewed process fitted both weak and strong signals, but their flows through the process were significantly different. A strong signal flowed seamlessly and swiftly through the perceptual filters into action. Weak signals ran the risk of rejection at each of the filters. A weak signal that made it into the interpretation stage required extensive interpretation before its meaning became clear. This suggested a positive relationship between the level of weakness and the extent of interpretation: the weaker the signals, the more extensive the interpretation. However, the second field study found a negative correlation. The more distant the signal was to the perceiver's frame, the less information in the frame could be employed to interpret the signal, thus the less extensive the interpretation. This finding pointed out that measuring levels of perceived weakness is crucial to the attribution of findings to the weak signal process. It also indicated that the reviewed studies might have used stimuli that triggered lower levels of perceived weakness (see section 6.1.2.).

The literature argued that the expert weak signal process had several distinct

characteristics as a result of the complexity of expert reference frames. Complexity consisted of links between meaningful patterns of signals and corresponding decision rules. It widened perceptual filters to include more signals into the process, and it enabled the simultaneous consideration of alternatives during interpretation. However, the dissertation's first field study revealed that experts could also exhibit quite simple frames. The simpler frames were focused on the interpretation stage of the process, and thus dealt with relatively more knowns. The more complex frames were focused on detection, when less was known. This implied that frame complexity might be used strategically. Simple frames may increase perceived weakness, thus compensating for a possible false sense of security through a focus on knowns. Complex frames may decrease perceived weakness, thus signifying the relative ease with which new signals were linked to the frame (see section 3.4.3.).

Furthermore, frame complexity only explained why experts were more efficient in the weak signal process. It did not explain why some experts interpreted signals accurately and others did not, as was the case in the subprime example that prompted the dissertation. Therefore, this dissertation explored the possibility that variance in expertise types may explain the difference.

An experiment involving twenty top-managers with varying expertise profiles resulted in 208 observations of the interpretation of weak signals. The observations were coded for six expertise types, four (levels) of perceived weakness, and three types of interpretation. Statistically significant correlations revealed that four of the six expertise types correlated with different interpretation patterns. Firstly, general expertise was positively correlated to three interpretation variables: (1) the use of frame information to make sense of a signal (sense-making); (2) the application of a signal to the company to assess impact (application); and (3) the interruptions of the flow of interpretation (no-flow). Secondly, the number of industries that top-managers had worked in for over five years correlated negatively with interrupted flow. Thirdly, the number of years that a top-manager had worked in the current industry correlated positively to application and interrupted flow. Finally, task expertise was positively correlated with application (see section 6.1.2.). The results indicated that the expertise types had different effects on the perceptual filters. General expertise seemed to widen filters and to reduce the difficulty of detecting very weak signals. Years in the current industry enabled the application of signals to the company's situation and thus seemed to contribute to the development of alternatives. Task expertise seemed to support general expertise in increasing the depth of perceptual filters.

Multiple factor analysis allowed visual inspection of the multivariate relationships between the variables. It supported the interpretation of the correlations (see section 6.2.).

Correlations and factor analysis results were interpreted as a second indication for the importance of cognitive diversity because the positive effects of one expertise type would compensate for the stringent focus of the other and vice versa. This brought more detail to the process adjustments that were found in the first field study. Their measures to include more distant information and multiple viewpoints seemed to refer to beneficial effects of combining multiple expertise types and frame structures into the process (see section 7.3.)

The exploratory nature of the dissertation limits the findings to two substantial theoretical contributions. Firstly, the negative correlation between perceived weakness and the extent of interpretation explains why weak signals are so hard to detect and interpret. In addition, weakness as distance to the frame enables the use of distance as a parameter for decision-making and as an index for decision alternatives. Secondly, the findings on expertise types and frames suggest that the absence of cognitive diversity can explain missed and misinterpreted signals. Its presence can explain higher process effectivity. The dissertation's scientific value is also expressed in a set of tools to add to the foresight field's toolbox. The definition and the design of the second field study resulted in standardized stimuli capable of triggering weakness perceptions, an effective experiment task, and an index to measure levels of perceived weakness. The use of the method in which scenarios trigger rateable articulations of weak signals (STRAWS) contributes to the validation of findings for distinct levels of perceived weakness (see chapter 4). Finally, top-managers who plan to or already manage a foresight process will benefit from the suggested process adjustments and the insights in distance and cognitive diversity (see section 7.5.).

The dissertation also points to exciting future research. The inclusive quality of the weak signal definition, which represents clusters of keywords of 68 other definitions, enables the strengthening of the framework of weak signal research. It can provide commonalities to which studies can be linked, thus building a validated framework. The STRAWS method is flexible enough to enable quantitative research, with which the dissertations theoretical insights can be tested. The findings themselves open up a new line on the role of cognitive diversity in weak signal perception and decision-making processes (see section 7.6.).

Samenvatting

Pas toen Lehman Brother's viel kreeg de wereld in de gaten dat de Amerikaanse subprime crisis wereldwijde gevolgen had in de vorm van een recessie. Beide kwamen als een donderslag bij heldere hemel, hoewel diverse financiële experts er in de media al jaren over aan het ruziën waren. Een dergelijke bijziendheid is exemplarisch voor wat we zwakke signalen (weak signals) noemen. Zwakke signalen bestaan uit percepties van strategische fenomenen, die op afstand staan van het referentiekader van de waarnemer en ontdekt worden in de bedrijfsomgeving of gecreëerd worden door interpretatie.

Als topmanagers zulke signalen vroeg genoeg ontdekken en juist interpreteren kunnen zij de overlevingskansen van hun bedrijf vergroten. Als ze signalen te laat ontdekken of onjuist interpreteren lopen hun bedrijven grote risico's. Zo konden wakkere topmanagers profiteren van een juiste blik op de subprime crisis als zij bijvoorbeeld hadden ingezet tegen de hypotheekmarkt of hun bedrijf op recessie hadden voorbereid. Topmanagers die pas later inzagen wat er aan de hand was moesten drastische maatregels nemen om hun bedrijf in staat te stellen een dubbele recessie te overleven. Het al dan niet hebben van inzicht in effectieve waarneming en interpretatie van zwakke signalen kunnen een bedrijf maken of breken.

Dit proefschrift onderzocht wat er gebeurde in het waarnemingsproces van Nederlandse topmanagers. Dertien expert topmanagers keken terug op de keren dat zij zwakke signalen misten, onjuist interpreteerden of juist wel tijdig en goed zagen. De daaropvolgende twintig topmanagers deden mee aan een experiment waarin ze meerdere signalen hardop interpreteerden. Beide studies resulteerden in bruikbare inzichten in de rol van referentiekaders en expertise in het waarnemingsproces.

Dit proefschrift legt de zwakte van signalen uit als de afstand van het signaal tot het referentiekader van degene die het signaal percipieert. Een grote afstand betekent dat het signaal niet vergelijkbaar is met informatie in het referentiekader, waardoor het moeilijk te ontdekken en interpreteren is. Een heel korte afstand refereert aan een sterk signaal, waarover het referentiekader veel meer informatie beschikbaar heeft. Hetzelfde signaal kan zwak zijn voor de ene manager en sterk voor de ander, afhankelijk van de beschikbare informatie in hun referentiekader. Dat betekent dat de zwakte van signalen een perceptie is en geen intrinsiek aspect van het signaal.

De definitie van zwakke signalen aan het slot van de eerste alinea ziet er op het eerste oog uit als een van de vele omschrijvingen van zwakke signalen, maar er zit meer in. Het literatuuronderzoek maakte duidelijk dat de 68 omschrijvingen uit de geanalyseerde papers zo uiteenlopend waren dat het de validiteit van onderzoeksresultaten in gevaar bracht. Een clusteranalyse van 30 kernwoorden uit de omschrijvingen werd gebruikt voor deze nieuwe definitie. De definitie maakte van een vaag begrip een meetbaar concept (frame afstand) en maak het mogelijk om de resultaten behorende bij de andere omschrijvingen met elkaar te verbinden (zie sectie 2.3.).

In de literatuur bestaat het proces voor zwakke signalen uit vier stappen: (1) de identificatie van problemen of zoekopdrachten; (2) het waarnemen van signalen; (3) het interpreteren van signalen; en (4) het ondernemen van actie op basis van de interpretatie. Perceptiefilters scheiden de stappen, zodat de hoeveelheid signalen behapbaar blijft en aan relevantie wint. Het eerste filter bestaat uit de bewuste en onbewuste criteria waaraan signalen moeten voldoen om waargenomen te worden. Het tweede filter bestaat uit de overtuigingen en kennis over de bedrijfsomgeving in het referentiekader van de topmanager. Het derde filter bestaat uit het verlies aan informatie door communicatie met anderen over interpretatie en actie (zie sectie 2.2.2.).

De eerste studie van het proefschrift ontdekte drie opvallende procesaanpassingen waarmee topmanagers de nadelige effecten van hun perceptiefilters compenseerden. Topmanagers schreven voor dat: (1) zoekopdrachten gefocust moesten zijn op informatie met grote afstand tot het referentiekader; (2) dat een brede reeks van specifieke bronnen aangesproken moest worden; en (3) dat interpretatie van signalen moest worden uitgesteld totdat meerdere perspectieven waren verzameld. Deze aanpassingen werden geïnterpreteerd als de eerste indicatie van de relevantie van frame afstand en cognitieve diversiteit voor het proces (zie sectie 3.4.2.).

Het proces voor sterke signalen had dezelfde stappen en filters als dat voor zwakke signalen, maar onderscheidde zich door de manier waarop het signaal het proces doorliep. Een sterk signaal stroomde naadloos en vlot door naar de actiestap. Een zwak signaal liep bij elk perceptiefilter het risico om uit het proces verwijderd te worden. Als een zwak signaal de interpretatiestap haalde, dan was de interpretatie stap zelf heel substantieel. Dit verschil suggereerde een positieve relatie tussen de zwakte van een signaal en de uitgebreidheid van interpretatie: hoe zwakker het signaal, hoe meer interpretatie er nodig is om het te begrijpen. De tweede studie van dit proefschrift vond echter een negatieve relatie. Hoe zwakker het signaal, hoe minder informatie over het signaal beschikbaar was in het referentiekader en dus hoe minder substantieel de interpretatie. Dit resultaat maakte duidelijk dat het meten van meerdere niveaus van zwakte cruciaal is voor het toerekenen van conclusies aan zwakke signalen. Het leek er ook op te wijzen dat de studies uit het literatuuronderzoek stimuli hadden gebruikt die tot lagere zwaktepercepties hadden geleid (zie sectie 6.1.2.).

De literatuur wees verder op de kenmerkende referentiekaders van experts. Het zou complexer zijn, hetgeen betekende dat het referentiekader meer koppelingen naar meer patronen van signalen en bijbehorende besluitregels had. De complexiteit maakte dat experts meer signalen ontdekten en meerdere alternatieve interpretaties naast elkaar konden ontwikkelen dan leken. Uit de eerste studie van de dissertatie bleek echter dat experts ook simpele referentiekaders konden hebben. De simpeler kaders bleken gefocust te zijn op interpretatie, de stap waarin meer bekend wordt over signalen. De complexere kaders waren gefocust op detectie, de stap waarin nog nauwelijks iets bekend is. Dit onderscheid leek erop te wijzen dat de referentiekaders van topmanagers een strategische rol spelen. Simpele referentiekaders leken ervoor te zorgen dat meer signalen als zwakker werden gezien. Dit zou de mogelijke gevoelens van veiligheid als resultaat van de focus op meer bekende informatie tegen gaan. Complexere referentiekaders verlaagden de zwakteperceptie omdat de complexiteit het makkelijker maakte om koppelingen met meer signalen te leggen (zie sectie 3.4.3.). Daar kwam nog eens bij dat de complexiteit van referentiekaders niet verklaart waarom de ene expert het zwakke signaal van de subprime crisis wel oppikte en de andere niet. Dit proefschrift onderzocht de mogelijkheid dat variantie in het type expertise dat verschil wel kon verklaren.

Een experiment met twintig topmanagers met verschillende expertise profielen leverde 208 observaties op waarin een topmanager een signaal interpreteerde. De observaties werden gecombineerd in een tabel met zes typen expertise, een zwakte-index en drie interpretatie variabelen. Statistisch significante correlaties werden gevonden voor vier van de zes expertise typen, steeds met andere interpretatie variabelen. Ten eerste was algemene expertise positief gecorreleerd aan alle interpretatie variabelen: (1) het gebruik van informatie uit het referentiekader om een signaal te duiden (duiding); (2) het toepassen van een signaal op de bedrijfssituatie (toepassing); en (3) de mate waarin interpretaties werden onderbroken door stotteren en uhms (stroom). Ten tweede, het aantal industrieën waarin topmanagers langer dan 5 jaar hadden gewerkt was negatief gecorreleerd met de interpretatiestroom. Ten derde, het aantal jaar dat topmanagers in de huidige industrie werkten was

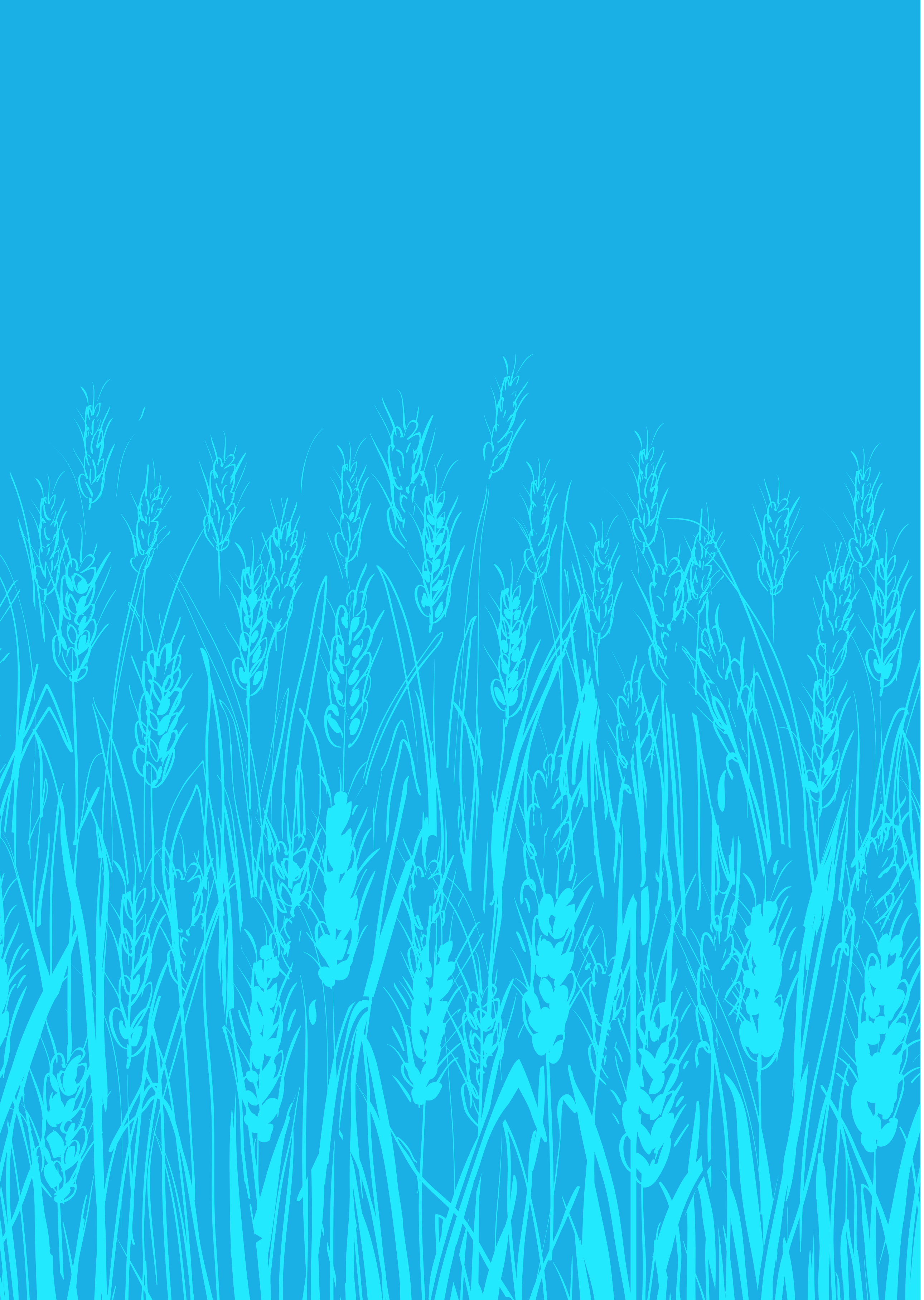
positief gecorreleerd met toepassing en stroom. Ten slotte was taakexpertise positief gecorreleerd met toepassing (zie sectie 6.1.2.). De correlaties leken te wijzen op verschillende effecten van expertise typen op de perceptiefilters. Het was aannemelijk dat algemene expertise perceptiefilters verbreedde en het makkelijker maakte om zwakke signalen waar te nemen. Jaren gewerkt in de huidige industrie maakte het makkelijker om meerdere alternatieve interpretaties te ontwikkelen door de kennis over mogelijke toepassingen. Taakexpertise leek algemene experts te ondersteunen door hun perceptiefilter te verdiepen en industriespecialisten door hun filter te verbreden.

Meervoudige factor analyse visualiseerde hoe de relatieve afhankelijkheden van de variabelen waren. De analyse liet opnieuw zien dat expertise typen bij gelijke zwaktepercepties verschillende effecten hadden op de inspanning die tijdens interpretatie van signalen werd geleverd (zie sectie 6.2.2.).

De correlaties en factor analyse werden geïnterpreteerd als een tweede indicatie van het belang van cognitieve diversiteit. De filter verbredende effecten van het ene type expertise kon de stringente focus van de andere compenseren. Deze interpretatie legde uit waarom de procesaanpassingen van de topmanagers uit de eerste studie zo effectief konden zijn. Hun maatregels om meer verre informatie waar te nemen en meerdere perspectieven in het proces bijeen te brengen, leek op de praktische vertaling van bredere combinaties van referentiekaders en expertise types (zie sectie 7.3.).

De verklarende aard van het proefschrift beperkt de conclusies tot twee inhoudelijke bijdragen aan de theoretische ontwikkeling van onderzoek naar zwakke signalen. Ten eerste, de negatieve correlatie tussen zwakteperceptie en de omvang van interpretatie verklaart waarom zwakke signalen zo moeilijk te zien en te duiden zijn. Bovendien maakt zwakte als afstand tot het referentiekader het mogelijk om afstand te gebruiken als parameter voor bijvoorbeeld besluitvorming en als index voor besluitalternatieven. Ten tweede, de resultaten inzake expertise types en referentiekaders suggereren dat de afwezigheid van cognitieve diversiteit het missen en onjuist interpreteren van zwakke signalen kan verklaren. De aanwezigheid van cognitieve diversiteit kan de effectiviteit van het proces verhogen. De wetenschappelijke waarde van het proefschrift wordt ook bepaald door de hulpmiddelen die het aan het instrumentarium van toekomstonderzoek toevoegt. De studies in het proefschrift leidden tot een meetbare definitie, het ontwerp van gestandaardiseerde stimuli die zwakteperceptie kunnen opwekken, een effectieve opzet van een experiment, en de index om zwakteperceptie mee te meten. Het gebruik van de methode waarbij scenario's meetbare zwaktepercepties opwekken (STRAWS) kan bijdragen aan de validatie van de conclusies voor meerdere niveaus van zwaktepercepties (zie sectie 4). Tenslotte, topmanagers die overwegen om een proces voor horizonverkenning op te zetten of al managen kunnen profijt trekken van de procesaanpassingen en de inzichten in afstand en cognitieve diversiteit (zie sectie 7.5.).

Het proefschrift verwijst ook naar opwindende richtingen voor toekomstig onderzoek. Het inclusieve karakter van de definitie, dat door clustering van kernwoorden 68 andere definities vertegenwoordigt, kan gebruikt worden om het raamwerk onder het onderzoek naar zwakke signalen te versterken. Clusters verwijzen naar de overeenkomsten tussen definities waardoor onderzoeken kunnen worden gekoppeld en winnen aan validatie. De STRAWS-methode is flexibel genoeg om een kwantitatieve opzet van het proefschrift mogelijk te maken, zodat de theoretische inzichten kunnen worden beproefd. De conclusies over afstand, expertise typen en referentiekaders kunnen leiden tot onderzoek naar de rol van cognitieve diversiteit in het waarnemings- en besluitvormingsproces (zie sectie 7.6.)



1

WEAK SIGNAL WEAKNESS

What's relevant, really, to the world?
Is it the Parliamentary elections or Google's new CEO?

Field Study II; Participant 08

Barbara Liesbeth Van Veen

It sounds counterintuitive to top-managers when they hear that their company's resilience benefits from searching for phenomena they cannot place, from searching in an unfocused way, and refraining from judgment until the people they disagree with have contributed to the interpretation. However, those are some of the significant conclusions of this dissertation's exploration of the weak signal process of top-managers. How these conclusions were reached is disclosed in the following chapters. Before the research is introduced, a few words are spent to clarify the concept of signal weakness.

Imagine going for a walk in the park during your lunch break. A sudden noise in the background is vying for your attention. It signals imminent danger, but only if you stop your train of thought to consider its meaning. If you do not, it remains just background noise.

There! You hear it again, but you cannot quite pinpoint what it is. Loud, yes, but clear? No. It could be anything from something heavy rolling down, to a plane passing in the distance. The signal is too weak to interpret accurately. You tilt your head to hear it better. Flash, bam! Now you know: it is thunder.

There is thunder in the background noise of the business environment as well. Top-managers can hear it or read it in information about developments with significant future impact. Once they become aware of the information, they turn noise into a signal relevant for their company's future. When the signal is hard to which includes in their frame of reference, it is called a weak signal.

Literature describes the process of interpreting weak signals with stages and filters (Ansoff, 1979; Ilmola & Kuusi, 2006). Firstly, top-managers become aware of the signal; then they interpret it. Perception shields them from information overload by acting as an information filter. Top-managers reject much noise, including signals before conscious detection, and detected signals before or after interpretation when signals seem irrelevant (see Figure 1).

It stands in stark contrast with the strong signal process. It has the same stages and filters, but the flow of the signal through the process is different (Aguilar, 1967). A signal is strong if its relevance and impact are evident in the mind of the perceiver. Hence, a strong signal passes the perceptual filters seamlessly and does not require much interpretation if any (see Figure 1).

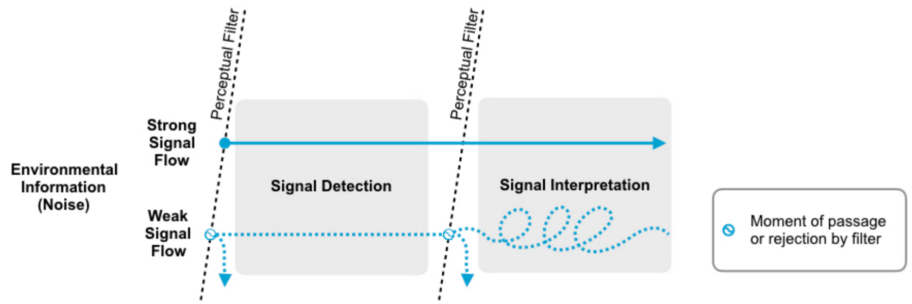


Figure 1: *Stages and filters of the weak signal process, including the distinct flow of strong and weak signals through the process*

The perception of weak signals is an intriguing phenomenon because of its paradoxical character. Firstly, the effects of *not* detecting weak signals are driving research on detection. Not detecting a weak signal means that a company does not respond when it is required. The resulting misalignment between a company and its environment can break a company. Hence the interest in the detection of developments yet to come. Secondly, rational deliberation is used to complete an

interpretive process that is not so rational. Only past and present signals can be used to interpret future impacts. Therefore, signal interpretation is bounded by the availability of information, time, and cognitive skills, and thus cannot be entirely rational. Thirdly, the detection of a signal and missing it are the same thing when a signal gets rejected by a perceptual filter. Both lead to the same dangerous strategic inertia. Finally, scholars in many fields have researched the process, but a precise grasp of the meaning of weakness is still lacking.

In other words, the weak signal process is like forecasting a thunderstorm. We have to predict without completely understanding the weather system, access to all data, or the time to wait for strong signals like thunderheads rolling in. Ignoring or misinterpreting the signal means exposure to its destructive force. What is more, the earlier we know a storm is coming, the more time we will have to take the necessary precautions. So, we watch the straws bend in the wind, telling us about the changing gusts of wind that precede a storm.

In business, thunderstorms may sweep across the company environment and destroy the mechanisms of the markets in it. It is not that easy to identify the telling straws. For instance, it was a straw in the shape of the US subprime crisis that signified the great recession. Prominent experts rejected the signal, even when deliberately and repeatedly exposed to it. In the next section, this example is used to illustrate the weak signal process and to establish the relevance of the process.

1.1. Managerial Relevance

Investor Peter Schiff was met with sarcasm as he summed up a pattern of developments weaving imminent crisis. It was the year 2005, and experts like the former Chair of the Federal Reserve Alan Greenspan disagreed fervently or ridiculed him. Schiff kept warning his audience up to the fall of Lehman Brothers in 2008 (Schiff, 2009). When the smoke from the collapse cleared, everyone knew Schiff had predicted right all along (Bezemer, 2011).

Schiff's message was the proverbial weak signal from the view of the experts. They perceived his message as ridiculous, so at odds was it with their frame of reference (see weak signal definition in the text box). Frames of reference refer to the implicit knowledge collections with which perceivers structure and interpret

WEAK SIGNAL
The perception of strategic phenomena detected in the environment or created during interpretation that are distant to the perceiver's frame of reference

weak signals (Schwarz, Kroehl, & Von der Gracht, 2014).

Three aspects of expert interpretations stood out. Firstly, conventional forecasting models did not include the problematic effects of the American housing boom (Bezemer, 2011). That meant that experts were hardly exposed to the effect or prompted to consider it. This omission in the forecasting models is representative of the first perceptual filter in the process model, the forecast filter (see 1 in Figure 2). Secondly, when Schiff confronted them, the experts drew on their expertise to find explanations that better suited their view. It was clear to Schiff that the debt in the wake of the housing boom would lead to a financial crisis, but the experts interpreted that same debt as a representation of real wealth (Schiff, 2009). Such alternative interpretations are exemplary of the second filter in the model, the mentality filter (see 2 in Figure 2). When new information is at odds with the perceivers' reference frame, the perceiver is probably going to reject it. Re-examining assumptions in the frame would have been a better response. Thirdly, it took three years of iterations to change the interpretation of Schiff's opponents (see 3 in Figure 2). In 2005, the experts perceived his assumptions about the housing market and its effects as entirely incorrect. When time went by and the housing crisis developed, experts had no choice but to agree on it happening. However, they still maintained that other developments would contain the damage to the housing market and cancel any possible spilling effects. Their inertia illustrates how stubborn the interpretation stage can be. The two filters and the iterative signal interpretation stage are the defining aspects of the weak signal process (see Figure 2).

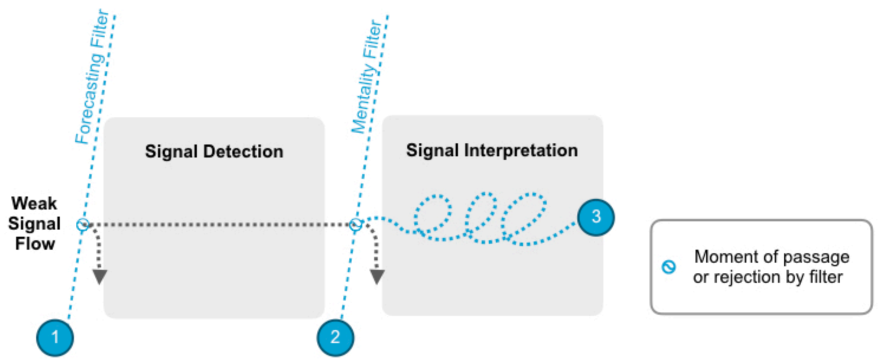


Figure 2: *Three defining aspects of the weak signal process. 1) forcasting filter; 2) mentality filter; 3) interactions during interpretation*

The emergence of the great recession illustrates the relevance of the timely and accurate interpretation of weak signals in the shape of threats. However, weak signals of opportunities are just as relevant, and their process flow just as complicated. For instance, top-managers now take the commercial benefits of the Internet for granted, but it took years before mainstream companies could interpret it accurately (Glowniak, 1998; Leitner, 2015). Knowledge about the Internet was initially restricted to circles within the military and science. When information about the Internet started to spread, it was interpreted as a game, a weapon, a sales technology, a thought framework, and many things in between (Schulte, 2013). These days, it is a known fact that the Internet had an overall positive economic effect (Choi & Yi, 2009; Tindale, Sheffey, & Scott, 1993). At the time, household names like Kodak or Blockbuster suffered because they interpreted the effects of the Internet wrong or too late (Manyika & Roxburgh, 2011).

In the aftermath of the Internet shake-out and the great recession, the value of research into the weak signal process seems obvious. Its purpose is to improve top-manager anticipatory skills and strategic decision-making so that companies can respond earlier and faster to new information.

The real-world examples in the previous paragraphs pointed out that even experts can miss and misinterpret weak signals. Their expertise had led them to interpret a weak signal in accordance with their existing view. Paradoxically, literature described two beneficial effects of expertise (Eisenhardt, 1989). Firstly, expertise was said to widen perceptual filters so that more signals would be included in the process. Secondly, it supposedly made interpretation more effective because experts were able to use their knowledge to develop complex hypotheses and test these in subsequent iterations quickly. These benefits implied that experts could interpret more signals and do it better than novices could in the same time. It seemed plausible that distinct types of expertise were responsible for this paradox. The experts in the Schiff and Internet examples were industry experts with narrow and deep knowledge of finance and communications, respectively. The experts in the comparison study were frequently involved in the weak signal process, which implied that they possessed high task expertise. Hence, the aim of the second field study was the exploration of the role of expertise *type* in the managerial weak signal process. The grounded theoretical insights on the role of expertise in the process form the major contribution of this dissertation to the advancement of managerial foresight.

The research of the weak signal process is part of the foresight practice, which recently matured into a field of its own (Kuosa, 2011; Rossel, 2011). The field has only the beginnings of shared methodologies and terminology (Giaoutzi & Sapio, 2013), and as a result, findings are fragmented and lacking validation. The dissertation wants to contribute to the development of the field.

1.2. Scientific Relevance

It is hardly surprising that managerial weak signal research took off in the 1970s in the wake of an economic shock. At the time, a small group of developing countries agreed to cut oil production as a political weapon against developed countries. The oil embargo came as a strategic surprise even to the experts who did foresee oil price increases (Issawi, 1978). The embargo led to a global recession, which prompted strategy scholars to theorize about the prevention of the next strategic surprise. Prevention was to be accomplished through a broader awareness of emerging developments, not by the more error-prone predictions (Ansoff, 1975; Molitor, 1977). These scholars named the information about emerging developments weak signals. They modeled the weak signal process with stages and perceptual filters and set the weak signal flow apart from the strong signal flow (Ansoff, 1979; Mintzberg & Waters, 1982). Finally, they also argued that the level of weakness of a signal was relative to the knowledge of that signal, and not a fixed state.

In the 1980s, two trends started to emerge in weak signal research. Previously siloed research started to mesh under the name of complexity studies, and, simultaneously, new disciplines became aware of their interest in the future and started to contribute (Kuosa, 2011). For instance, linguists explored the role of language as a means of expressing the future in the present. Organizational learning perceived the process as a learning cycle. Information theorists looked upon the process as the transition of information from one network or system to another. In other words: each discipline researched the process through its distinct lens (Giaoutzi & Sapio, 2013). Both trends led to new viewpoints and findings, but also to increasing fragmentation (Kuosa, 2011).

Ideally, a shared understanding of the terms weakness and signal should form the foundations of weak signal research. In reality, fragmentation has led to dozens of definitions ranging between rather extreme poles. Weakness referred to objective traits like industry volatility, or perceived developments like future trend combinations. Signals ranged from undefined pressures to specific events. Such fragmentation made it quite imaginable that theoretical contributions were based on incomparable weak signals. When scholars are unaware that they may be measuring different

constructs, they build theory as strong as quicksand. Hence, the dissertation's first scientific contribution is to bring clarity to the weak signal construct (see chapter 2).

From the outset, weakness was tabulated into several levels. When a new signal was detected, sometimes only sensed, much about the signal was unknown. As time went on, more information would become available. More information facilitated the extrapolation of a signal's impact and the required response. Thus, weakness and knowledge were opposing factors in weak signal research. Field studies took the notion a step further and treated weakness as binary: a signal was either strong (known) or it was not. This seemed to reduce weak signal research to not-strong signal research. Aggregating all not-strong signals had two severe effects. Firstly, it allowed the confusion on weakness to continue. Secondly, it obscured possible distinct behaviors per weakness level. It was plausible that severely weak signals would run a bigger risk of rejection than signals that were hardly weak, and that these levels would have very different interpretation patterns. If there were such a distinction between levels, foresight methodologies might need severe adjustments to accommodate the detection and interpretation per level. Thus, the dissertation's second contribution consists of a method with scenario triggered rateable articulations of weak signals, dubbed STRAWS. The method includes guidelines for stimuli to trigger perceived weakness, an experiment task design to approximate the weak signal process, and an index with multiple weakness levels to measure perceived weakness.

1.3. Focus on the Top-Manager

In every company, at every level, workers now and again consider new possibilities and induce new policy. It happens in groups and individually, for the short and the long term, and on small and large issues. Within that vast array of foresight practices, the weak signal process stands out because of its input. This process is reserved for the perceptions of strategic phenomena detected in the environment or created during interpretation, that are distant to the perceiver's frame of reference.

Authors have argued that the weak signal process belongs to the responsibilities of the top-management team. Top management teams oversee the company as a whole and interpret environmental information for company-level action (Daft & Weick, 1984; Mintzberg & Waters, 1982). However, the dissertation focuses on the highest responsible functionary from the top team. Several considerations led to this decision. Firstly, the joint analysis of weak signals takes place based on individual perceptions (Tapinos & Pyper, 2017). Logically, the investigation of weak signal analysis starts with the individual interpretation of the highest responsible functionary in the management team. This functionary presumably has the widest view of the environment (Lawrence & Lorsch, 1967; Weick, 1979). Secondly, the focus on the individual eliminated noise from interaction effects from the studies (Dörner & Dorner, 1996).

The focus on the individual top-manager had several consequences. Firstly, it led to the restriction of the process to two process stages and filters (see Figure 2). Secondly, the focus on individual top-managers implied that their characteristics influenced the process. Characteristics like personality type, work experience, or cognitive skills may explain variation and must somehow be accounted for. Initially, this seemed problematic because it required extensive personality testing of the sample of top-managers. These people are extremely busy, so their valuable time should be spent on their process, not on their personality. Research has bundled these characteristics in a construct called "individual human capital" (Alvarez & Busenitz, 2001), and then disaggregated it into general and specific expertise (Alvarez & Busenitz, 2001; Shepherd, Williams, & Patzelt, 2015; Westhead, Ucbasaran, & Wright, 2005). General expertise pertained to age, level of education, or gender. Specific expertise included knowledge about a particular domain, awareness of the main problems in it, and the skills to solve those problems. This approach simplified the research set-up because accounting for the influence of managerial characteristics was now reduced to including the curriculum vitae of participants in the data. It also enabled comparisons between top-managers with either high general or specific expertise.

A simple model of variables and relationships was developed. It contained three variable groups: expertise types, perceived weakness levels, and interpretation patterns (see Figure 3).

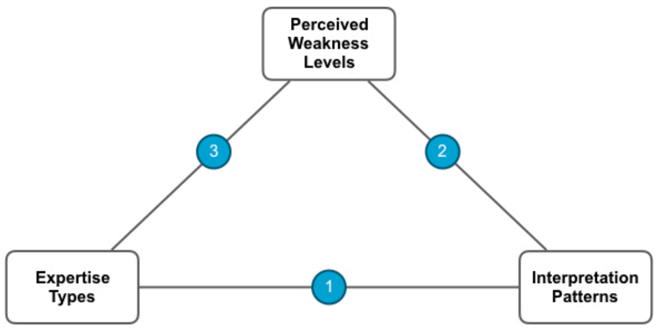


Figure 3: *The underlying model*

First of all, some or all of the expertise types and levels may lead to a distinct interpretation pattern (see section 1.1. and Figure 3, line 1). Secondly, some or all of the levels of perceived weakness may lead to distinct patterns as well (see section 1.2. and Figure 3, line 2). Thirdly, some or all of the expertise types and levels may affect the level of perceived weakness (Figure 3, line 3). Hence, the following research questions were postulated:

1) Do different types of expertise influence interpretation patterns differently?
2) Does the level of perceived weakness of a signal influence the interpretation patterns?
3) Do the expertise types lead to different levels of perceived weakness?

1.4. Methodology

The confusion and lack of validation of weak signal research through fragmentation (see section 1.2.) called for an exploratory approach to better understand the relationships between expertise, perceived weakness, and interpretation patterns. Five steps were taken towards grounded insights that validated fundamental concepts, enriched theory, and directed managerial foresight practice (see Figure 4).

First, relevant literature from multiple disciplines was explored to develop the basics for the research: the definition of a weak signal, the process model, and the weak signal flow through the model. A cluster analysis was used to develop a new definition of weak signals. Relevant refinements of the basics, for instance, about the role of expertise in the process, were noted for comparison with the results of the field studies (see chapter 2).

Secondly, an initial field study was done to validate the basics, as well as a first exploration of expert frames. The field study consisted of exploratory interviews with 13 successful top-managers of companies that were leading in its industry. The interviews were coded using a constant comparative method. Analysis of the codes let patterns emerge, which were used to develop theory about the workings of the expert frame (see chapter 3).

Thirdly, the reviewed literature was used to design an experiment that would trigger the weak signal process. Additional literature on expertise was reviewed to develop the criteria for the sample. Literature on decision-making cues was reviewed to develop criteria for stimuli and to collect ideas for their research design. The resulted method was named Scenario Triggered Rateable Articulations of Weak Signals, or STRAWS (see chapter 4).

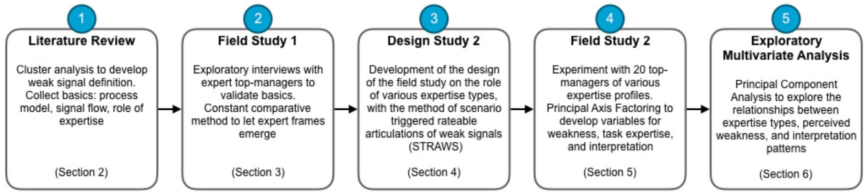


Figure 4: *Methodology*

Fourthly, the second field study, the experiment, was conducted among 20 top-managers with distinct expertise profiles. They were asked to interpret ambiguous stimuli while thinking out loud. Their thoughts were audiotaped, transcribed, and coded for evidence of perceived weakness, logic, and linguistic patterns. Variables for perceived weakness, task expertise, and interpretation patterns were formed with factorial analysis of the codes. Variables for general and specific expertise were formed based on the curriculum vitae of the participants (chapter 5).

A multiple factor analysis was used to explore the research questions about the relationships between expertise types, perceived weakness, and interpretation patterns (see chapter 6).

1.5. Contributions

This dissertation explored the weak signal process of top-managers with various expertise types and levels. It was prompted by the astonishing myopia of industry experts for weak signals of emerging crisis and change in the business environment. Fragmentation of previous research had led to a myriad of weak signal definitions, which severely limited validation. The dissertation was designed to validate fundamentals such as a weak signal definition, a weak signal process model, and the defining aspects of the flow of weak signals through the process. It also was to build on previous research with regards to the role of expertise in the process. Findings contribute to both the scientific and the managerial foresight practice.

Firstly, tools were developed to address the confusion and lack of validation in the

scientific foresight practice. Most importantly, a weak signal definition was developed that clarified what weakness represented. The definition was developed based on a cluster analysis of 40 definitions retrieved from literature. The analysis separated keyword clusters that explained most of the variance in the 40 definitions. Existing definitions could be related to the new one using common keywords. This way, the new definition can function as a linking pin between studies with inconsistent definitions and support at least partial validations (see chapter 2).

In addition, an index for perceived weakness was developed to enable the emergence of distinct interpretation patterns per weakness level. An index might help explain the discrepancy between two theoretical assumptions about weakness. Firstly, it was assumed that perceived weakness covaried with knowledge about a signal. Perceived weakness could decrease when knowledge on a signal increased. Secondly, it was also assumed that weak and strong signals differed in process flow: strong signals followed a smooth pattern, and weak signals an iterative pattern. In other words: a binary pattern difference for a continuous variable. This discrepancy may hide variation in process flows per weakness level, that in turn may lead to the development of less effective foresight methodologies. The index did indeed reveal variation in process flows per weakness level. Thus, the dissertation's index adds to the fundamental tools of the field (see chapter 5).

Furthermore, a systematic method was developed to trigger weakness perceptions. Because the perception of weakness is idiosyncratic, studies on perceived weakness can collapse when the sample perceives stimuli as strong. Likewise, earlier studies had also developed stimuli sets that were most likely to trigger weakness. Among their solutions were sets containing fictional new technologies or the recollections of weak signals. These sets did trigger weakness, but also led to questions about the homogeneity of stimuli within a set. The absence of homogeneity may lead to a set that induces more response types than the one under investigation. The dissertation's systematic method reduces that risk and is not limited in its application. Its stimulus design guidelines give researchers the freedom to develop weak signals for specific audiences while maintaining generalizability and validations (see chapter 4).

Secondly, the dissertation's findings contribute to theory in two respects. The variation in process flows per weakness level was the most fundamental finding. The variation showed that the largest difference in interpretation patterns occurred between strong and hardly weak signals instead of strong and very weak signals. It also showed that a very weak signal and a strong signal exhibited a similar flow.

The variation indicated that perceived strength and weakness may be two separate factors and thus provide new arguments for a separate, distinctive process and methodology for weak signals. The smoother flow for weaker signals may also reflect why weak signal interpretation is so tricky. Because perceivers know less about the weaker signal and have fewer signal similes in their reference frame, they can identify fewer clues to use in meaningful logics. This suggests that effective foresight methodologies should include tools to link very weak signals to existing knowledge. If such tools are not included, methodologies may merely result in myopia for weaker signals and thus lead to false feelings of safety and control (see chapter 6).

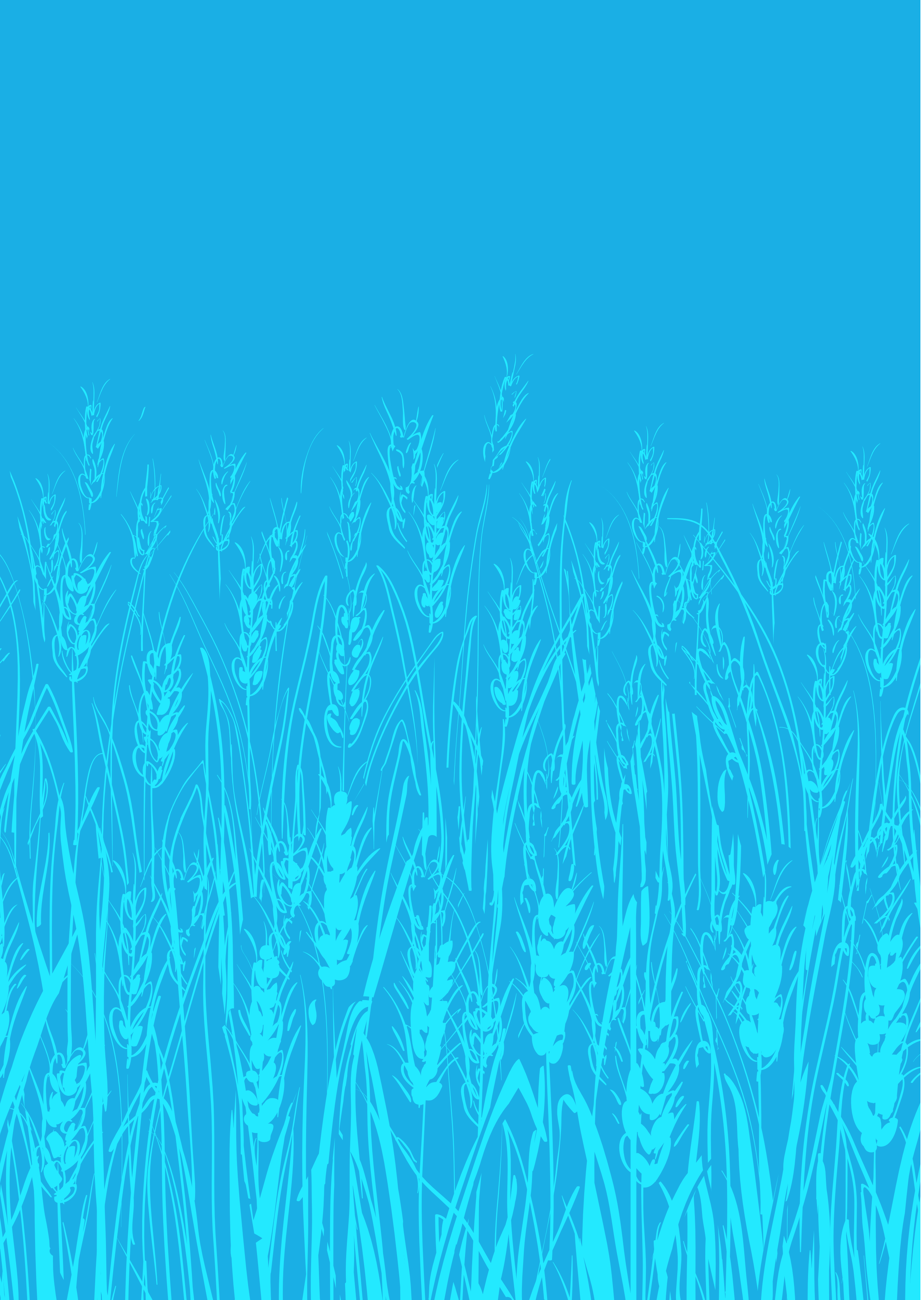
Another fundamental theoretical contribution concerned the role of various expertise types. Findings indicate that expertise types do improve weak signal processing but at different stages of the weak signal process. At the detection stage, general expertise can increase the number of detected signals. During the interpretation stage, general and task expertise can improve argumentation logics, while deep industry expertise can connect signal interpretation to existing and former policy, processes and outcomes (see chapter 6).

Thirdly, the dissertation's findings contribute to the managerial foresight practice. Findings can assist top-managers when they want to design or improve a process to increase their company's awareness of emerging threats and opportunities. The findings explain how conventional approaches can improve by decreasing focus, distribution of expertise throughout the process, and the use of specific logics. They also explain why the popular wish for more diversity in top-teams is justified, albeit in a different way than authors and instructors explain. Instead of a focus on gender or cultural background, it may have more effect if the focus is on the diversity of type and quality of expertise in the board room (see chapter 7).

1.6. Dissertation Structure

The structure follows the research design presented in section 1.4. Chapter 2 presents substantial findings from the literature review on the weak signal process and the role of expertise. It also includes the development of the new weak signal definition. Chapter 3 includes the first field study design and results. Findings validated the basics from the literature review and brought new insight into the role of expert frames. Chapter 4 offers the methodological findings from the literature review and the subsequent design of the second field study. Part of the design is the STRAWS method: the scenario triggered rateable articulations of weak signals.

The method was developed for the second field study but broader applications in mind. Chapter 5 describes the data collection in the second field study and the subsequent development of variables such as the index for perceived weakness and a variable for task expertise. Chapter 6 details the method of data analysis of the second field study and its results for the relationships between expertise type, perceived weakness, and interpretation patterns. Chapter 7 compares and contrasts the findings from the literature review and both field studies. Implications of the findings for the managerial and scientific foresight practice are discussed, as well as suggestions for future research. The epilogue presents learnings from dead-ends in the exploration.



2

WEAK SIGNAL BASICS FROM LITERATURE

*You actually only want **that** piece… uhm…*
want to know what signal applies to your business at this point in time.

Field Study II; Participant 11

A multidisciplinary review of weak signal literature was performed to establish the current state of knowledge on the process. Its results were used to develop a weak signal definition that encompassed the many meanings of weakness from each contributing discipline. The multidisciplinary approach was chosen because a classic systematic search led to unhelpful search results. Too few papers surfaced from the Web of Science and Scopus databases when keywords were restricted to titles, and far too many when the title parameter was toggled to topic. Other review methods were perused (Grant & Booth, 2009), but only a multidisciplinary approach resulted in a substantive list of results within the dissertation's focus.

Papers on weak signals can be found in loosely related research disciplines that range from climate impact to semiotics and medical diagnostics. Somewhere in between reside the most relevant disciplines to find out what happens in the weak signal process of top-managers. The discipline selection is explained in the first section (section 2.1.).

Section 2.2. presents the findings in three themes: the process, the role of expertise, and the concept of weakness (section 2.2.). Weakness emerged as an ambiguous concept, that was described and operationalized in a multitude of ways. The next section presents the cluster analysis of the reviewed weak signal descriptions and the new weak signal definition that emerged from it (section 2.3.). In the last section, the implications of the literature findings for the next step in the dissertation's research are discussed (section 2.4.).

2.1. Search

The literature search followed the usual approach of multidisciplinary reviews (Aboelela et al., 2007; El Akrouchi, Benbrahim, & Kassou, 2015; Forbes & Milliken, 1999; Rohrbeck & Bade, 2012; Rossel, 2011). Search consisted of multiple iterations of a broad search query to which a keyword for a research area was added. The keyword search was based on the steps developed by Tranfield, Denyer & Smart (2003). First, keywords were selected from the focus description: top-managers perceiving weak signals from the environment for strategy formation. Second, a list of synonyms for each keyword was developed. For instance, the synonyms for signal were sign, cue, clue, information, knowledge, intelligence, information, and stimulus. Third, various combinations of keywords and synonyms were used for multiple search queries in the Web of Science Database and SCOPUS. Lastly, titles and abstracts were read to assess the effectiveness of the synonyms in the query. The most promising titles were added to a master list of eight must-have papers. On the list were two types of papers. First of all, the list contained seminal papers such as the paper by Ansoff in which weak signals were introduced as a concept (Ansoff, 1975). The second type of papers were studies at the core of the dissertation's focus, such as the paper by Ilmola and Kuusi about the workings of perceptual filters (Ilmola & Kuusi, 2006). The master list is included in appendix A (see appendix A).

When the keywords in the query were found effective, subsequent queries ventured systematically into various research areas. Among the research areas were business and economics, psychology, communication (particularly information theory), and behavioral sciences. After reading the lists of titles per research area, several disciplines began to stand out because they had significantly more papers on signal perception than others. Within these well-represented disciplines, only the disciplines inside the dissertation's focus on the weak signal process of top-managers remained. Papers on lower management levels, objective forecasts, specialized environments, or different tasks were disregarded. Disciplines that focused on top-manager perceptions of signals in the general environment for the purpose of strategy formation remained. Within the group of remaining disciplines,

four were selected. Foresight was the obvious choice as it focused on methodologies to improve weak signal perception (Bell, 2001; Rossel, 2012). Sense-making was included because it shared the dissertation's focus on signal perception, albeit in retrospect (Maitlis & Christianson, 2014). Entrepreneurship research was included because of its focus on perceptions of new opportunities (Ardichvili, Cardozo, & Ray, 2003). Strategic choice was added for its emphasis on the perception of strategic issues in uncertain environments (Child, 1997). Other disciplines were rejected because their foci overlapped less with ours. For instance, upper-echelon theory was discarded because it focused on personality traits rather than perceptions.

The results from the queries into the disciplines of foresight, sense-making, entrepreneurship research, and strategic choice were combined into a single list of papers. The quality of the list was checked with the master list of must-have papers. All must-haves were there, so it was assumed that a sufficient number of relevant papers were collected to start the review.

In total, 152 papers were selected and analyzed; 17 were literature reviews, 54 theoretical papers, and the remaining 81 papers were empirical studies.

2.2. Findings

The analysis began with an assessment of the overlap between the four disciplines. Shared features were used to develop a general overview of the weak signal process. Their outline is presented in section 2.2.1. The second step explored the overlap in more detail.

Foresight, sense-making, entrepreneurship research, and strategic choice each had a substantial research line on the weak signal process. The research lines worked with similar process inputs and assumptions about the process. Inputs were invariably confusing, yet likely to have a significant impact on a company's domain. The lines shared the conviction that cognition determined and limited the inclusion of signals into the weak signal process. Moreover, they also emphasized the extensive interpretive stage of the process (see Table 1). The research lines also had subtle differences.

In the next paragraphs, the disciplines are further introduced.

Foresight

Foresight described weak signals as ambiguous indications of forthcoming impactful disruption (Ansoff, 1979), and 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 were alien to the belief system of the observers (Poshtekooh, 2014; Goosen, 2014; Holopainen & Toivonen, 2012; Ilmola & Kuusi, 2006). The discipline contributed significantly to the development of formal methods to reduce the limiting effects of perceptual filters (Carbonell, Sánchez-Esguevillas, & Carro, 2017; Dhami, Belton, & Careless, 2016; Fritzsche, 2017; Li, 2017; Smith, Collins, & Mavris, 2017).

Table 1: *Shared features between reviewed research disciplines*

	Research Disciplines Comparison			
	Foresight:	**Sense-making:**	**Strategic Choice:**	**Entrepreneurship:**
Input	Changes in the environment with significant future impact (prospective)	Unanticipated challenges (retrospective)	Changes in the environment with significant future impact (prospective)	Non-salient opportunities (prospective)
Cognitive Limitations	Individual perceptual filters	Individual belief systems	Individual belief systems	Prior knowledge
Interpretation Stage	Multiple possible meanings of a signal or lack of meaning	Multiple possible meanings of a signal or lack of meaning	Multiple possible types of importance such as urgency or threat	Multiple possible fits with company resources
Reference:	Ansoff (1979)	Weick (1995)	Dutton (1993)	Shane (2000)

Sense-Making

Sense-making was the process that described the perception of a type of threat called wicked problems (Daft & Weick, 1984; Maitlis & Christianson, 2014; Weick, 1979). A wicked problem was a unique, ill-defined and ambiguous challenge to a company. The main difference between foresight and sense-making was the direction of reasoning: foresight anticipated change and sense-making looked back on change.

Foresight and sense-making scholars shared the assumption that individual belief systems determined what signals got detected and interpreted. Belief systems led to varying responses to the same environmental change (Brozovic, 2016; Palich & Bagby, 1995a). Consequently, anticipating change was mainly relying on individual perceptions (Blanco & Lesca, 1997; Lesca, Caron-Fasan, & Falcy, 2012; Lyles & Thomas, 1988; Wang & Chan, 1995), and cognitive limitations were seen as a major cause of failure (Garg, Walters, & Priem, 2003; Kiesler & Sproull, 1982; Yasai-Ardekani & Nystrom, 1996).

Foresight tried to remedy cognitive limitations with formal methodologies that widened perceptual filters and belief systems. Sense-making did so by exploring the development of anticipatory skills through exposure to unanticipated threats (Kiss & Barr, 2015; Lyles & Thomas, 1988). The anticipatory skills were described as expertise in the weak signal process, or, rather, task expertise, which contributed to this dissertation's emphasis on the role of expertise.

Strategic Choice

Strategic Choice was the process of organizational learning with which a company adapts to changes in its environment (Child, 1972). Foresight and strategic choice shared explicit references to the original weak signal descriptions when stimuli were defined (Ansoff, 1979; Dutton & Jackson, 1987), but foresight focused on the methodologies and strategic choice on, well, the choice.

Strategic choice pointed out a shortcoming of sense-making with regards to weak signal analysis. Sense-making focused on solely on threats, while strategic choice showed that threats were interpreted differently, led to a different sense-making process, and resided in a different mental schema than opportunities (Anderson & Nichols, 2007; Jackson & Dutton, 1988; Jennings & Lumpkin, 1992). Thus, next to foresight's weak signals and sense-making's problems, the literature review should include research on opportunities to raise the generalizability of the analysis results. The focus of entrepreneurship research on opportunity discovery was a welcome addition to balance the review.

Entrepreneurship Research

Entrepreneurial opportunity discovery was the process that described how entrepreneurs detected opportunities in the noise of their environment (Venkatraman, 1989). Foresight and entrepreneurship research shared the emphasis on the role of prior knowledge as a determinant of the quality of the process. Foresight focused on the possible impact of external developments on a company, while entrepreneurship focused probable fits between external developments and internal resources.

The four disciplines shared and complementary findings form a general overview of the weak signal process. The following subsections group the findings in three themes. First, the term weak signal is discussed, then the signal process, and lastly, the role of expertise in the process.

2.2.1. Signal

The term “weak signal” first appeared in scientific literature in 1975. It was used to describe relevant but ambiguous or incomplete information on changes in the environment with a probable future impact on the company’s strategy. The description left the measure of weakness implicit, but contextual references were made to its decrease over time. Continuously monitoring developments would lead to more knowledge and thus decrease weakness (Ansoff, 1975). Since that first appearance, many other weak signal descriptions surfaced in literature, which befuddled how weakness should be understood.

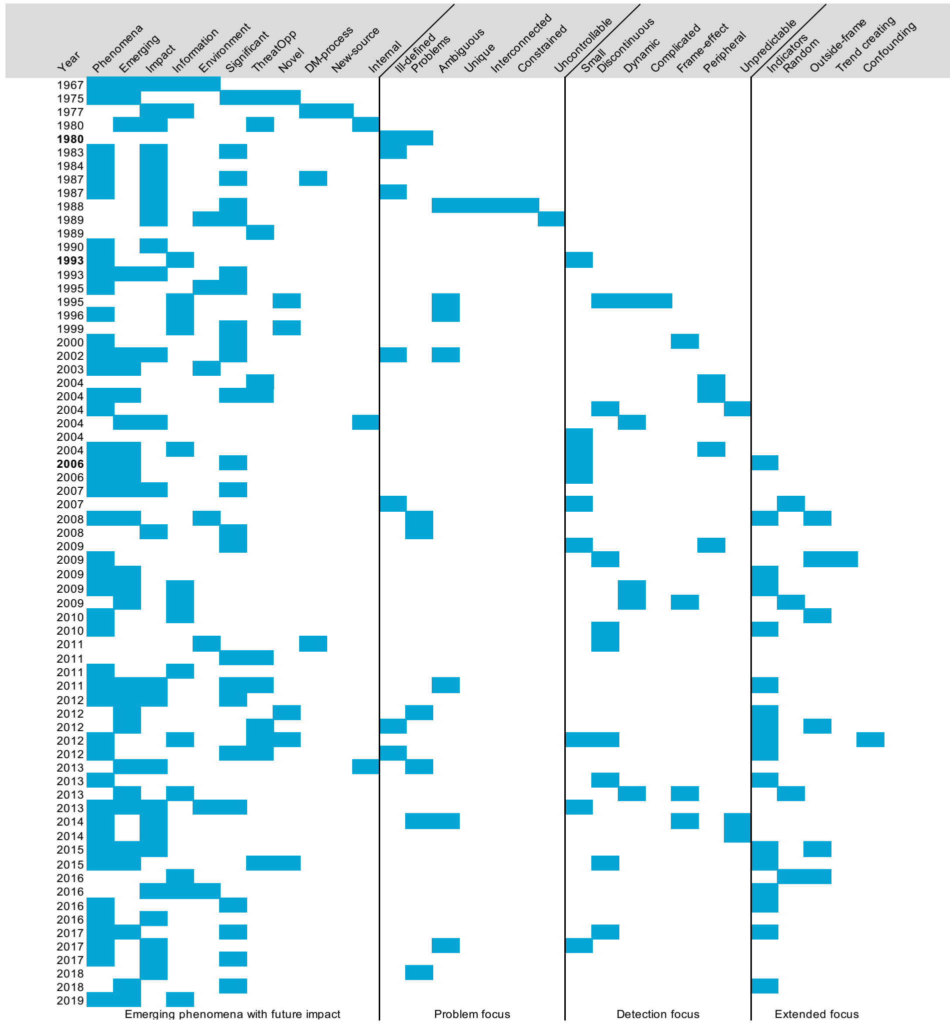
The papers included in the literature review were read to collect descriptions of weak signals. From the 152 papers, 68 explicitly described its signals. Each of the four research disciplines were represented. Most papers belonged to foresight (23 papers), strategic choice (20 papers) and sense-making (20 papers). Entrepreneurship research was underrepresented with five papers. In entrepreneurship research, papers foremost referred to weakness without explicitly describing its meaning.

The descriptions were tabulated in chronological order to extract and analyze the keywords from the descriptions to find the meanings of weakness. Extraction of keywords began with the first description. Its keywords were used to create column headers. When subsequent descriptions led to new keywords, new headers were created. Synonymous keywords were added to the header belonging to the first synonym. For instance, the column labeled with the keyword “important” was supplemented with synonyms such as “significant,” “high impact,” and “critical.” In all, 30 keyword columns were created. The occurrences of keywords in descriptions were noted in the table’s cells (see appendix B for the data table).

The table gave quick insights into the meaning of weakness. The table’s frequency pattern indicated that the focus of weak signals changed slightly through the years. Before 1980, weakness mostly referred to emerging phenomena with future impact. During the 1980s, additional keywords focused on the problems of weak signals like its ill-defined sources, problem focus, or uncontrollable impact. During the 1990s, new keywords focused on why signals were so difficult to detect. They were small, dynamic, in the periphery, and so on. From the 2000s, keywords focused on the capture of weak signals in their earliest stage. For instance, weak signals started to refer to indicators of a phenomenon instead of the phenomena themselves or signals still outside the frame (see Table 2).

The changing focus in weak signal research raised the likelihood that weak signal descriptions referred to several distinct meanings.

Table 2: *Keywords ordered per year of first occurrence (blue cells refer to keyword presence)*



In addition, the tabulated frequency counts pointed out that the weak signal concept was quite fuzzy. Frequencies ranged from 43 to 1. The most frequent occurring keyword referred to the phenomenon a weak signal referred to, such as an event, trend, or change in the environment. It was present in 63% of the descriptions (f =

43). The keyword with the second-highest frequency (f = 28) was present in 41% of the descriptions and referred to the emerging character of weak signals. From the 30 keywords, eight keywords had a frequency score of 1 (see Figure 5).

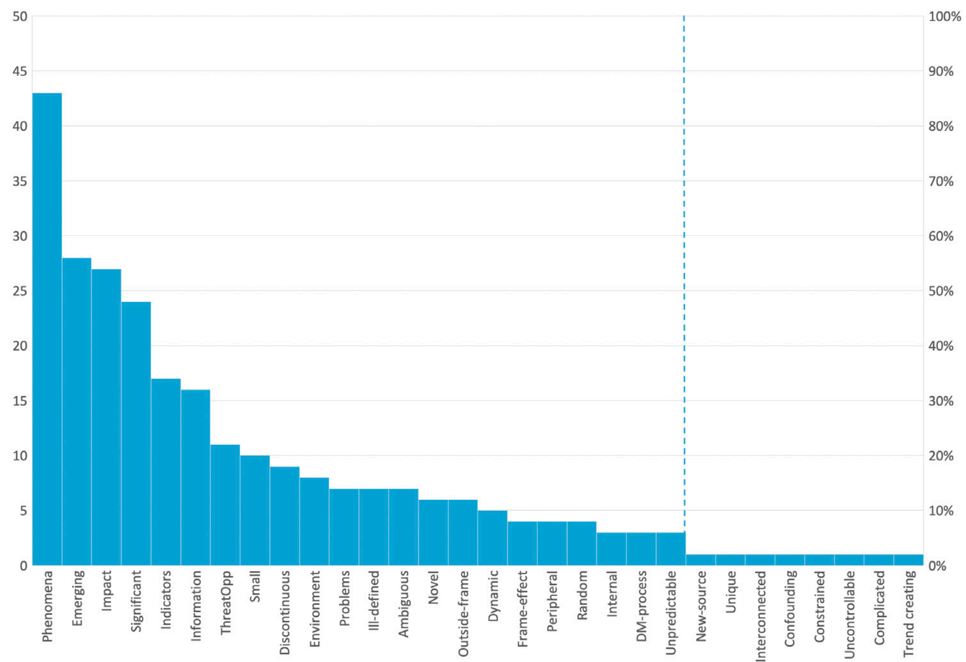


Figure 5: *Frequencies of keywords in weak signal descriptions; eight keywords with frequency (f = 1) were not included in hierarchical clustering*

The changing meaning of weak signals and its fuzziness led to doubts about validation between studies; a problem that needed solving before interpreting the literature further. Hence, a cluster analysis was done to check if the fuzziness was an effect of the combination of four research disciplines or the time of publication. If there were an effect of combined disciplines, the inertia within and between clusters would be caused by the disciplines. A two-step hierarchical cluster analysis using Ward's criterion was performed in R (see appendix C for the R script) (Team, 2019). In the analysis, signal descriptions were treated as observations of categorical data (N=68), and keywords as variables. The eight keywords with the lowest frequency (f = 1) were not included in the clustering. The research discipline labels were included as a supplementary qualitative variable. The number of clusters was set to four to allow

the emergence of a discipline per cluster. Two results indicated that the clusters did not represent disciplines. Firstly, the analysis returned four clusters, but three clusters contained mixed disciplines. The smallest cluster was supposed to represent the five descriptions from entrepreneurship research. Instead, it contained three descriptions from strategic choice. Secondly, as many as nine variables were most responsible for the partitioning. These variables described three aspects of a signal: its origin, the type of information that a signal held, and its effects (see Table 3).

Table 3: *Lowest probabilities describing the partitioning of the cluster analysis*

Partitioning				
Variable	**Description**	**Type**	**p Value**	**df**
Internal	Signal originates from within company	Origin	< .01	3
Peripheral	Signal originates from perceptual periphery	Origin	< .01	3
Random	Signal consists of random information	Info Type	< .01	3
Threat/Opportunity	Signal consists of threats and/or opportunities	Info Type	< .01	3
Novel	Signal consists of novel information	Info Type	< .01	3
Phenomena	Signal consists of environmental phenomena	Info Type	< .01	3
Dynamic	Signal consists of multiple perceptions over time	Info Type	< .01	3
Impact	Signal will have significant impact on company	Effect	< .01	3
Frame-effect	Signal disrupts frame once interpreted	Effect	< .01	3

The three aspects ranged widely. The variables describing a signal's origin included the company internally as well as the perceptual periphery. Variables describing the type of information included phenomena as well as perceptions. Variables describing effects included effect on the perceiver's reference frame as well as the perceiver's company.

Hence, neither discipline or period-specific foci were responsible for weak signal fuzziness. Instead, it resulted from the variation in meaning. This outcome made it plausible that the weakness concept could benefit from clarification.

2.2.2. Process

The weak signal process was described as the detection and interpretation of signals from the environment (Kiesler & Sproull, 1982). Authors agreed that the process model was the same for weak and strong signals, but that their flow through the process was different. Strong signals moved seamlessly from detection into action, while weak signals could be rejected at every stage and led to a more intense interpretation stage (Anderson & Nichols, 2007; Ansoff, 1975; Blanco & Lesca, 1997; Dutton et al., 1983; Lyles & Mitroff, 1980; Mintzberg, Raisinghani, & Theoret, 1976).

Real-world examples of both patterns were observed in case analyses (Mintzberg et al., 1976; Mintzberg & Waters, 1982).

The process began when top-managers became aware of information from the environment. At that point, information passed a first perceptual filter into the detection stage, thereby turning information into a signal. For instance, the moment that Apple top-manager Steve Jobs presented the first iPhone at MacWorld 2007, the broadcasted launch of the iPhone was just noise. When Microsoft top-manager Steve Ballmer saw a video of the broadcast and became aware of the iPhone's pricing, the video turned into a signal (Skrinak, 2012). The first perceptual filter was called forecasting or surveillance filter after the search criteria or methodology that sifted relevant signals from the noise (Ansoff, 1979).

Perceptual filters varied in width and depth (Ilmola & Kuusi, 2006). Width referred to the number of signal categories and depth to the number of signals per category (see Figure 6). A wide and flat filter included many signal categories and few signals per category (see Figure 6, filter A). A narrow and deep filter included few signal categories and many signals per category (see Figure 6, filter B).

Signals could pass the forecasting filter through focused search or by exposure. Focused search referred to the active search for more information on an already identified issue (Camillus & Datta, 1991; Daft & Weick, 1984; Rindova, 1999). In focused search, the forecasting filter was narrow and deep (see Figure 6, Filter B).

Exposure could have an active and a passive mode. In the active mode, a company would do a broad sweep to identify the issues that a company may want to investigate further (Anderson & Nichols, 2007; King, 1984; Schwenk, 1984). In the passive mode, a company merely became aware of issues that needed further investigation (Blanco & Lesca, 1997; Milliken, 1990). In both modes, the perceptual filter was wide and flat (see Figure 6, filter A).

Authors argued that the forecasting filter should be wide and flat so that more signals from more signal categories were allowed passage. Therefore, the active mode of exposure that consisted of a broad sweep of the environment to identify issues was best fitted for the weak signal process (Ilmola & Kuusi, 2006).

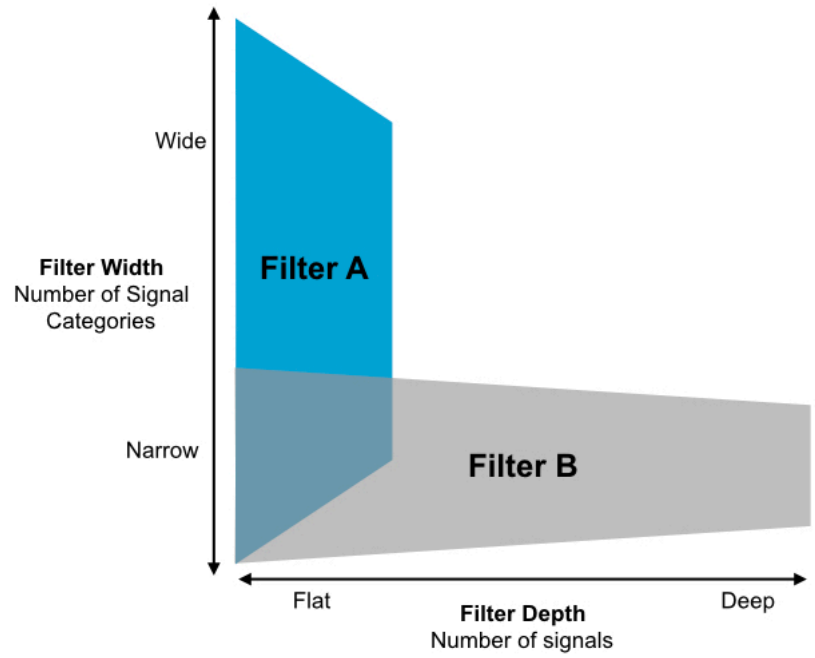


Figure 6: *Shape of two perceptual filters: wide and flat (filter A), and narrow and deep (filter B) (Ilmola & Kuusi, 2006)*

Detected signals had to pass a second perceptual filter, called mentality filter, to the interpretation stage. The mentality filter's width and depth were determined by the frame of reference of the perceiver (Bogner & Barr, 2000; Daft & Weick, 1984; Hutzschenreuter & Kleindienst, 2006). The frame held the acquired knowledge, experiences, and beliefs of the perceiver. The more complex knowledge and experiences, the more information passed the mentality filter (Nadkarni & Narayanan, 2007; Westhead et al., 2005). Beliefs of irrelevancy and inaccuracy could lead to the rejection of information (Ansoff, 1979). For instance, when Ballmer interpreted the iPhone launch video, he believed that only business people could afford the iPhone, but their extensive emailing would require a keyboard. The combination of a high price and lack of keyboard were to prevent the adoption of the iPhone as a business phone. At that time, Ballmer had no knowledge of the business model behind the iPhone. It was a new business model, where mobile operators allowed subscribers to pay off the phone in the monthly subscription fee (Chang & Bass, 2016). Ballmer's mentality filter with beliefs on business models and product adequacy led to the rejection of the iPhone as a serious competitor.

The interpretation stage described the situation in which signals were given meaning (Daft & Weick, 1984; Dutton & Jackson, 1987). Some studies separated the stage in assessment and analysis. When separated, the first step entailed the prioritization of information in terms of relevance, urgency, or actionability. The second step involved the analysis of the meaning of the information for the company (King, 1984; Schwenk, 1984). Some studies added a feedback loop to allow multiple process iterations in which meaning could develop based on new signals (Dutton et al., 1983; Dutton & Jackson, 1987). The Schiff example illustrates assessment, analysis, and process iteration. The first time that Schiff confronted experts with his message, they only assessed it briefly before stating its irrelevance. At one of the following iterations, the experts had accumulated information in favor for their assessment and started to discuss their own analysis. Schiff's repetition of his analysis only resulted in a Dr. Doom nickname, but not in an open-minded debate of perspectives. Then, when the crisis was there, the experts had to concur with Schiff's assessment of relevance, but differed in the analysis of the duration and severity of the crisis (Schiff, 2009).

The literature extended the process with a preliminary stage before detection, and a filter and stage following interpretation (see Figure 7). Although outside the focus of this dissertation, a few remarks hereon before returning to detection and interpretation.

In some research disciplines, the process was extended with a preliminary stage. Sense-making added problem recognition (Andersen, 2000; Fredrickson & Mitchell, 1984; Nutt, 1984; Schwenk, 1988). Others added a stage called preparation, in which the company devised a scanning method (Murphy, 1989; Olsen, Murthy, & Teare, 1994).

The third filter was called the power filter. It referred to the involuntary loss of information caused by communication chains or the intentional loss in case of conflicts of interest (Ansoff, 1979). Signals had to pass this filter into the action stage, the last stage of the process. The action stage was shaped by the focus of the field that described it. For instance, in strategic choice, action could refer to integration of a signal into the strategy process (Martini, Neirotti, & Appio, 2017; Murphy, 1989; Wang & Chan, 1995). In entrepreneurship research, the action stage usually referred to opportunity exploitation (Sadler-Smith, 2004).

The process stages and filters are depicted in Figure 7.

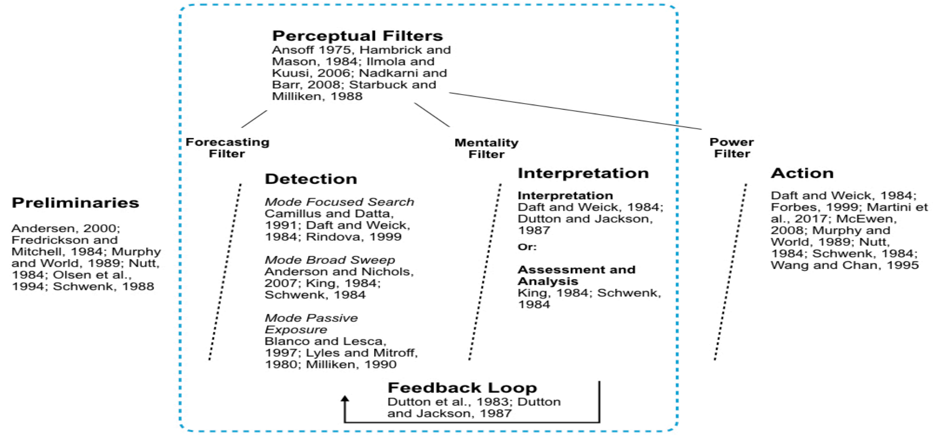


Figure 7: *Findings on the weak signal process (the blue dotted line represents this dissertation's focus)*

This dissertation focused on the detection and interpretation stages and the forecasting and mentality filter. From this point on, the dissertation refers to this part of the weak signal process unless otherwise stated (see Figure 7, blue dotted line).

2.2.3. Expertise

Authors saw the weak signal process as the cognitive process to understand changes in the environment (Ericson, 2001). Central to cognition was the concept of the perceiver's reference frame. The frame consisted of a perceiver's mental representation of the environment that he developed from education and experience. Several characteristics of the frame are central to the understanding of the weak signal process.

Frame Characteristics

The reference frame consisted of knowledge and beliefs about the environment as well as decision rules (Maitland & Sammartino, 2015). Signals were defined relative to the frame (Brown, Tumeo, Larey, & Paulus, 1998), and could change the structure of the frame (Bogner & Barr, 2000). Structure referred to way frame contents were organized and focused. Frame structure influenced the width and depth of the forecasting and mentality filters and thus the effectiveness of the process (Dutton & Jackson, 1987; Hambrick & Mason, 1984; Nadkarni & Narayanan, 2007).

When reference frames were problem-focused, perceptual filters were narrow. A narrow forecasting filter led to the rejection of signals that were perceived as unrelated to the problem. In contrast, during exposure these signals could slip through the forecasting filter, despite the problem focus (Hambrick & Mason, 1984; Ilmola & Kuusi, 2006; Nadkarni & Barr, 2008; Starbuck & Milliken, 1988). Thus, focused search narrowed the perceptual filter of a problem focus further.

Changes in frame structure were also linked to the duration of process stages. More time spent in the detection stage (more searches and sweeps) caused more signals to be interpreted as threats. This so-called threat bias in the interpretation stage took place at the expense of opportunity detection (Anderson & Nichols, 2007). Threat interpretation took longer than opportunity interpretation (Dutton & Jackson, 1987).

Expert Frames

Research into expert frames usually compared and contrasted the frames of novices and experts. Novice frames had a simple structure. Simple frames were associated with narrow filters during focused search, so fewer signals were included in detection and interpretation (Kiesler & Sproull, 1982). During exposure, novices detected fewer signals, and these were foremost interpreted as opportunities (Hodgkinson, Bown, Maule, Glaister, & Pearman, 1999).

Expert frames were much more complex. These frames consisted of systems of signal patterns with numerous, complex inferences. Experience kept certain signals and decision rules salient and ignored others (Bogner & Barr, 2000; Daft & Weick, 1984; Kiesler & Sproull, 1982). Clusters of salient signals and rules acted as key constructs. A focus on key constructs allowed experts to be effective decision-makers despite the complexity of their frames (Clarke & Mackaness, 2001; Kiesler & Sproull, 1982; Kiss & Barr, 2015; Rindova, 1999). Expert frames were associated with wider perceptual filters. More signals from more signal categories were detected during search. In the interpretation stage, frame complexity helped to consider alternative interpretations simultaneously (Dutton et al., 1983).

Thus, it was argued that wide filters increased the probability of more accurate and complete signal perception (Ilmola & Kuusi, 2006), which in turn led to more competent action and strategic flexibility (Bartunek, Gordon, & Weathersby, 1983) (see Figure 8).

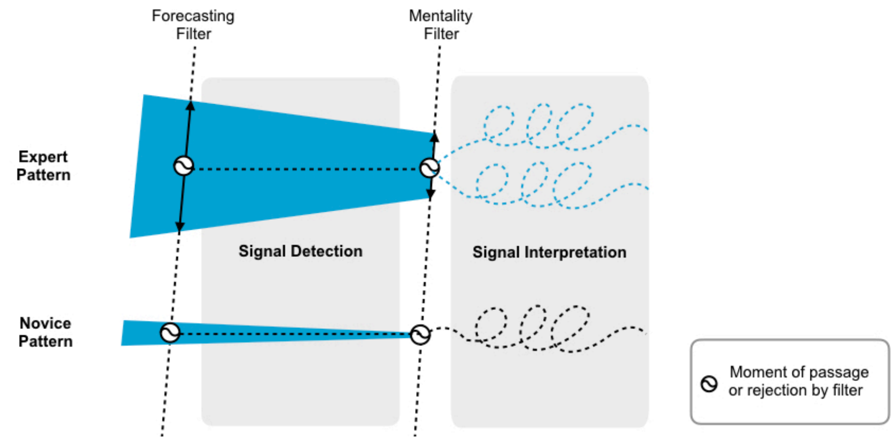


Figure 8: *Wider filters of expert frames help to detect more signals and interpret alternative meanings simultaneously (differences from the usual process in blue)*

Interestingly, a difference was found between the process of experts and top-managers. Experts processed more signals because their filters were wider, and their frames could process more signals simultaneously than novices (Rindova, 1999). Top-managers were also able to process more signals, but only because they processed signals faster. Faster process speeds helped top-managers to iterate alternative meanings within a given period (see Figure 9).

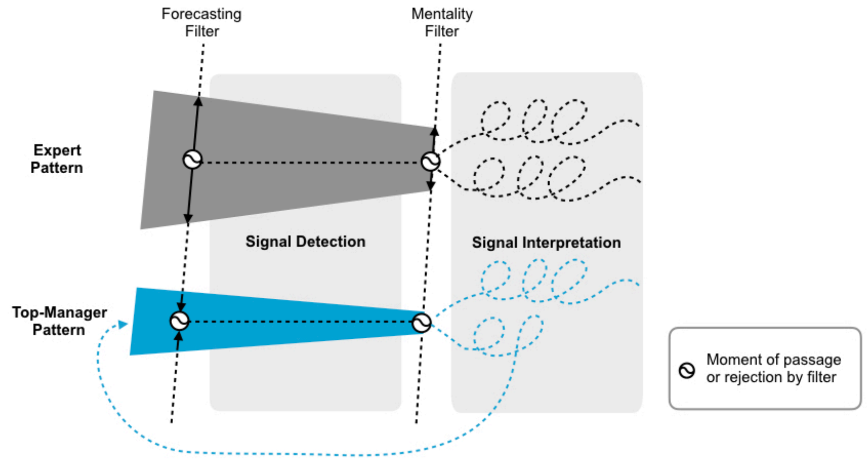


Figure 9: *Experts process multiple signals simultaneously and fast top-managers iteratively (the difference between the two processes in blue)*

Fast top-managers used real-time information instead of forecasts. Developing and reiterating a forecast would take relatively more time than the immediate processing of real-time information. Real-time information was readily available and thus permitted multiple iterations in the interpretive stage. The iterations spurred the developments of more possible responses (Eisenhardt, 1989).

2.3. Consequences

The variety and frequencies of keywords in weak signal descriptions pointed toward fuzziness of the weak signal concept (see section 2.2.1. Figure 7). This had two consequences: one, a clarification of weak signals was required to achieve a sound research design, and, two, a validation of the process was necessary for the building of new theory. Clarification is given in section 2.3.1. and the lack of validation is explained in section 2.3.2. Validation of the weak signal process is raised by the field study presented in chapter 3.

2.3.1. Definition

Reviews on the state of weak signal research already noted the variety in descriptions and made an appeal for defining weak signals more clearly (Carbonell, Sánchez-Esguevillas, & Carro, 2015; Hiltunen, 2008; Saritas & Smith, 2011). It seemed that the lack of clarity could be solved with one new definition if it overlapped the reviewed descriptions. Then, the new definition could delineate commonalities and differences between studies based on their descriptions.

Three options were available for the development of a new weak signal definition. Firstly, a new definition could be logically developed, but that would only increase the fuzziness. Secondly, a promising description could be chosen from the reviewed ones. Copying a description would not contribute to greater validity in the body of research on weak signals. Thirdly, a new definition could be developed through cluster analysis, which integrated most meanings in the reviewed descriptions. Using the commonalities from cluster analysis as the definition's basis could provide keywords as linking pins between the reviewed descriptions

The data frame in section 2.2.1 was used for the cluster analysis. Inertia gain was used as the criterion to determine the number of clusters. A dendrogram was used to interpret the quality of the partition. Six clusters were chosen.

Visual inspection of the dendrogram showed that the clusters were not equal in

size. This was expected because of the fuzziness of the descriptions and the presumed bias for stronger signals in the research (see section 2.2.1.). Despite their size, the clusters represented the descriptions in a meaningful way because they were constructed from single categories of the keyword variables. With their unique combination of variable categories, clusters summarized the descriptions that explained most of the variance in the descriptions. The new definition was developed based on these summaries so that it could become apparent if and how reviewed or future studies connected to the dissertation's work. The summarization is presented first, and then the development of the definition is described.

Summarizing the Clusters

Table 4 presents the sets of significant keywords ($p < .05$) and their categories per cluster (see Table 4).

Table 4: *Variable categories describing the clusters*

Cluster Analysis Weak Signal Descriptions (N = 68)					
Cluster	**Variable**	**Category**	**Proportion in cluster**	**p Value**	**Characterization**
1	Phenomena in environment	y	79.55	< .01	Less weak signals from the environment
	New to perceiver	n	69.36	< .01	
	Threat or opportunity	n	70.18	.01	
	Seemingly random signals	n	67.19	.02	
	From periphery (outside focus)	n	67.19	.02	
2	Leading up to decision-making	y	100.00	< .01	Assessed signals, to be analyzed
3	Unpredictable outcome	y	100.00	< .01	Analyzed signals
4	New to perceiver	y	100.00	< .01	Detected signals outside the focus
	Threat or opportunity	y	63.64	< .01	
	From periphery (outside focus)	y	100.00	< .01	
5	From within company	y	100.00	< .01	Internal signals
6	Seemingly random signals	y	100.00	< .01	Weak signals created during interpretation
	Disrupts frame once interpreted	y	50.00	< .01	
	Set of signals (pattern)	y	40.00	< .01	

The first cluster summarized descriptions that referred to weak signals as phenomena in the environment. This cluster did not contain descriptions with keywords indicating novelty, threat and opportunity perception, seeming randomness of information, from the periphery (outside the focus). This was interpreted as an indication that the studies at the root of cluster 1 had findings particular for less weak signals from the environment.

The second cluster represented weak signals that should lead up to the decision-making process. This cluster referred implicitly to signals that were already assessed as relevant, but not yet analyzed (see Figure 7, interpretation stage).

The third cluster represented weak signals that had unpredictable outcomes. This cluster referred implicitly to signals that were assessed and classified as relevant, but their development or impact was impossible to analyze and could only be extrapolated into the future (see Figure 7, interpretation stage).

The fourth cluster represented weak signals in the shape of threats and opportunities that were new to the perceiver because they had remained outside the perceiver's focus. These were the weaker signals that had just passed the forecasting filter through exposure, not focused search (see Figure 7, detection stage).

The fifth cluster represented weak signals that originated from a perceived weakness of the company itself, not from the environment.

The sixth cluster represented weak signals that consisted of seemingly random bits of information which disrupted the reference frame of the perceiver once interpreted as a pattern. These were the weaker signals that were created during interpretation (see Figure 7, interpretation stage).

The clusters separated the descriptions, and thus the studies to which descriptions belonged. Descriptions were separated in signals that varied in source (external or internal environment), strength (less weak or weak), and process stage (detection or interpretation). The separation of clusters could be visualized with the process map (see Figure 10).

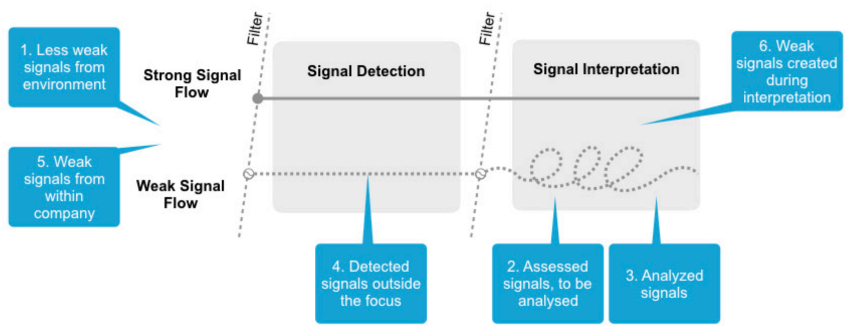


Figure 10: *Clusters mapped onto the process*

Developing the Definition

The characterizations pointed out that signals originated from the environment (cluster 1) or from within the company (cluster 5). The dissertation is focused on perceptions of the environment, so cluster 5 was ignored in the development of the definition. This immediately uncovered one of its limitations (this and other limitations are discussed in chapter 7). Only external phenomena were included in the definition.

Weakness could arise from different process stages. During detection, new threats and opportunities were weak to the perceiver (cluster 4), and during interpretation, new patterns of previously random signals were weak (cluster 6). This implied that signals could also become weaker after passing the second perceptual filter, not just stronger through interpretation. The definition should name both stages so that possible changes in weakness levels or the occurrence of weakness during interpretation could surface in research. Hence, "either detected in the environment or created during interpretation" was included in the definition.

Weakness referred to several aspects of the phenomena: novelty, strategic relevance, and unpredictability. Signals were novel to the perceiver during detection (cluster 4) or interpretation 6). Signals were strategically relevant because they had yet to be analyzed (cluster 2), were nearly missed threats or opportunities that entered the frame (cluster 4), or disrupted established notions about the environment and/or the company (cluster 6). The unpredictability of impact caused weakness regardless of the weakness of the phenomenon (cluster 3). Strangely enough, signals that were simultaneously novel, strategically relevant, and unpredictable, could still be strong. For instance, the use of a well-explained, proven technology such as the Internet, relevant to most industries in the late 1990s, could still be new to the perceiving top-manager of, say a video rental company like Blockbuster, while nobody could predict the Internet's impact on Blockbuster because business models like Netflix (founded in 1997) were not on the radar yet (Harraf, Soltwisch, & Talbott, 2016). So, something was missing: the aspect that made novel, strategic signals with unpredictable impact weak.

Novel signals were signals that resided in the periphery, which meant: outside the reference frame of the perceiver. Such signals would become weak if they were difficult to place into the prior frame or were even disruptive to the frame (cluster 6). Thus, weak signals were very different from information already in the frame, or, in other words, distant to the frame. Similarly, in cluster analysis, the difference between clusters is measured in distance: the larger the distance, the more different the clusters are. This implied that the distance of a signal to the frame should be large to trigger a perception of weakness. Hence, “distant to the perceiver’s reference frame” was included in the definition.

Strategic relevance remained essential to keep signals in the process because weak signals that were not perceived as relevant would be discarded. Thus, “strategic” was included.

Unpredictability, like the randomness in cluster 6, referred to a factor that may lead to an increase in weakness during interpretation. While cluster 6 implied that weakness could surge when seemingly random signals were combined into a pattern, cluster 3 implied that seemingly strong signals could lead to a similar surge when it was analyzed as unpredictable. It was this effect of unpredictability that should be included in the definition instead of unpredictability as an aspect of the signal, for three reasons. Firstly, unpredictability in itself did not refer to weakness, as was discussed above. Secondly, there were more signal aspects besides unpredictability that could eventually lead to a surge in weakness perception, such as complexity or dynamism. The new definition should not be limited to just one of these. Thirdly, unpredictability, like complexity and dynamism, was quite manageable for agile companies. Therefore, the essence of unpredictability lay in its effect on the level of weakness, which was already captured. Thus, unpredictability was not included in the definition.

Hence, weak signals were defined as:

> **The perception of strategic phenomena detected in the environment or created during interpretation that are distant to the perceiver’s frame of reference**

The definition reflected the collective wisdom of the 68 studies on whose descriptions it was based. Together, these studies clarified the meaning of weakness in terms of distance to the frame. Combining the significant keywords enabled the comparison of findings. Studies that focused on environmental phenomena (cluster 1) contributed to the initialization of the process. Other studies contributed to knowledge about the detection and interpretation stages (cluster 2-4) of workings of the mentality filter (cluster 6).

2.3.2. Validity

Weak signal fuzziness limited the validity of the process findings. Only when the level of weakness is known, the reported process and patterns can be attributed to stronger or weaker signal patterns. Cluster analysis resulted in two clusters on weak signals that were outside the perceivers’ reference frames (clusters 5 and 6; 5 studies or 7%). and four clusters of detected signals in various stages, thus, stronger signals (clusters 1 to 4; 63 studies or 93%).

Signals were foremost elicited from participant recall, which may have biased the research in favor of stronger signals. During recall, people generally use rules of thumb instead of deep introspective thought (Nisbett & Wilson, 1977). Rules of thumb include salient cause and effects relationships and thus reflect a lower weakness level. Some studies redistributed recalled signals so that participants interpreted signals from their colleagues. However, no mention was made if the new perceiver perceived the signal as weak. Because these studies rotated signals among the managers of a single company, it is plausible that signals belonged to shared knowledge and logics and were less weak despite the rotation. This underlined the lack of validity of the findings. It did not seem sensible to develop new theory without a validation of the basics first. Thus, the dissertation’s first field study was designed to at least validate the process and patterns (see Chapter 3 for the field study’s design and findings).

2.3.3. Next step

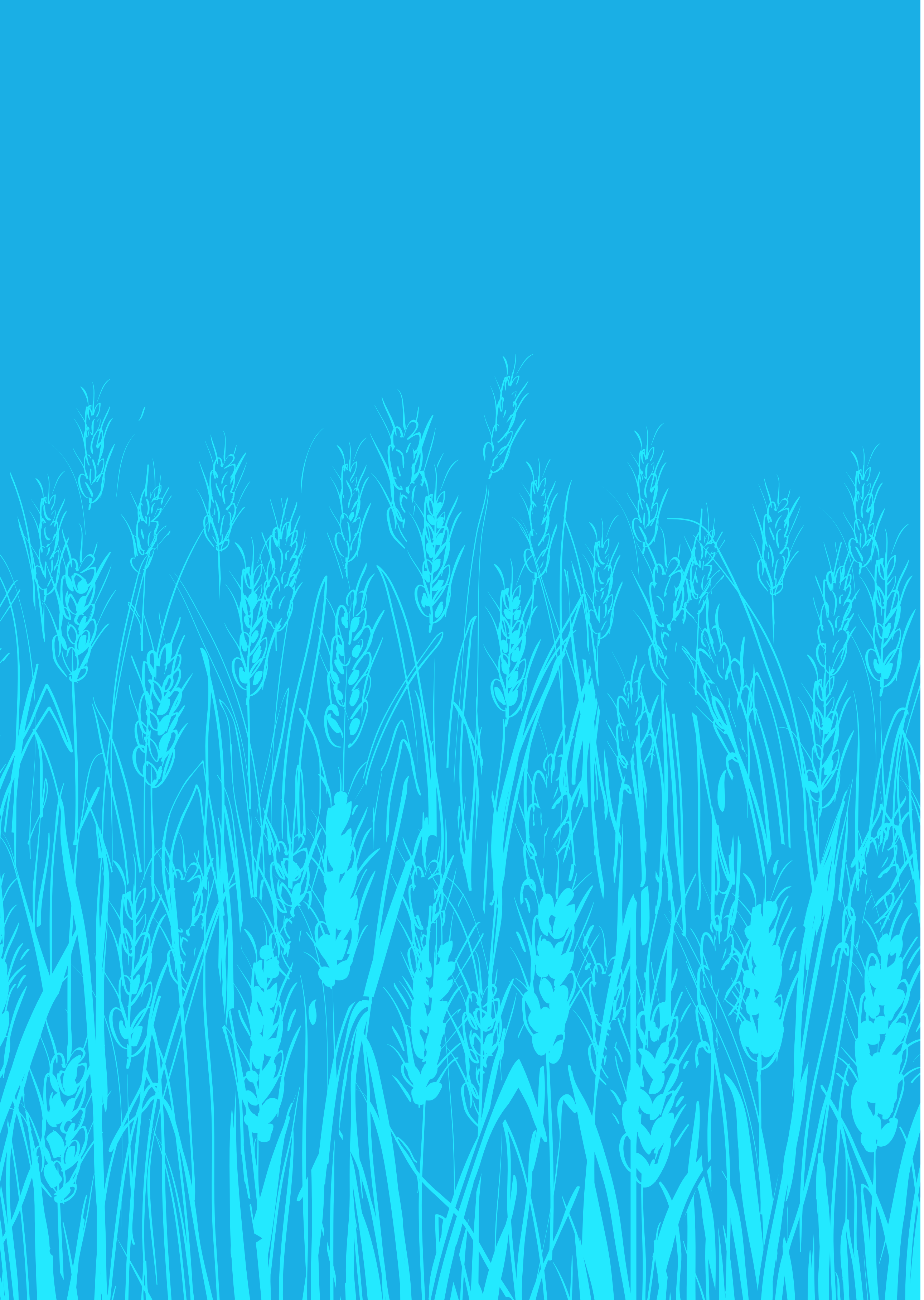
Chapter 2 showed that weak signal research was dispersed into multiple separate research disciplines. Papers from four research disciplines were included in the review: foresight, sense-making, strategic choice, and entrepreneurship research. Each discipline developed a line of research on information detection and interpretation and used different terms and operationalizations. Foresight called the process weak signal analysis, sense-making called it sense-making of wicked problems, strategic choice called it strategic issue analysis, and entrepreneurship research opportunity discovery. The disciplines shared information characteristics, cognitive limitations, and the presence of a distinct interpretive stage in the perceptual process. The combination of disciplines had merit because respective studies and theoretical papers led to the specification of process and patterns, as well as the role of cognition.

The process consisted of alternating stages and filters. Strong signals flowed seamlessly through the filters, while weak signals could be rejected at each filter.

Strong signals hardly required interpretation, while weak signals required an extensive, iterative interpretation stage.

The studies from each of the disciplines shared a characteristic in empirical designs: the measurement of weak signals was done in ways that did not check the level of perceived weakness. Findings were attributed to the weak signal processes, but the cluster analysis of weak signal descriptions showed that multiple levels of perceived weakness might exist. Therefore, the distinctive flow of strong and weak signals may deviate from literature, even though the process and patterns were rather uniformly described.

This chapter compared and contrasted notions from the disciplines, created an overarching definition, and called for new ways to measure perceived weakness. The dissertation's first field study was designed to validate process and patterns, as well as to explore the expert weak signal process. The second field study was designed to develop a measure of perceived weakness and to explore the role of different expertise types on the process. Chapter 3 presents the results of the first field study.



3

EXPERT FRAMES – FIELD STUDY I

Because I know that I can't know it all

Field Study I; Participant 1

The fuzziness of weak signal descriptions had shaken the foundations of weak signal research to the point that even the utter basics needed validation. So, before all else, the field study should do exactly that. Furthermore, the field study explored the expert weak signal process. This meant that, if perceived weakness was accounted for, the study's findings either supported or helped to redesign the two-stage filtering process (see section 2.2.2.). Findings would also contribute to insights on expert frames and their role in the process.

The next sections offer the research design (section 3.1.), the method for data collection (section 3.2.), the grounded approach to data analysis (section 3.3.), and the results (section 3.4.). The result section has three subsections: in section 3.4.1. the presence of perceived weakness is established. Section 3.4.2. is focused on validation and section 3.4.3. is focused on the expert frame. Section 3.5. presents the discussion and conclusions.

3.1. Research Design

The research design for the field study was based on two forerunners. The first forerunner had been credited as one of the first studies on the managerial detection of weak signals in the environment (Aguilar, 1967). In this seminal paper, top-managers were interviewed about the information they used for new strategy formation. The second forerunner was done around 25 years later and explicitly built onto the first (Auster & Choo, 1994). Thus, at two points in time, the same weak signal detection process had been described, but without establishing the presence of weakness. The forerunners also referred to the characteristic intense interpretation stage and the role of perceptual filters. These forerunners were selected because their quality is highly regarded. Also, if findings were congruent, the process would be validated by three studies over a time-span of half a century.

As in the forerunning studies, top-managers were asked to recall the information leading up to recent domain discussions in personal, open interviews. These top-managers could be considered experts in weak signal analysis by way of their successful track record in managing leading companies through at least a decade of turbulence.

One of the primary responsibilities of top-managers is to have strategic issues in the environment identified and addressed to keep the company healthy (Miles, Snow, Meyer, & Coleman, 1978). Top-managers partake personally in scanning (McGee & Sawyerr, 2003). They perceive a wider environment than lower-level managers because they are responsible for the company as a whole (Lawrence & Lorsch, 1967). This means that top-managers are likely to be familiar with weak signals.

Top-managers can be considered experts in the weak signal process when their companies have ensured long-term profitability (Buyl, Boone, & Matthyssens, 2011; Finkelstein & Hambrick, 1996; Rutherford & Holt, 2007). Thus, expertise was operationalized by setting three conditions for participation in the study. Firstly, the top-managers should be at the helm of companies that belonged to the top three in market share in their industry for ten years or longer. Secondly, they should be the person highest in the hierarchy responsible for overall strategy. Thirdly, they must have over ten years of experience at this level. In all, 13 top-managers were included in the sample (see Table 5).

All participating top-managers had the Dutch nationality and were based in the Netherlands, reducing unknown effects of region on interpretation of information in the environment by sample and interviewer (Khatri & Ng, 2000). The sample was also homogeneous in terms of gender (12 men, one woman), age (40-65 years), level of education (bachelors and masters), and seniority (top). The author was aware of age and expertise as influencers of perception (Carpenter & Westphal, 2001; McKenzie, Woolf, Van Winkelen, & Morgan, 2009; Rodenbach & Brettel, 2012), but restricting the sample to experts was a deliberate choice to include as many participants capable of weak signal identification. The sample composition required caution during interpretation due to these restrictions and limited findings to the population of Dutch top-managers of certain age and expertise.

However, in exploratory studies, heterogeneity is required to let variety in data emerge. Therefore, the sample was kept as heterogeneous as possible in terms of company characteristics like size, centralization, and industry. The dissertation's underlying assumption was that company characteristics and top-manager perceptions were correlated (Duncan, 1972; Huber, Sutcliffe, Miller, & Glick, 1993). Hence, heterogeneity in perceptions was large given the substantial variation in these characteristics within the sample.

Company size was selected because it was likely that large and small companies differ in the way that weak information is detected and interpreted (Weinzimmer & Nystrom, 1996). For example, top-managers from larger companies may have institutionalized the task, while top-managers from smaller companies may manage it in a less formalized way. Top-managers from smaller companies may not have delegated the task and can perform the task more implicit or ad-hoc. Thus, variation in size may let different expert processes and patterns emerge. Centralization, or the extent to which authority is concentrated at the top level of the organization, was selected following research on its positive relationship with the cognitive demands placed on the top-manager (Fredrickson, 1984; Milliken, 1990; Sutcliffe, 1994). It was likely that experts were able to overcome negative effects of higher cognitive demands by for instance, delegation. Thus, variation in centralization may also let different expert processes and patterns emerge. Industry was selected because it was likely that different industries have different environments (Lawrence & Lorsch, 1967), which may lead to different frames of the environment and thus to different expert processes and patterns.

Studies on very senior top-managers usually have to make do with proxies or quick phone surveys. Because the top-managers belonged to the professional network of the researcher, there was a personal connection between participant and researcher. Therefore, the researcher was permitted to collect the data from personal conversations at the office or home address of the top-managers. It also ensured that there was enough trust to share confidential information and mistakes. Thus, the personal connection provided us with robust, active conversation partners who would grant the researcher the benefit of their extensive expertise. It led to rich data on the process and reflections on expertise that helped develop theory. In this way, participants were directed by the interviewer and the interviewer by the participants. Together, participants and interviewer constructed a perceptual view of weak signal analysis (Charmaz & Belgrave, 2012; Charmaz & Mitchell, 1996).

Table 5: *Expert sample characteristics*

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

3.2. Data Collection

Both forerunners used open interviews to collect data. Interviews were initiated with a prompt to trigger the recall of specific experiences, called the Critical Incident Technique (Flanagan, 1954). In both studies, the incident referred to a complete, recent event of domain discussions and the environmental assessments leading up to it. The prompt from the second forerunner was copied verbatim:

> “Please try to recall a recent instance in which you received important information about a specific event or trend in the external environment 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 & Choo, 1994, p. 609).

When the prompted recall had run its course, probing questions invited the participants to clarify points in their recollections and to discuss the process in their company. Further probes helped participants to relay uncertainties and failures if they had not yet done so.

A single researcher had the role of interviewer to reduce the variety in data collection. Her primary role was to prompt and probe recollections and to take notes. Notes included the verbatim expressions and analogies of participants as much as possible.

Immediately after an interview, observations of signal types and process details from the recall were listed. This list was presented to the next participant at the end of the interview, to jog the participant’s memory for relevant, but less salient aspects (adapted from Glaser 1978; Glaser & Holton 2004; Scheibelhofer 2008). It also led to comparisons and contrasts, thus making data collection richer. Therefore, individual recollections were more than just an instance of hindsight bias and justification, but also contained new reflections and insights (Charmaz & McMullen, 2011; Charmaz & Mitchell, 1996). The steps of the interview are represented in the following flow chart (see Figure 11).

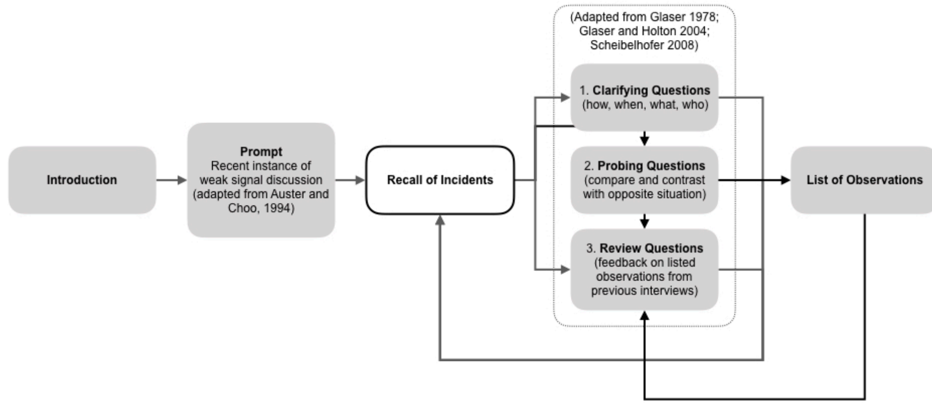


Figure 11: *Interview flow chart*

Interviews took place from October 2014 to February 2015.

Participants did not want to be taped, so notes were taken to record the interviews. The notes taken by the researcher were checked by the interviewee for accuracy and completeness. This raised the interpretive validity of the interviewer's perspective, as the joint production of notes by the interviewer and the participants was known to lead to sound results (Clausen, 2012).

3.3. Methodology

In contrast to the forerunners, interview notes were analyzed in a grounded way so that reference frames could emerge from the data. Grounded refers to the systematic methodology to inductively analyze qualitative data by continuously comparing data incidents to an initial question (Glaser & Strauss, 2009). In this field study, the initial question was what happened during expert weak signal processes.

The classical grounded approach stipulates that the researcher should interfere as little as possible during data collection and analysis to avoid framing. For instance, the literature review is preferably done post-experiment, and the researcher should be absent during data collection. Neither was the case in the field study. The more recent constructivist approach looks differently upon the role of the researcher. Instead of trying to remove the researcher from the experiment, this approach prefers that researcher and participants construct new theory together. Findings from the literature review are treated like the notes from another participant's interview (Ramalho, Adams, Huggard, & Hoare, 2015). This way, findings help build patterns with a holistic view of the data.

The presence of the researcher during the interview has framed interviews without a doubt. However, the negative effects most probably did not outweigh the positive. In the first place, the professional expertise of the interviewer as a futurologist engaged the participants to be honest about remote weak signals such as missed and extremely misinterpreted developments. In the futurologist practice, having plenty of missed and misinterpreted signals is a given by-product of the process, not a judgment error. Secondly, the researcher used the data to challenge insights from practice critically. This led to several astonishing outcomes, thus indicating that participants had been able to withstand at least some of the framing by the researcher (Charmaz & Mitchell, 1996).

The analysis followed the steps described by O'Reilly (2012). The steps are described in the next paragraphs and visualized in a chart (see Figure 12).

The analysis began with the coding of text fragments of the interview notes. Codes

were developed from answers to guiding questions, such as: "In this fragment, what main concern does the participant relate?", and "What category does this fragment indicate?" (Glaser & Holton, 2004).

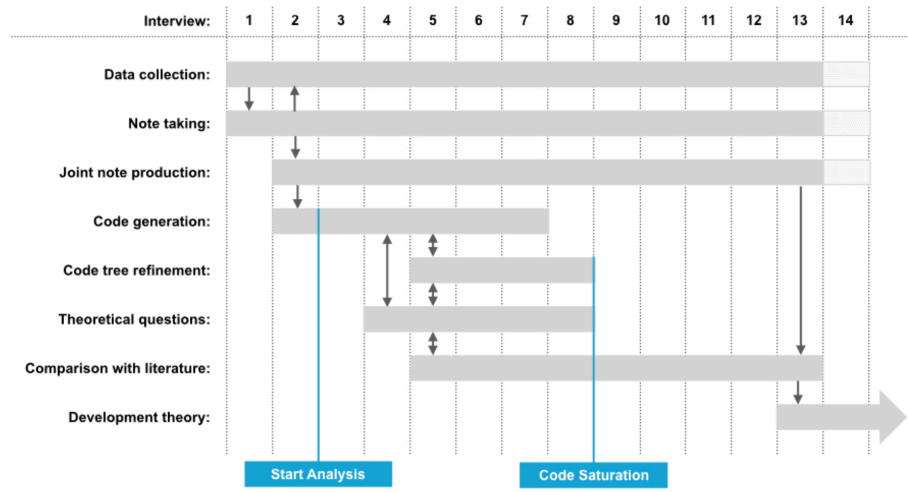


Figure 12: *Steps taken in data collection and analysis*

Strict use of guided questions forced the verification and saturation of code categories as well as a reduction of overlooked codes. More systematic and complete coding thus ensured the grounding of code categories in managerial practice beyond impressionism. The reliability of coding was checked by another researcher, who, without training, was able to code the same text fragments with the same codes. Also, Dedoose software, which is prepared for grounded research, was used to manage the data tightly (Dedoose, 2012).

Whenever new codes were developed from the notes of the next interview, previous interview notes were checked for that code. The codes were grouped in themes when their number became abundant. Thus, a code tree was formed. All codes were kept in the analysis but were sometimes moved to another theme or merged whenever they had a similar meaning. Whenever a text fragment, code or theme led to theoretical questions, a memo was attached to record the incident.

New interviews were planned sequentially to be able to stop the data collection when new codes no longer emerged. This moment of code saturation was determined before the analysis began by means of a stopping criterion: whenever the coding of five sequential interviews did not lead to new codes or changes in the code tree (Eisenhardt, 1989; Glaser & Holton, 2004; Glaser & Strauss, 2009; O'Reilly, 2012). After seven interviews, no new codes were added, but the code tree kept refining and the number of memo's increasing. The coding of the interviews nine to thirteen did not result in any changes, which implied that saturation was reached. Three measures were taken to verify saturation. First, a coherence check of the code tree by two researchers not involved in the coding, should not, and did not, lead to changes. Second, a literature search, based on the themes in the code tree, was done and analyzed to detect possible missing codes per theme. No codes had to be added. Third, an interview with a top-manager of a trade association was added (interview 14) because it was likely that a trade association might have a well-established, ongoing weak signal process doing broad sweeps of the environment. Indeed, trade associations monitor industry developments continuously, keep longer-term trend watch and organize conferences on strategic issues and innovation. Missing codes were almost certain to surface from the coding of this interview. Yet, no new codes, tree changes, or theoretical questions emerged. This led to the decision to stop interviewing after 13 interviews.

Codes, themes, and memos were sorted and integrated into insights on the process of weak signal interpretation and reference frames. The insights are presented in the next section.

3.4. Analysis

The field study's exploration of the expert weak signal process aimed at three goals. Firstly, to find support for or redesign the two-stage filtering process (see section 2.2.2.) and, secondly, to contribute to the weak signals pattern typical for experts (see section 2.2.3. Figure 8). Thirdly, to develop theory from emerging insights on the role of expert frames. The field study could only deliver results if the presence of weak signals was established so that the results on process, patterns, and frames were indeed particular to weak signals. The field study used the new weak signal definition (see section 2.3.1.) to find evidence of weak signals in the data. Section 3.4.1 delivers this evidence. Section 3.4.2 validates the weak signal process and pattern validation. Section 3.4.3 explores expert frames. Section 3.5. concisely discusses the findings and their consequences for the next steps in the dissertation.

3.4.1. Presence of weak signals

Weak signals are the perceptions of strategic phenomena detected in the environment or created during interpretation, that are distant to the perceiver's frame of reference (see section 2.3.1.). The reviewed studies had already indicated how distance could be recognized in recollections and narratives. For instance, distance to the frame was reflected in spatial terms such as periphery (McKenzie et al., 2009), in spatial-temporal terms as a result from the unpredictable speed of developments (Mendonca, Cardoso, & Caraca, 2012), in social terms in the shape of new sources (Fahey & King, 1977), or in terms of hypotheticality with expressions of ridiculousness of new information or opposition to new information (Kuosa, 2010; Schoemaker & Day, 2009).

Participants mentioned such keywords as well as other distance-related observations. For instance, signals were placed in the *outer* layer of the business environment (participant 2) or came from people at the *other end* of the hierarchy (participant 1) or from *dissonant* sources (participant 3). Whenever distance-related fragments were found in the recollections of the participants, it was coded with "Perceiving as weak." Thus coded, it was established that eleven of the thirteen participants referred to weak signals. In total, the eleven participants supplied 23 weak signals.

The two participants who did not label signals in terms of frame distance were both managing companies at the forefront of technological innovation (participants 5 and 12). When they talked about signals, they referred to envisioned technologies that did not exist yet. These technologies were distant because they were placed on the *furthest* strategic horizon. However, it was part of a salient system of horizons that corresponded with a process to manage the development of such technologies (participant 12) or the impact of such technologies on the business model (participant 5). Their stories lacked expressions of uncertainty or surprise that weak signals common to the other top-managers' recollections. Thus, it was likely that these signals were strong. These two interviews were compared and contrasted with the other interviews.

In conclusion, the field study contained weak signals, and did supply data from which weak and strong processes and their patterns could be inferred.

3.4.2. Process and patterns

The participants mentioned all stages, filters, and patterns that the literature had suggested. Examples of the most explicit references to each phenomenon are presented in the next paragraphs. Participants also mentioned additional aspects, which are presented at the end of this section.

Process Stages and Filters

In the reviewed literature, the process had four stages: a preliminary stage of developing search or identifying problems, two perceiving stages (detection and interpretation), and a final action stage. Information had to pass perceptual filters to be detected as a signal and to flow from stage to stage. The first filter, called forecasting filter, rejected signals that did not comply with the search criteria of the perceiver. After detection, a signal had to pass the second filter, called mentality filter, to get into the interpretation stage. The mentality filter rejected signals when they were diametral to the reference frame of the perceiver. When including signals in the frame was challenging, weakness was perceived, and extensive interpretation commenced. Finally, interpreted signals had to pass a third filter, the power filter, to get into the action stage. The power filter rejected signals as a result of the communication about signals for further interpretation by larger groups of managers or managers from different levels in the company (see section 2.2.2. Figure 7).

The best mention of the preliminary stage came from participant 2 when he recalled how his organization had struggled because necessary signals were missed. This prompted the appointment of a functionary responsible for the collection of weak signals. He relayed how they had tried to pinpoint what to search for and had eventually arrived at dissonant signals.

Participant 2 also talked about his stringent focus as a means to reduce signals to a manageable number. This fragment was coded with “forecasting filter”. In contrast, participant 11 said that he deliberately included information from orthogonal thinkers to stretch his view.

The detection stage was mostly recognizable from mere mentions about seeing signals for the first time after which top-managers would reflect on its meaning. For instance, participant 1 recalled that he would test his reflections about new signals on peers or coworkers in one-on-one, ad hoc, “coffee machine” talks. Only when others expressed surprise and relevance, a signal would be more formally interpreted.

Overcoming the effects of the mentality filter was described best by participant 11. He relayed an example of a recent crisis. The company had not responded to fake negative news because they were, well, fake. Anyone who wanted could have checked that the ‘facts’ were fake, and they had said so on their website. Despite easily retrievable truths and the denouncement of the fake news on the website, things escalated in social media and harmed the company’s reputation. The top-manager concluded the example by saying that he had to learn that feelings are also facts, even when they are based on fake news.

In the interpretive stage, many takes on the possible meanings and effects of a signal were developed. The best example gave participant 10, who explained a cascading process in which every department and level of the company participated. Special teams were responsible for the detection of signals, and IT helped to store signals and make them easily accessible. HR trained others to interpret signals together and to share interpretations with peers.

The existence of the power filter emerged from fragments about the difficulty of sensitizing others or getting signals implemented. For instance, participant 1 mentioned the lack of curiosity of lower-level managers, participant 7 named the lack of sharing of information, and participant 9 recalled group-think and other biases.

In the action stage, new policies were formed and shared (participant 2), new stakeholders or business partners sought (participant 5), new business models developed (participant 10), and other new initiatives taken.

Interestingly, the literature had presented the process as sequential, and only a few papers mentioned feedback loops. In contrast, the participants recalled that stages could take place simultaneously or separately and in various sequences and combinations. This was interpreted as a symptom of the messy real world, where multiple signal processes and iterations would co-occur.

Strong and Weak Patterns

In the literature, strong and weak signal process patterns differed in the flow of the signal through the process. A strong signal flowed seamlessly and smoothly from detection into action. A weak signal could be rejected at each filter and required elaborate deliberation during the interpretive stage. During the interpretive stage, multiple iterations could occur when new perceptions or data were linked to the signal (see section 1.1. Figure 2).

Participants mentioned missed and rejected signals, so the interruptions of the weak signal flow by perceptual filters was present. The multiple iterations during the interpretive stage were also mentioned. Personal iterations emerged from stories about the informal scrutinization of a broad but specific selection of sources. Iteration could also include seeking the perspective of others. This varied from individual informal conversations with lower-level staff, peers, and family members to collective conversations during formal sessions, often away from the office.

The recollections of participant 5 and 12 seemed typical for strong signals. Formal, rule-based processes had been developed to deal with signals like emerging and non-existing technologies. In contrast to the other participants, participant 5 and 12 expected these technologies. The gestalt of these technologies was already part of their companies' logics on business development, and were described as "ideas already sold" (participant 5), and "good business" (participant 12). Finding the right timing to join the market for these technologies was more crucial than the technologies themselves. Participant 5 called timing discussions "the permanent issue", and participant 12 "pure necessity". Their recall of domain discussion focused also on mergers and acquisitions of new knowledge to make the company more resilient against new entrants and technologies. In contrast to the interviews of the other participants, these two recalled discussions about focused search and action alternatives, but not of interpretations of new phenomena. This seemed to signify the seamless flow of strong signals through a routine process.

Additional Process Characteristics[1]

In addition to the stages and filters mentioned in literature, top-managers recalled additional process characteristics with which they compensated for the rejection of signals by perceptual filters. These characteristics were combined into three specific measures. Firstly, top-managers deliberately looked for new information diametral to their mental model or experience to compensate for the foresight filter. The larger distance of information to their frame would trigger inclusion rather than the usual rejection. Using frame distance as a search parameter also meant the absence of domain limited search parameters. Thus, signals could originate from the wide environment, not just the industry environment.

Secondly, top-managers also made sure that the number of signals processed would be as wide and deep as possible. In effect, this meant the widening and deepening of perceptual filters. They took particular care to include a wide range of sources that were known for their orthogonal view. This widened the forecasting filter to let in more signals of more categories. Top-managers also deliberately collected a wide

1 These findings are already published. Reference: van Veen, B. L., Ortt, J. R., & Badke-Schaub, P. G. (2019). Compensating for perceptual filters in weak signal assessments. Futures, 108

variety of perspectives during the interpretive stage so that loss of signals caused by their mentality filter was compensated. They invited the feedback from stakeholders both internal and external to the company, with the widest variety in backgrounds as they could manage. A synthesis of these perspectives would then form the basis for judgment and decision-making.

Thirdly, top-managers also deferred their judgments on interpretations so that a more accurate understanding could develop over time see Figure 13).

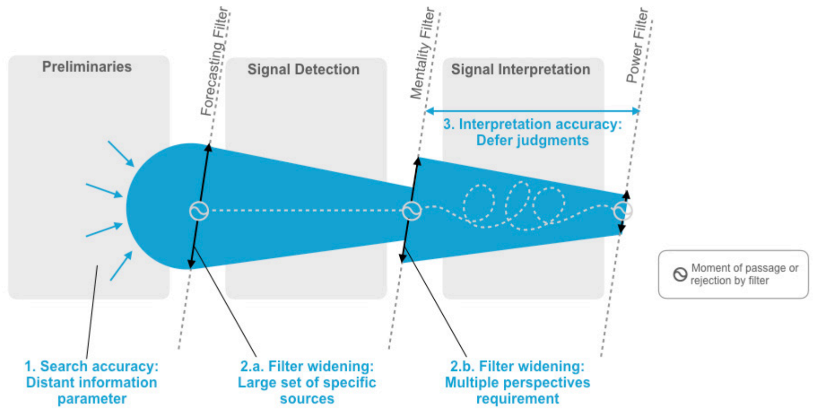


Figure 13: *Adjustments for the compensation of process filter effects*

Validation

The evidence of the process stages, the filters, and the two process patterns supported the findings from literature in Chapter 2. Additional findings were part of the original process and did not indicate radical changes in the process. The strong parallels between the field study and its forerunners are indicative of the robustness of the findings. Thus, process and patterns were valid representations.

3.4.3. Expert frames and patterns[2]

In the reviewed literature, it was assumed that frames were responsible for the width and depth of the perceptual filters in the process and thus for the quantity and quality of signal interpretations. Wide and flat filters let in more signals from more signal categories. Narrow and deep filters let in more signals from just a few categories (see section 2.2.2. Figure 6). Frames were also active during the interpretation

2 These findings were presented in a conference paper and won a best paper award at the EIASM 15th Workshop on Corporate Governance in Brussels, Belgium, on November 5-6, 2018.

stage. New signals were linked to concepts already in the frame. Possible meanings of the signals emerged from comparing and contrasting them to known concepts. When new signals could be linked to the map, they could also be linked to the response rules for comparable signals if these were available (Dutton & Jackson, 1987). The perceived weakness of a signal reflected its compatibility with the frame (Ansoff, 1979; Nicolai & Seidl, 2010). Thus, frames seemed crucial to the success of the weak signal process.

Expert frames had more complex structures that were summarized in key constructs. This enabled experts to keep filters wide and process signals differently. The defining aspects of the expert signal pattern were that experts detected more signals and generated more interpretation alternatives simultaneously than novices (see section 2.2.3. Figure 8). Because the field study's sample did not include novices, the contrasting patterns for experts and novices could not be validated. However, the expert pattern itself could be examined more closely with regards to the emergence of the frame during the process stages. First, the expert frames in the sample are introduced, and then the relationships between these frames and the weak signal process are discussed.

Variation in Frame Complexity

The actual structure and substance of frames are still unknown, but it is assumed that the top-manager frame for the environment includes knowledge and beliefs about causal relationships in the environment (Daft & Weick, 1984; Rasmussen, 1983). Researchers have visualized frames by way of mapping linked concepts in graphs that are similar to the nodes and links in mind maps (Clarke & Mackaness, 2001; Hodgkinson et al., 1999; Kiss & Barr, 2015). So much even, that cognitive mapping has become a common and validated technique (Caspar & Berger, 2007).

Special care had been taken to note the precise metaphors and keywords that the top-managers used during recall. Metaphors and similes are seen as the implicit part of language that reflects how the frame interprets new signals. It is assumed that metaphors provide the bridge between new and existing information in the frame. Metaphors also accentuate and mask certain aspects in signals, and thus determine the width and depth of perceptual filters (Allbritton, 1995; Lakoff & Johnson, 2008; Mason, 1991; Mason & Mitroff, 1973).

Participants had used different metaphors and similes during recall, but only one referred to the structure of the environment. These structural metaphors were

used to explain the origin of weak signals to the researcher. Thus, it was likely that these metaphors represented the structure of the expert frame of the environment. Metaphors and similes were visualized by way of a guiding question: "What does this metaphor or simile look like in simple design language containing circles (nodes) and straight lines (links)?". For example, participant 6 characterized himself as a matchmaker between different worlds. This was visualized as a hub (node) and spoke (links) structure, with the matchmaker as hub and the worlds as spokes.

In some cases, non-verbal communication could be included in the consideration. Participants 2 and 10 had air-sketched the environment in concentric circles during the recall of a layered environment. Thus, this structure was dubbed with concentric circles. Participant 3 had made a looped gesture during the recall of a lengthy process with multiple iterations, and therefore this structure was called nested loops.

An overview of the fragments of metaphors or similes and the induced frame structures is presented in Table 6. The metaphors and simile are printed in bold (see Table 6).

Table 6: *Frame metaphors, induced structures, and process foci*

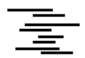
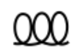
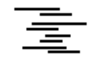
Frame Structures				
Participant	**Metaphor or Simile**	**Induced Structure**	**Visualization**	**Process Focus**
1.	There is a mess of information you can use. But your brain can't handle it. So: gut feeling. Walking in a **thick fog** and despite that saying: let's turn right	Fuzzy systems		Lack of analyzability: interpretation stage
2.	Everything changes all the time. Being alert is OK. You must be busy **with three circles**: the company, substitutes, and related technology (sketch of concentric circles)	Concentric circles		Be alert all the time: detection stage
3.	It was teeming with signals which we saw, heard, and understood. But we did not know to what they would lead. They were a roll call for special sessions **over the years**. We saw fragments and looked individually. **Only later did we** compare images. **After** a stakeholder decision, **we found scope and new channels opened** (looped gesture)	Nested loops		Changing channels and scope refer to search criteria: preliminary stage
4.	I **often** ask: guys, how does it feel? We have to discover the way together. We go outside and look around, **learn** what needs to be done [explains iterations on information about specific competitors, best practices, peers, industry association]	Nested loops		Go outside, discover distinct information refer to search criteria: preliminary stage

Table 6 continued:

Frame Structures				
Participant	**Metaphor or Simile**	**Induced Structure**	**Visualization**	**Process Focus**
5.	Our general vision is that developing technology will solve all problems. People, institutions, processes, and procedures stall progress and make the wrong selections. For the acceptance capabilities of our company with older employees, **opposite thinkers** like hi-pos **are essential**	Orthogonal systems		Acceptance capabilities: Interpretation stage/ mentality filter
6.	I live in separate worlds, I am the **matchmaker**, the catalyst of ideas and financial means	Hub and spokes		Catalyst of ideas of others: action stage
7.	Essentially, there are **three worlds**. Their perceptions are not connected. You must not choose between worlds but connect them by enacting our vision. All three worlds want to accelerate with us. They must, they don't get a choice	Hub and spokes		Others must accelerate: action stage
8.	I'm inspired by everything I see, but the penny drops later. The board and I will take a day a year to go to the woods. There, we talk about what we think will happen next year. With **the big picture** [on competition, inflation, consumer confidence], not the data, we get a feel for how it will go	Single system		Getting a feel: interpretation stage
9.	How you see the future **depends on where you are**. The global stage determines the sentiment. Emerging markets will show you the long-term trends. **We are all connected**. Money in the economy, demography, housing market, the process is hard to catch. When you monitor the long-term trends and connect them, you can see interesting things	Web		Seeing, monitoring: detection stage
10.	We take care of feeding the company: continuous and varied nutrition. Keeps the company healthy. The **right doses on the right time** is essential (sketch of concentric circles) [explains collection process as a combined effort of all functional levels, roles and sub-environments]	Concentric circles		Getting fodder to feed the company: detection stage
11.	When we think about the long-term, we do this in terms of processes, thematically [demographics, digitalization]. How will this change us? You **need opposite thinkers to generate ideas**. Opposites in culture, attitude, age. Ideas flow through the company informally, so you have to **destroy silos**	Orthogonal systems		Opposite thinkers to generate ideas [meaning]: Interpretation stage
12.	Our industry is a **close-knit community**. Partner or competitor, **we all know each other and help each other**. We are open about trends: not many secrets. We share them openly and proudly. It is the way to show that you're leading the way. Besides, things are havrd to follow or you were already in the know	Single system		Help each other: action stage

Table 6 continued:

Frame Structures				
Participant	**Metaphor or Simile**	**Induced Structure**	**Visualization**	**Process Focus**
13.	What do you hear in the **noise** from the universe? It takes time before you can see the contours of change. It's like hearing or reading a phrase and you suddenly think: "wait a minute!"	Fuzzy systems		Intuiting the meaning of noise: interpretation stage

For the analysis of frame structures, insights from the related field of perceived environmental uncertainty were borrowed. Perceived uncertainty reflects the extent to which information about the environment is lacking in the reference frame of the perceiver (Duncan, 1972; Oreja-Rodriguez & Yanes-Estévez, 2007). In literature on perceived uncertainty in the company environment, uncertainty has foremost been described by two dimensions: complexity and dynamism. Complexity was measured in the number of perceived links between developments in the environment. Dynamism reflected the perceived change rate of the same developments (Duncan, 1972). The process with which uncertainty is perceived follows similar steps to the weak signal process. First, a development is detected, then its complexity and change rate are interpreted, which can result in various levels of uncertainty (Downey & Slocum, 1975). So-called boundary scanning activities influence the level of perceived uncertainty. These are the organizational activities to interpret environmental conditions (Leifer & Huber, 1977) and can consist of weak signal analysis (Daft & Weick, 1984). Different levels of perceived uncertainty require different coping strategies. In environments with the highest level of uncertainty, various strategic paths should be developed, and continuous monitoring of the environment provides the insights that lead to maintaining or switching paths. Monitoring focuses on signals similar to weak signals, which emerge and grow stronger over time (Hermans, Haasnoot, ter Maat, & Kwakkel, 2017; Walker et al., 2003). In this field, reference frames have been described in terms of complexity and dynamism (Nadkarni & Narayanan, 2007; Oreja-Rodriguez & Yanes-Estévez, 2007). In this dissertation, the node and link structures seemed to reflect complexity and dynamism as well.

The node and link structures exhibited two dimensions: complexity (linkage) and dynamism (iteration over time). Following the literature on frame complexity, complexity was defined as a reflection of the relative number of nodes and links in a frame. A simple frame represented a single system of nodes and links and a complex frame multiple systems. For instance, the big picture of participant 8 was limited to his industry environment and thus categorized as simple. The fog of participants 1 and 13 had so many links and nodes, that the participants could zoom in and talk at length about distinct nodes and links (big picture level), zoom out a little to talk about systems of nodes and links, or zoom out even more to fog level.

Dynamism ranged from static to dynamic. A static state referred to relatively fixed frames, such as the frame of participant 8. He referred to the big picture that served as a baseline for strategic action. It was reviewed once a year, to remain passive until the next review, and it was shared with stakeholders like shareholders and customers as the horizon. In this sense, the big picture can be interpreted as a movie still. In contrast, a dynamic state referred to frames that can be interpreted as the movie trailer: an overview of the developments leading up to change. These frames encompassed dynamic aspects such as interaction or iteration. For instance, the most dynamic frames were the nested loops frames of participants 3 and 4. These described the iterations over time of entire systems of links and nodes.

Perceived weakness was likely to increase with higher levels of complexity and dynamism (see Figure 14a). This implied that managers with static, simple frames perceived less weakness than those with dynamic, complex frames (see Figure 14b).

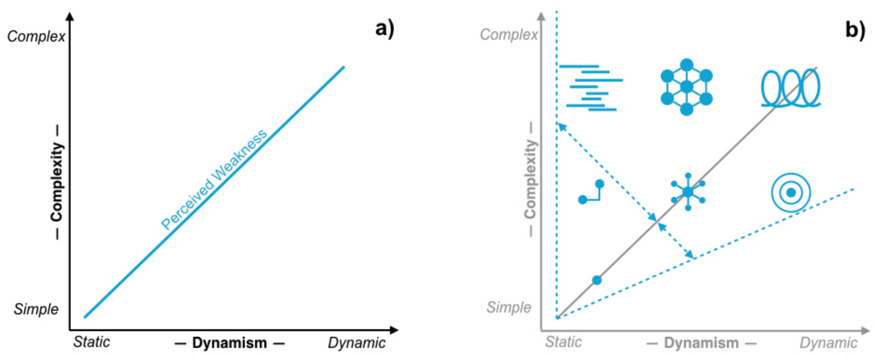


Figure 14: *Perceived weakness as a function of dynamism and complexity (a), reflected in frame structure variance (b)*

Figure 14b also revealed a skewed variance in frame structure in favor of complexity, which may have been caused by the level of expertise represented in the sample.

Literature on expert frames had explained that the complexity of the expert frame and its focus on key constructs were the prerequisites for better performance (Clarke & Mackaness, 2001). In contrast, the expert frames in the field study could exhibit several levels of complexity and dynamism. The analysis pointed towards two possible explanations for the variance: a manager's focus on distinct process stages and the sensitivity this required to remain open to weak signals.

Frames and Process Foci

Metaphors were tied to distinct process stages. For instance, participant 1 used the fog metaphor to express his perceived lack of analyzability of the environment. This top-manager refrained from goal-oriented search because he felt his field of sight was too limited. Instead, he made sense of the signals he was exposed to. This conviction implied that the locus of his uncertainty did not reside in the environment which was not analyzable anyway, but in the effectiveness of his and his company's interpretive skills when signals were detected. Thus, the fog metaphor seemed to be tied to a focus on interpretation. Likewise, participant 2 sketched circles as he referred to the layers of the environment that must be searched for signals. The point of the metaphor was to explain that weak signals were searched for in the outer circle. The search orientation of the metaphor tied in with a focus on the detection stage. Table 7 presents the induced foci for each participant (see Table 7).

Metaphor structure mostly decreased per step in the process. For instance, the nested loop structure represented a system of linked concepts that iterated over time. Thus, the structure was based on two dimensions: complexity (links) and dynamism (change over time). This structure was tied to the preliminary stage. In contrast, the single system was a simple and static notion of the environment (the big yearly picture). This was tied to the action stage (see Figure 15).

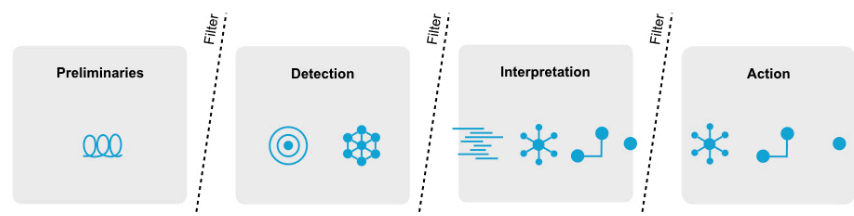


Figure 15: *Frame structures per process stage*

Logically, top-managers needed a more complex frame structure to make sense of unknowns than of knowns. For unknowns, a connection with the frame must be found first before it could be detected or interpreted. More complex frames contained more links and nodes to which an unknown could connect. There are more unknowns at the beginning of the weak signal process than at the end. Likewise, literature assumed that perceived weakness decreased through-out the process (Ansoff, 1979; Molitor, 1977). Interestingly, a slightly different perceived weakness pattern had emerged from the cluster analysis of keywords in weak signal descriptions (see section 2.3.1.). It became apparent that weak signals also originated from the interpretation of seemingly random signals. This implied that stronger signals were recombined (interpreted) into a new signal, that could lead to higher perceived weakness. Thus, after a decrease from the preliminary stage up to interpretation, a new curve followed, like a wave pattern.

Logically, the surge in weakness should be reflected in frames with an interpretation focus. Seen in this light, it seemed fitting that the more complex fog structured frames interrupted the decrease in frame complexity in the process (see Figure 16).

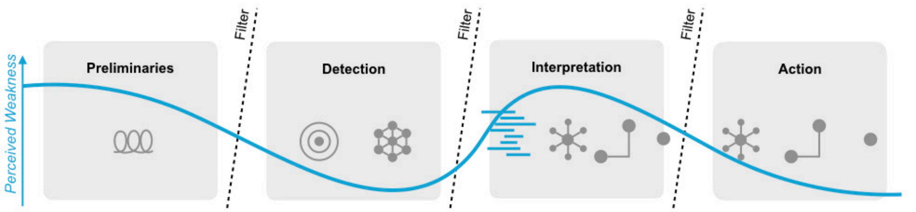


Figure 16: *Surge of perceived weakness and frame complexity during interpretation*

Frame Sensitivity

All interviewed top-managers stated that their knowledge of the environment was not, probably could never be, and should not be seen as a complete representation of the environment. They were very aware of the vastness of environmental signals and the boundaries of their detection and interpretation capacities and skills. When the top-managers talked about these limitations, it meant more to them than just a disclaimer for missed or misinterpreted signals. The awareness of cognitive limitations urged top-managers to take measures to remain sensitive to weak signals. In entrepreneurship literature, a similar sensitivity was described as the prepared mind (Alvarez & Busenitz, 2001) or alertness (Barreto, 2012). Both terms referred to the cognitive readiness that top-managers needed to detect opportunities.

Participant 1 gave an explicit rationale for his need for more sensitivity. He wanted to remain sensitive to weak signals, "Because I know that I can't know it all." He could not solve his cognitive limits with upping the search for weak signals because the thick fog of his environment rendered focused search useless. Thus, remaining as sensitive as possible for vague shapes (signals) looming in the mist was his only option. Consequently, he had a broad action repertoire at the ready so that he could spring into action whenever he could make sense of a looming signal.

His rationale put the spotlight on an ambiguous consequence of complex frames. Complex frames had so many systems of links and nodes that weak signals were more easily linked to the frame. Hence, it was plausible that fewer signals from the environment would be perceived as weak (see Figure 17a). Thus, the chance of misinterpreted signals was relatively high. On the other hand, a complex frame helped top-managers to manage an abundance of signals.

Top-managers with dynamic-complex frames (participants 2, 3, 4, 9, and 10) explicitly mentioned the abundance of detected signals. Constant exposure to or detection of an abundance of signals may have led to more complex frames, but it could also have motivated the top-managers to develop a frame that decreased the number of weak signals perceived (see Figure 17b).

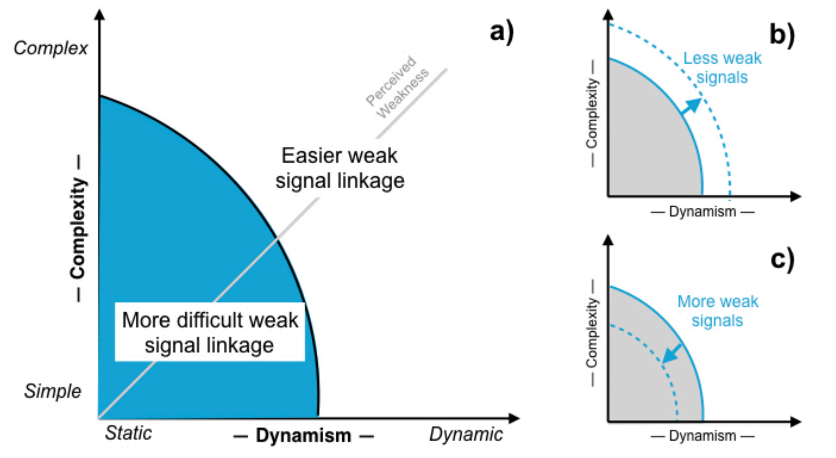


Figure 17: *Variance of perceived weakness in frames and their effects*

Similarly, top-managers who had developed static-simple frames (participants 5, 8, 11, and 12) may have been motivated to decrease frame complexity so that more signals could be perceived as weak (see Figure 15c). These top-managers were not complexity averse at all. Like participant 12 said: they thoroughly enjoyed complexity. It seemed to inspire them that they had limited sight because, in complex situations, they could put their expertise to good use.

Frame Pervasiveness in Search

The reviewed literature already showed that frames influenced the process stages: complex frames kept multiple signals salient during the process and allowed the development of multiple interpretation alternatives simultaneously. Research had also found partial relations between frames and search. Search was positively related to beliefs about the analyzability of the environment (Daft & Weick, 1984), as were complex structures and search (Jane E Dutton, Fahey, & Narayanan, 1983). Complex, dynamic structures mirrored rapidly changing environments that required increased search (McGee & Sawyerr, 2003). The exploration supported these findings.

Multiple indications of the pervasiveness of frames in search parameters emerged from the analysis. Top-managers illustrated their scanning recalls with signals specific to their reference frame structure. For instance, it is useless to search for signals in fuzzy systems (participants 1 and 12). In these systems, change is sensed when signals loom, or rather, when a pattern starts to form. This observation of weak signal shapes as an extension of frame structure has a parallel in the strong signal process. Participants 5 and 12 expressed strong signals in terms of frame structure as well. In the orthogonal structure of participant 5, signals were co-created by the two systems in the model. In the single system of participant 12, signals were a result of their innovation effort.

In the concentric circles structure (participants 2 and 10), the environment consisted of layers of spatial and temporal distances to the company domain. Participant 1 actively searched for unfamiliar but scalable developments in domains that were one or two steps removed. Participant 2 actively searched for competing developments in the layers.

The coherence between structure and search was similar to that of modern strategy paradigms based on multiple levels of environmental dynamism and complexity. The paradigms proposed different search strategies per level (Makridakis, Hogarth, & Gaba, 2009; Walker, Marchau, & Swanson, 2010). Simple, static environments were seen as knowable. More defined search could eliminate uncertainty. Uncertainty in simple, dynamic environments could be reduced by forecasting. A more permanent state of uncertainty in more complex environments could be managed by systematic probing for change.

3.5. Discussion

In Chapter 2, the descriptions of weak signals, the process, and weak and strong signal flow in the reviewed literature were discussed. The field study's findings supported the process and flow descriptions. New findings contributed to theory. The most important contributions and their implications are summarized below.

Firstly, top-managers invariantly referred to their reference frames as incomplete, regardless of process stage or frame structure. They took several process measures to compensate for it. The loss of signals caused by perceptual filters was reduced by changing search parameters to focus on dissonants and adding a distinct and broad array of sources. Possible misinterpretation was compensated for by deferring judgment until a multitude of different perspectives on a signal had led to detailed insight into its meaning and effects (see section 3.4.2.).

Foresight methodologies like scenario planning or voroscoping[3] employ the classical view of a layered environment (Schoemaker, Day, & Snyder, 2013; Van der Heijden, 2011; Voros, 2003). Methodologies unravel each layer with detailed trends analysis to widen perceptual filters and to extend the bigger picture. The assumption is that process accuracy always benefits from wider filters. However, the findings show that experts have a more precise instrumentarium. Their measures are aimed at letting in more relevant weak signals, instead of more signals that may or may not be relevant or weak.

Secondly, expert metaphors for the environment varied widely beyond the classical view of a layered environment that underpins foresight methodologies. The metaphors represented frame structures that varied in terms of dynamism and complexity (see section 3.4.3.). The classical view sat at the simpler and more static end of the continuum.

Thirdly, frame dynamism and complexity decreased per process stage, with a surge

3 Scenario planning and voroscoping both refer to the development of possible futures on the basis of trends from multiple environmental segments. Scenario planning uses a matrix of trends, while voroscoping uses a cone with multiple layers to the same frame widening effect.

in the interpretation stage. Dynamic, complex frames were focused on search and detection and static, simple frames on action. This observation was similar to the decreasing level of perceived weakness represented in the cluster analysis of weak signal descriptions, which could surge when random stronger signals were interpreted as a weak signal pattern (see section 2.3.1.).

The findings were interpreted as a managerial balancing act between the narrowing of filters against unmanageable numbers of weak signals and the need for sensitivity to avoid large numbers of missed or misinterpreted signals. The first stages of the process exhibited many unknowns, so it was important to be able to detect many signals. Thus, frames were dynamic and complex so that weak signals could be more easily linked to the frame. Simultaneously, more dynamic and complex frames reduced the likelihood of perceiving weak signals. In effect, the frame reduced the number of unknowns to manage.

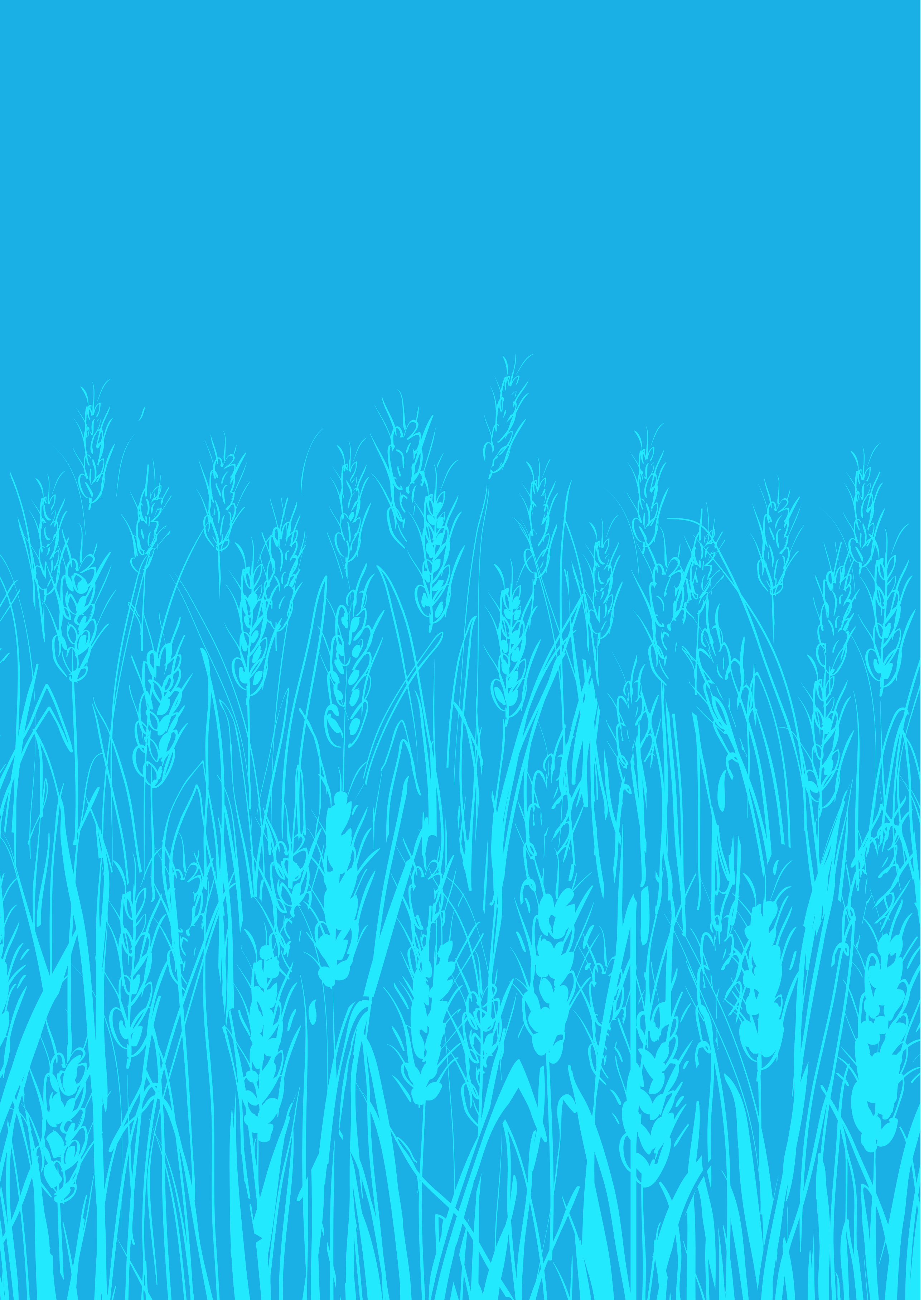
Inversely, frames that focused on the latter part of the process were more static and simpler. These frames had fewer links and nodes to link with new signals; thus, in effect, left relatively more weak signals in the environment. At the same time, at the latter stages, fewer signals were left in the process through the rejection of the perceptual filters. Thus, there was a need to combine an action focus with a simpler frame so that process kept iterating and myopia was avoided.

Finally, the metaphors were pervasive because they also encompassed search parameters and source selections.

The findings were bounded to the theoretical development of the structure and role of expert frames because of its explorative nature, sample size, and sample composition. However, they did indicate that frame structure and substance are crucial to the weak signal process. Much is assumed about frame substance and structure, but less is known (see section 3.4.3.). The findings are a step forward towards a clearer understanding of variety in frame structure and the pervasiveness of frames in every stage and filter of the process. They emphasized the significance of the role of expertise because its acquisition contributes heavily to frame structure and substance. Thus, the findings contributed to the relevance of the second field study, which focused on the role of expertise types in the process. It looked into the relationships between levels of perceived weakness, expertise types and interpretation.

The interview method relied on the recall of critical incidents. The method can elicit rich data when the interviewer intervenes minimally, but data will be colored by the memory of the participants (Gubrium, Holstein, Marvasti, & McKinney, 2012). The use of multiple interviews does overcome some of the biases induced by memory (Guest, Bunce, & Johnson, 2006; Scheibelhofer, 2008), but not all. Thus, the second field study should compensate for the possible bias from recall.

The following chapters present the second field study. Chapter 4 describes the method, chapter 5 explains the development of the variables, and chapter 6 presents the results.



4

THE STRAWS METHOD

You can compare [the weak signal process] to the following assignment: develop a car that can drive around the world 10 times, via the north pole, Sahara, and south pole, without stopping for gas or maintenance. That doesn't come to you instantaneously either…

Field Study I; Participant 12

It was intended to copy a suitable research design for the field study on the role of expertise types in the weak signal process. However, there were persistent inconsistencies going on in weak signal research. Since the 1960s, scholars were aware that the signal weakness decreased over time, yet they designed studies as if there was only a dichotomy between strong and weak signals. The scholars who viewed weakness as a perception, thus as intrinsically idiosyncratic, did not check if their sample actually perceived weakness.

These inconsistencies between theory and research design must be remedied so that the actual perceptions of weak signals can be captured. It so happened that the new weak signal definition enabled a design in which weakness could be rated as the distance of a signal to the perceiver's frame (see section 2.3.1.). This way, the actual perceiving of weak signals could be established, as well as a rating of the degree of weakness participants perceived. The only thing left to do was to develop a design in which participants were triggered to perceive weak signals. The design should be replicable despite the idiosyncrasy of weakness perceptions so that findings could be validated. It should supply fellow researchers with insights and tools to help build designs and methodologies to capture weakness perceptions even better. This design was dubbed the STRAWS method: scenario triggered rateable articulations of weak signals.

In the next sections, the research design of the field study is presented with a dual purpose. Firstly, to account for the design. Secondly, to present the design as a series of instructive steps for the benefit of future weak signal researchers. In this light, the sections on the development of the experiment task and stimuli are of special interest. Together, they form a way to trigger perceived weakness.

The sections successively present the research questions and model underlying the field study (section 4.1.); the choice for action research to collect data (section 4.2.); the sample (section 4.3.); the task (section 4.4.); the stimuli (section 4.5.); and the choice for mixed methods for the analysis (section 4.6.). A separate section is dedicated to the overview of the STRAWS method (section 4.7.). Finally, section 4.7. discusses the validity and reliability of the design.

4.1. Research Questions and Model

The second field study was to focus on the role of expertise in the detection and interpretation stage of weak signal process. Literature already gave evidence that expertise widened the forecasting and mentality filters and influenced the interpretation pattern. Wider filters let in more weak signals. A more complex frame enabled the simultaneous development of multiple interpretation alternatives. More signals and more alternatives were assumed to lead to more accurate judgments on emerging environmental phenomena (see section 2.2.3. Figure 9). However, real-world examples such as financial experts ridiculing investor Peter Schiff's signals of the imminent recession, or industry expert Steve Ballmer ridiculing another industry expert's iPhone, made painfully clear that experts of different kinds missed and misinterpreted weak signals too. Studies in which the accuracy of predictions was checked had already showed that experts were not better predictors (Holopainen & Toivonen, 2012; Meehl, 1954; Tetlock & Gardner, 2016). So the question remained: what is it in expertise that makes some experts better weak signal interpreters than others?

A longitudinal study on forecasters of all levels showed that those who remained open-minded predicted most accurately. Accuracy could improve by, among others, widening perceptual filters (Tetlock & Gardner, 2016). Foresight accuracy was therefore an acquired skill that could lead to expertise as the highest stage of skill acquisition (Dreyfus & Dreyfus, 2017). As such, foresight accuracy could be seen

as the product of wider perceptual filter caused by high task expertise. However, it could just as likely be attributed to the wider filters caused by the broader view usually associated with high general expertise (Kiesler & Sproull, 1982; McEwen, 2008). To complicate things further, weak signal researchers usually worked with samples of top-managers who became experts by regularly contributing to strategy (Clarke & Mackaness, 2001; Rindova, 1999), so their wider filters might be attributed to high job expertise. Thus, expertise was seen as a requirement for weak signal research, but how expertise contributed to weak signal processing varied between superior information processing skills (Kiss & Barr, 2015) and paradigm blindness (Holopainen & Toivonen, 2012). The connection between expertise and perceptual filters width was assumed but not tied to expertise type (Dutton & Jackson, 1987; Ilmola & Kuusi, 2006; Nadkarni & Narayanan, 2007; Starbuck & Milliken, 1988).

In literature on expertise, it was argued that expertise consisted of the combination of experience and cognition (Reuber, 1997). Among the manifold operationalizations of experience were tenure in the organization, functional background, education, social-economic roots, financial position (Hambrick & Mason, 1984; Starbuck & Milliken, 1988) and performance (Gerloff, Muir, & Bodensteiner, 1991). Cognitions were defined as beliefs about the environment (Daft & Weick, 1984), mental categories (Dutton & Jackson, 1987; Stubbart, 1989) or the psychological context of a decision (Bateman & Zeithaml, 1989).

Interestingly, more recent research bundled these aspects into a construct called "individual human capital" (Alvarez & Busenitz, 2001, p. 767) and then separated it again into general and specific traits of expertise (Alvarez & Busenitz, 2001; Shepherd et al., 2015; Westhead et al., 2005). General expertise referred to the general knowledge accumulated through age and general education. Specific expertise referred to knowledge about a distinct domain, awareness of the main problems in it, and skills to solve those problems. It was separated into industry expertise and job expertise, and task expertise. This implied that these expertise types largely covered the part of knowledge and beliefs that formed the top-manager frame for the company environment.

That some experts did see the great recession in the subprime crisis and others did not, may be partly explained by opposite effects of the four expertise types on the weak process filters. Hypothetically speaking, high general expertise loaded the frame with a wide variety of experiences. The wide variety may make it easier to link new signals, and thus widen the perceptual filter. In contrast, high job expertise loaded the frame with many years of experience in the same job. Therefore, signals distant to the job environment would not be easy to link; thus the filter would be narrower and deeper. Also, foresight (task) expertise loaded the frame with all kinds of new signals and rules to interpret them. This may help to deepen a wide filter and let in more signals per signal category or help to widen a narrow filter and let in signals from categories not directly related to the job (see Figure 18).

Literature already suggested that weak signals differed from strong signals in the way they flowed through the process. A strong signal flowed smoothly through interpretation, but a weak signal required multiple iterations to develop meaning. The expert weak signal flow was busier because experts were able to iterate multiple interpretation alternatives simultaneously (see section 2.2.3.). This implied that interpretation patterns were indicative of both perceived signal weakness and expertise.

Hence, the first research question was: "Do different types of expertise influence interpretation patterns differently?"

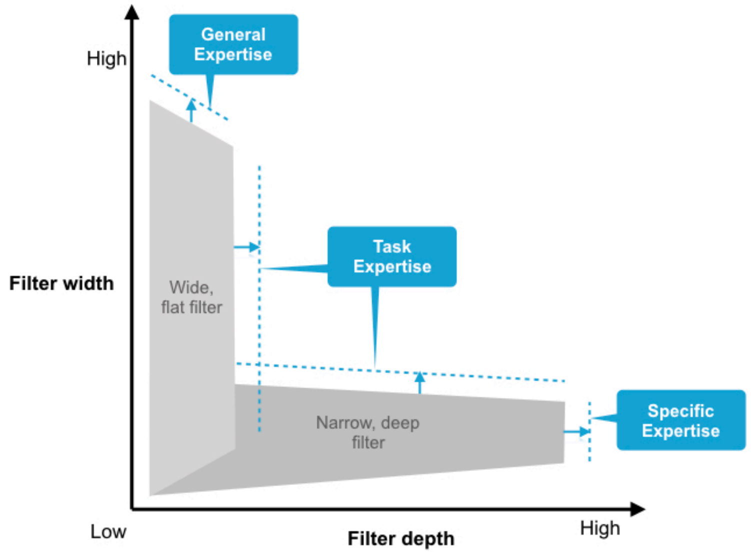


Figure 18: *Possible influences of expertise types on the width and depth of the perceptual filters*

The reviewed empirical studies only distinguished strong and weak signals, although theoretical contributions said that weakness decreased in levels as the process went on (Ansoff, 1979; Molitor, 1977). Furthermore, it was inferred from the logical analysis of weak signal descriptions that the level of weakness could surge during interpretation when stronger random signals were combined into a pattern (see section 2.3.1.). The surge was reflected in the field study findings. Frame structure seemed to be tied to process stages and its complexity decreased per stage, with a more complex frame structure in the interpretation stage (see section 3.4.3). These findings supported the idea of continuous levels of perceived weakness.

From the distinct signal flow of strong, weak, and expert weak signal patterns as described in literature (see sections 1.1. and 2.2.3.), it was a small step to assume that different levels of perceived weakness would exhibit different interpretation patterns. Hence, the second research question was: "Does the level of perceived weakness influence interpretation patterns?"

The observations in the dissertation's first field study led to the hypothesis that expert frame complexity may make weak signals easier to link and thus lower the perceived weakness of a signal (see section 3.4.3.). Hence, the third research question was: Do expertise types influence the level of perceived weakness?

Thus, the field study's underlying model consisted of relationships between expertise type, perceived weakness, and interpretation pattern (see Figure 19). The first research question explored the relationship between expertise types and interpretation patterns (see Figure 19, line 1). The second research question explores the relationship between the level of perceived weakness and interpretation patterns (see Figure 19, line 2). The third research question explored the relationship between expertise type and the level of perceived weakness (see Figure 19, line 3).

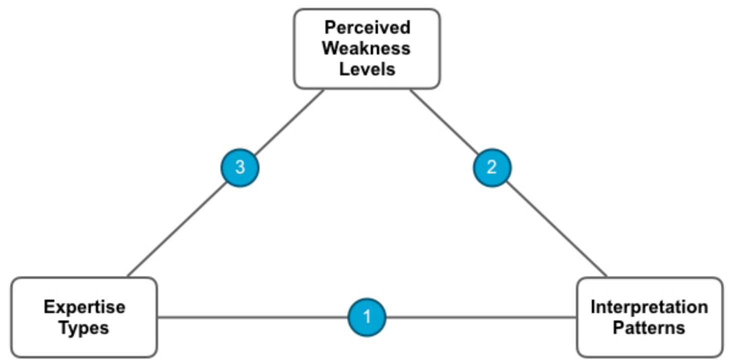


Figure 19: *The model of relationships that the expertise study explored; numbers indicate the research questions*

4.2. Data Collection Methodology

Data was collected through action research with a single task design because this allowed direct observation of the individual top-manager weak signal process. Direct observation would enable us to systematically gain in-depth knowledge about the process stage in which weakness would be perceived and to which interpretation characteristics that would lead.

Action research had also proven its worth in weak signal process research (Blanco & Lesca, 1997), and could be used in a qualitative design. This was important for several reasons. Firstly, participants had to process ill-defined, ambiguous information so that weakness would be perceived. This made the experiment task (to detect and interpret weak signals) hard to program in quantifiable terms. Secondly, to admit and work with ambiguity required effort and courage from the participants. This meant that the task environment should support safe and open communication. A qualitative approach was flexible enough to provide such conditions. Finally, several of the variables required in the study had yet to be developed and were to emerge from an explorative approach.

Other qualitative methodologies were considered, but these were less well-suited. For instance, longitudinal research had been used to explore process patterns (Leitner, 2015; Mintzberg & Waters, 1982), but the field study was set up to look into the immediate effect of perceived weakness for a given level of expertise. The process recall from the first field study was also less suited because of the delay between the task and the recall. This delay may cause the loss of significant data about the actual occurrence of perceived weakness and made measurements of its level prone to memory distortions.

The design of the experiment task is presented in section 4.4.

4.3. Sample Composition Criteria

In literature, samples were usually drawn from populations expected to be capable weak signal interpreters. Samples consisted of foresight practitioners who interpreted weak signals for a living (Saritas & Smith, 2011; Tapinos & Pyper, 2017), top-managers responsible for weak signal detection (Blanco & Lesca, 1997; Elenkov, 1997; Ilmola & Kuusi, 2006; Kuvaas, 2002; Milliken, 1990), advanced MBA students who were taught trend research (Schwarz et al., 2014), or subject matter academics (Kuvaas, 2002; Yasai-Ardekani & Nystrom, 1996).

Researchers had taken various measures to interpret the data derived from such highly capable samples correctly. For instance, when samples were restricted to one company, they were composed of subsets of managers from various management levels. Because lower levels were assumed to be less apt at weak signal analysis than top-managers, such samples would give a well-rounded picture of the process (Blanco & Lesca, 1997; Ilmola & Kuusi, 2006). In another study, the sample was split into task experts and novices (Honda et al., 2017).

The focus on top-managers was maintained because they were the most likely functionaries to be frequently exposed to a wider environment. Lower management levels were assumed to consider environments specific to their level or department, which were narrower than the company environment of the top-manager (Lawrence & Lorsch, 1967). This was crucial to the set-up because the sample must be able to include stimuli into their frame to perceive weakness. Managers from narrower environments may have more difficulty to recognize or be prone to reject weak signals outside their environment.

Following human capital theory, expertise was defined as the combination of general expertise and specific expertise (Alvarez & Busenitz, 2001; Shepherd et al., 2015; Westhead et al., 2005). General expertise referred to the variables age, level of education, and gender (Westhead et al., 2005). Specific expertise was subdivided into industry specific expertise, job specific expertise, and task specific expertise (Ericsson & Smith, 1991). Research also reported that specific expertise should be split into width and depth of expertise. Width or diversity of expertise was associated with more learning. Depth or repetition of tasks was associated with loss of flexibility in thinking, also in the case of weak signals (Reuber, 1997; Westhead et al., 2005).

Expertise types were operationalized in various measures so that these could be included in the sample criteria. In literature, general expertise was measured in age, level of education, and gender. However, the Dutch top-manager population was foremost male and academically educated, so general expertise was narrowed down to age (see variable description in appendix E.1).

Specific expertise was operationalized in industry expertise and job expertise. These were subdivided into width and depth. Width of industry expertise was measured in the number of industries worked in for more than five years at management level (see variable description in appendix E.2). Depth of industry expertise was measured in years worked in the current industry (see variable description in appendix E.3).

Width of job expertise was measured in years worked on board level (see variable description in appendix E.4). Depth of job expertise was measured in years in the current job (see variable description in appendix E.5).

Limiting the sample to active top-managers and extending the sample to include various levels of general and job expertise enabled the emergence of various levels of task expertise. This was important because it was likely that task expertise included a variety of personal, ad-hoc, and implicit processes that were not captured by common task expertise descriptions.

A stratified sample was assembled of active top-managers who possessed a wide variety of expertise types and levels. Furthermore, industry sector was included as a criterion to make sure that a variety of sectors would be represented in the sample. In all, 23 top-managers were selected from the researcher's professional network. Two declined because they did not want to disclose their practices. One refrained from stimuli interpretation (ID 14). Hence, the sample consisted of 20 top-managers (see Table 7).

Table 7: *Sample composition second field study*

Sample Composition						
ID	General Expertise: Age group	Industry Expertise		Job Expertise		Industry Sector
		Depth: Years in current industry	**Width:** Industries worked in > 5 years	**Depth**: Years in current job	**Width**: Years at board level	
1	(61,65]	9	2	11	32	Tertiary
2	(56,60]	28	1	3	15	Tertiary
3	(51,55]	0	1	1	18	Tertiary
4	(46,50]	31	1	13	31	Primary
5	(51,55]	23	1	4	21	Tertiary
6	(51,55]	25	1	3	18	Tertiary
7	(51,55]	26	1	13	17	Secondary
8	(51,55]	6	2	6	7	Tertiary
9	(56,60]	1	1	1	11	Primary
10	(51,55]	11	1	11	11	Tertiary
11	[36,40]	11	1	7	9	Tertiary
12	(46,50]	2	1	2	15	Tertiary
13	(51,55]	5	2	5	10	Secondary
15	(46,50]	25	1	11	17	Tertiary
16	(46,50]	21	1	6	6	Primary
17	(46,50]	2	2	2	17	Tertiary
18	(51,55]	25	2	25	25	Secondary

Table 7 continued:

Sample Composition						
ID	General Expertise: Age group	Industry Expertise		Job Expertise		Industry Sector
		Depth: Years in current industry	**Width:** Industries worked in > 5 years	**Depth**: Years in current job	**Width**: Years at board level	
19	(46,50]	15	2	15	16	Tertiary
20	(56,60]	25	1	1	1	Primary
21	(56,60]	30	1	6	25	Quartiary

Cluster analysis (N=20) resulted in five clusters based on inertia gain. Paragons, the participants closest to the mean of a cluster, were used to characterize the clusters. Paragons point out both the commonalities within a cluster, as well as the difference between clusters. The commonalities and differences enabled precise characterization of each cluster. Together, the characterizations were indicative of the representation of expertise types and levels in the sample (see Table 8).

Table 8: *Participants best representing a cluster (paragons)and the differences between clusters measured in inertia (λ)*

Cluster Representation by Inertia					
Cluster	**1**	**2**	**3**	**4**	**5**
The participant best representing the cluster (lowest within cluster inertia)	3 (λ =0.56)	20 (λ =0.41)	7 (λ =0.66)	1 (λ =0.78)	11 (λ =0.45)
The participant best representing the difference with other clusters (highest between cluster inertia	13 (λ =1.77)	21 (λ =1.53)	4 (λ =1.68)	1 (λ =1.84)	11 (λ =1.92)

Participant 3 represented cluster 1 best (lowest within inertia: λ =0.56), and participant 13 represented the difference with other clusters best (highest between cluster inertia: λ =1.77). The cluster represented medium general expertise, narrow, flat industry expertise, and somewhat wide, flat job expertise. The cluster differed most in industry width (participant 13 possessed wide industry expertise). So, this cluster represented job width, or managerial proficiency.

Participant 20 represented cluster 2 best (lowest within inertia: λ =0.41), and participant 21 represented the difference with other clusters best (highest between cluster inertia: λ =1.53). The cluster represented high general expertise, narrow, deep industry expertise, and narrow, flat job expertise. The cluster differed most from the others in job expertise (participant 21 possessed medium depth and wide job expertise). So, this cluster represented general experts in new jobs.

Participant 7 represented cluster 3 best (lowest within inertia: λ =0.66), and participant 4 represented the difference with other clusters best (highest between cluster inertia: λ =1.68). The cluster represented medium general expertise, narrow, deep industry expertise, and somewhat wide, deep job expertise. So, this cluster represented top-managers that were both industry and job specialists.

Participant 1 represented cluster 4 best (lowest within inertia: λ =0.78), and also the difference with other clusters (highest between cluster inertia: λ =1.84). The cluster represented high general expertise, wide, somewhat deep industry expertise, and wide, deep job expertise. So, this cluster represented top-managers with overall expertise.

Participant 11 represented cluster 5 best (lowest within inertia: λ =0.45), and also the difference with other clusters (highest between cluster inertia: λ =1.92). The cluster represented low general expertise, narrow, somewhat deep industry expertise, and somewhat wide, deep job expertise. So, this cluster represented top-managers with lowest overall expertise, thus relative beginners.

Together, the clusters separated participants into managerial proficiency, general expertise in new jobs, industry-job specialists, overall experts and overall beginners. Thus, expertise types and levels were spread, and the sample composition was regarded as adequate.

4.4. Experiment Task

The task design resembled the two stages of the weak signal process as closely as possible (see Figure 20). The exposure to signals was mimicked with the presentation of several stimuli in random order (see A in Figure 20). The working of the forecasting filter was represented by choosing between stimuli to reject or include in further interpretation (see B in Figure 20). The actual choice of stimuli to include represented the detection stage (see C in Figure 20). If the forecasting filter were at its widest, all stimuli would pass into interpretation (see D in Figure 20). The working of the mentality filter was represented by thinking out loud during interpretation, which would let new or existing links to the prior frame emerge (see E in Figure 20). Patterns in the interpretation stage were also to emerge from thinking out loud (see F in Figure 20). The interpretation of multiple stimuli could let several

levels of perceived weakness per participant emerge (see G in Figure 20).

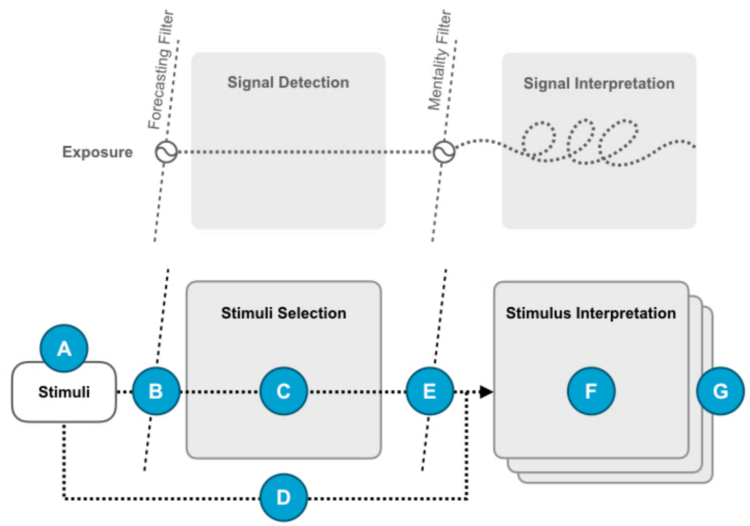


Figure 20: *Approximating process stages and filters in the experiment design*

The sample had been sparingly introduced to the task with an introductory email, explaining that the researcher would appreciate their opinion on emerging developments. The participants were informed that this would take around an hour and a half and that the researcher would like to audiotape the interview for the purpose of analysis. It was also explained that the data would remain with the researcher, and only anonymized transcripts were to be shared with other researchers for the purpose of analysis, and after discretion was secured (see A in Figure 21).

Interviews took place in a quiet, closed room of the participants' choosing. After introductions, the interviewer again asked for permission to audiotape the meeting. When the participant said yes, the tape was started, and the interview began with handing over the stimuli in random order (see B in Figure 21).

At handing over the stimuli, the request was made to interpret several or all scenarios and to think out loud during the interpretation (Goel & Pirolli, 1989; Klein, 1992; Olson & Biolsi, 1991). Then, the top-manager would begin the task by either selecting stimuli as they saw fit, or by instantly interpreting stimuli. Stimuli were interpreted one after another.

Participants were asked to think out loud during the task and to include anything and everything that came into their minds when they read or tried to make sense of the stimuli. The thinking out loud protocol was selected out of several approaches for cognitive task analysis (Klein, 1993) because it reduced the role of the researcher as much as possible while preserving a maximum of detail in the interpretation. The wish to reduce researcher influence ruled out interviews and questionnaires, as well as several types of controlled observation when information is first withheld. The want for maximum detail ruled out both unobserved task-completion, as well as retrospective recall.

The thinking out loud protocol minimized the role of the researcher to specific actions and prompts. The researcher introduced the task, handed out the stimuli, and prompted the thinking out loud. When participants were finished interpreting the stimuli of their choice, the researcher prompted the interpretation of the rejected stimuli. This was important because of the risk that only stronger stimuli would be interpreted. Indeed, it was quite imaginable that participants would reject the stimuli that were very distant to their frame. If the majority of the participants did so, the highest level of perceived weakness and its effects might not emerge from the data (see C in Figure 21).

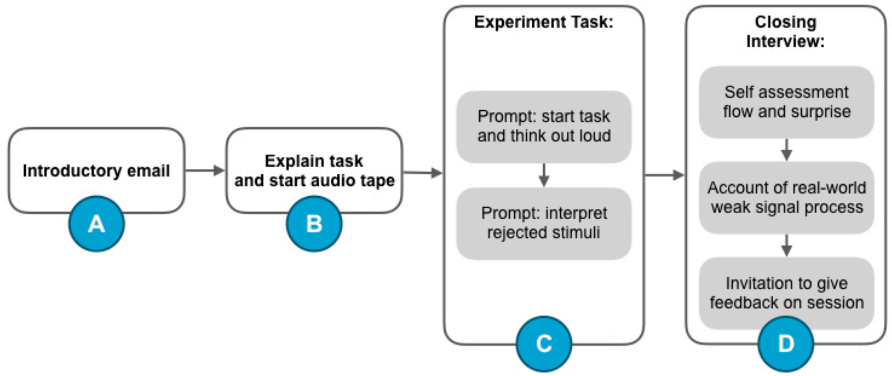


Figure 21: *Flow of researcher actions and prompts*

The thinking out loud protocol has its critics (Schoenfeld, 1985) and the criticisms were taken to heart. For instance, care was taken to only lead the participant into considerations he would have otherwise partaken. For example, no why-questions were asked during the task. Prompts were limited to open questions such as: "What are you thinking about?", "What do you think of the scenarios you initially set aside?". Furthermore, when a single person is asked to think out loud, negative effects can occur for lack of peer support for self-conscious or otherwise nervous participants. The protocol was introduced in an introductory email to minimize these so that top-managers would not feel ambushed by the request. More importantly, sessions took place at an interview room from the top-manager's choosing, where sessions could run without disturbance or unwanted onlookers. This was either the top-manager's office or a closed meeting room, wherever the participant would feel most comfortable.

Criticism also suggested that the cognitive energy of thinking out loud may affect performance. However, the design allowed for multiple iterations of the task, thus enabling a learning experience that may reduce that effect. Furthermore, instructions could strongly affect task performance. Therefore, the introduction of the task was kept short and neutral. The stimuli were handed over while asking: "Please, interpret several or all scenarios as you see fit, while thinking out loud". Some managers wanted to know what selection criteria were needed, and the invariable response was the suggestion to use the criteria the manager always used. Whenever a manager tried to get approval for a selection or a decision, the reply would be: "Please, do as you see fit".

When the participant had finished interpreting stimuli, a closing interview took place to rate levels of perceived weakness and to let task expertise emerge (see D in Figure 21). Two lines of inquiry were created, one for each goal. The first began with a question about the perceived ease of task completion. Considering the work on flow (Csikszentmihalyi & Rathunde, 1993), it was likely that task experts were more likely to experience flow than novices and thus would experience lower levels of perceived weakness. The next question extended the participants' assessments to include the level of surprise or novelty they perceived in the stimuli. It was assumed that ease of task completion would coincide with a lack of surprise and vice versa. It was also assumed that expressions of high surprise would indicate high perceived weakness. Then, participants were nudged to compare their experienced ease or surprise during task completion with their feelings of ease or surprise during the last time they were exposed to new strategic information at work. It was assumed that the comparison would help us judge the salience of the task better.

The second line of inquiry began with a question about the real-world process. It moved the narrative from the experiment task to an account of the actions and policies the participant usually took or oversaw with regards to a possible weak signal process in his company. This narration was extended in two ways. First, participants were invited to position themselves with respect to their colleagues and stakeholders. Positioning elicits language in which participants explain their role and performance in the weak signal process relative to the context they are in. Second, participants were invited to include exposure to or involvement with weak signal processes earlier in their career or personal life. In this part of the inquiry, it was assumed to find the phenomena indicating the depth and width of task expertise.

During the closing interview, the researcher took part actively. The interview used a narrative approach to stimulate the telling about weak signal process experiences, both in the real-world of the participant as well as during experiment task completion. Nonverbal signs of empathy, pauses, and encouragement to say more nudged participants to expand their accounts of their weak signal process. Nudging and following a participant's train of thought was more likely to provide contextual and associative clues than standardized interviewing would have (Gubrium et al., 2012).

The session was concluded with an open question inviting participants to look back on the session and to relay their feedback.

4.5. Stimuli

Research on decision-making has suggested that the quality of decision-making in the lab could be related to its real-world counterpart if it approximated the real-world situation closely enough (Parker & Fischhoff, 2005). Ideally, stimuli should consist of real-world signals and be mutually consistent so that task performance could be generalized over all stimuli. A standardized design could make stimuli mutually consistent. This way, the effect of the stimulus format on the variation of perceived weakness and interpretation patterns could be reduced.

The dissertation's definition described weak signals as perceptions of strategic phenomena detected in the environment or created during interpretation, that are distant to the perceiver's frame of reference. In the real-world, such perceptions were based on incoming information in any shape, whether it be textual, numerical or pictorial, and from any type of source. For the experiment, written information was chosen to serve as stimuli to stay close to the information in newspapers, journals, research reports, and memos top-managers use most apart from personal sources (Auster & Choo, 1992; Robinson & Simmons, 2018). However, a set of

such texts would encompass to much variation to get even a resemblance of stimuli consistency, so one type of written information was reworked into a standardized format such as a written scenario vignette. Scenario vignettes were used before because they could be made ambiguous deliberately to mirror ill-defined real-world information. Ambiguous scenarios were used to explore variation in interpretations (Palich & Bagby, 1995b; Thomas, McDaniel Jr., & McDaniel, 1990), choice of decision strategies (Payne, Bettman, & Johnson, 1988), or the influence of information on strategic assessments (Kuvaas, 2002).

The scenarios had to trigger weakness perceptions in a sample of participants from a wide variety of industries. This meant that industry-specific information would be close to the frames of some participants and distant to others, and thus not well-suited for the development of standardized stimuli. So, a more generic type of information was used that overarched the various industry environments: global trend reports from multiple environmental segments. This way, a wide range of stimuli could be developed that were more likely to trigger weakness perceptions in all participants. The usual segmentation of the environment into a political, economic, societal, technological, and legal segment was followed (Aguilar, 1967; Kotler, 2002; Mendonca et al., 2012; Rowe, Wright, & Derbyshire, 2017). Three scenarios were developed for each segment; 15 in total.

The format of the scenario texts was subject to a specific build-up of information to increase standardization as well as ambiguity. The build-up was borrowed from research into heuristic decision-making, where scenarios are operationalized as a package of multiple environmental cues (Gigerenzer & Goldstein, 1996). A cue is a piece of information that is perceived as a predictor for accurate decision-making; a bit like the perception of the direction and power of the winds rippling through the straw fields is used to predict changes in the weather.

A cue package should consist of five cues because fewer cues were likely to trigger intuitive reasoning and more cues rational analysis (Hammond, Hamm, Grassia, & Pearson, 1987). Capping the number of cues at five would leave room for both reasoning styles. Hence, each of the scenarios would contain five cues. The cues were developed from the trend forecasts of reliable organizations such as OECD and IMF to stay close to relevant real-world future scenarios. Then, cues were deliberately made ambiguous to mimic ill-defined real-world signals. It was likely that this would increase the probability that weakness perceptions could be triggered. Three steps were taken to achieve stimulus ambiguity. First, cues were framed in different levels of certainty. The most uncertain cue would start with “If”, and the most certain cue contained words like “already”. Second, to account for the different effects of threat and opportunity framing (Jackson & Dutton, 1988; Saebi, Lien, & Foss, 2016), one cue was framed in neutral language, and then cues alternated between negative and positive frames. Third, cues were made contradictory to increase the level of ambiguity. The idea of contradictory cues was borrowed from psychological experiments that used ambiguity purposefully to study various forms of information processing (McDermott, 2002). Contradictory cues began with “At the same time,”, and “But” to accentuate them (see Figure 22).

The sequence of cues was identical for each stimulus: the first indicated dynamism and the emergent quality of a signal, the second framed further development of the signal in a positive way by naming drivers, the third in a negative way by naming barriers, the fourth framed possible effects positively, and the fifth framed effects negatively (see appendix D for the 15 scenarios in Dutch).

Each scenario was printed on a separate index card so that scenarios could be shuffled in random order before they were handed as a pile to a participant. An English representation of one of the scenarios is presented in Figure 22.

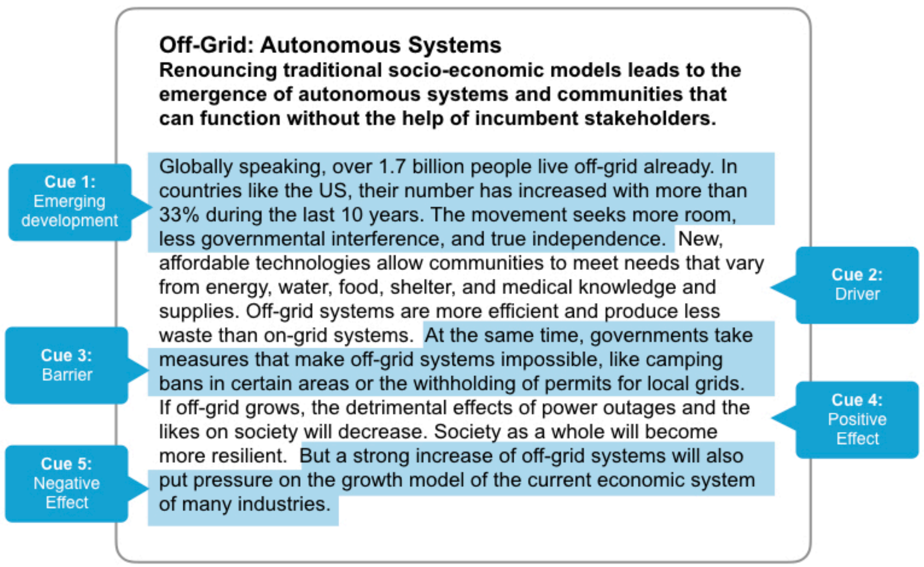


Figure 22: *Stimulus (English translation of one of the 15 Dutch stimulus texts)*

4.6. Data Analysis

The reviewed literature had supplied measures for general, industry, and job expertise, but not for task expertise, perceived weakness, and interpretation patterns. Literature did indicate that such variables could emerge from the qualitative coding of data. Thus, a two-step analysis took place. First, a grounded theory approach was applied to develop the variables, and then multivariate statistical analysis was applied to explore the relationships between the variables.

In the reviewed research, mixed methods were already used to statistically assess aspects that had emerged from qualitative methods (Büchel, Nieminen, Armbruster-Domeyer, & Denison, 2013; Lesca et al., 2012). The sample of top-managers seemed too small for a mixed approach, but the level of analysis was changed from top-managers to task repetitions. The 20 top-managers in the sample could each interpret 15 stimuli, thus reaching a theoretical maximum of 300 task repetitions. This number sufficed for the application of mixed methods.

Coding and variable development are presented in Chapter 5. Statistical analysis is presented in Chapter 6.

4.7. STRAWS Method

In short, the STRAWS method is a type of controlled field research, in which written scenarios trigger rateable articulations of weak signals. The defining elements of the method are the standardized format of the scenarios describing developments per environmental segment in packages of five future-oriented, ambiguous and contradicting cues; the selection and interpretation of scenarios while thinking out loud, and the rating of articulations of perceived weakness (see Figure 23). The rating is done with an index for perceived weakness, which is presented in the Chapter 5.

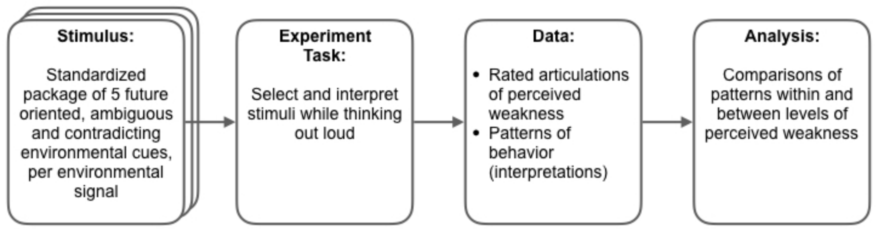


Figure 23: *STRAWS method*

4.8. Validity and Reliability

Experiment designs that require participants to execute a task with the researcher present are prone to experimenter effects. These are caused by monetary rewards, time restraints, issues of experiment realism, and of validation (McDermott, 2002). In the field study, the participants did not receive rewards, monetary, or other. The time frame was set to an hour and a half, to allow enough time for in-depth interpretation of a few stimuli or the more superficial interpretation of all stimuli. Two conditions enforced experiment realism. Firstly, the experiments took place at the office of the participants to approximate realism in the place of action. More importantly, participants had to believe that they were interpreting relevant and real information. Therefore, each stimulus started with the anchoring of its theme in current, broadly dispersed changes in the business environment.

Construct validity was reached by a theoretical assessment that the set-up would expose measurable concepts of the underlying model of expertise types, perceived weakness, and interpretation patterns (see Figure 19, section 4.1.). Measures for general, industry, and job expertise were copied from reviewed studies. Variability of these expertise types was handled by the sample composition (see section 4.3.). Literature on expertise showed that task expertise could emerge from data. Manifestations of its levels were triggered by exposing the stratified sample to ambiguous stimuli under a specific time constraint. According to the reviewed literature, interpretation patterns should have the shape of multiple iterations of the development of meaning. It was likely that iterations would be recognizable in fragments of thinking out loud. Other patterns besides iteration may also emerge from the data. Variation in these patterns was secured by the various types and levels of expertise and by task repetition. The 20 participants could, theoretically, interpret 15 stimuli each. Thus, maximal 300 task repetitions could be compared and contrasted to let patterns emerge. Literature showed that measures for weakness perceptions could emerge from data as well, and its occurrence was checked with a line of inquiry during the closing interview. Finally, a standardized set of stimuli was created to be able to measure as precisely as possible.

Internal validity required certainty that perceived weakness would be triggered, and then influenced interpretation patterns. However, the idiosyncratic nature of perception meant that its occurrence could only be encouraged, not guaranteed. Stimuli were fitted with triggers to encourage weakness perceptions. Triggers were grounded in literature on decision-making and weak signal processing (see section 4.5.). Hence, internal validity could only be judged in hindsight. Internal validity was

raised by changing the unit of analysis from twenty individuals to possibly 300 task repetitions.

External validity must occur through replication of the experiment in successive studies. Thus, the thesis cannot be used to generalize findings beyond its population. However, similar stimuli and tasks have been used in earlier weak signal studies.

Coding reliability was checked with two other coders, who received a transcript, the code tree with 44 codes and short descriptions per code. The coders coded two pages of the transcript. Then their codes and those of the researcher were compared. Two perspectives were used: first, the text fragments that were coded were compared to check that the same fragments were coded or remained un-coded. Second, the codes per fragment were compared to check that the same codes were applied. Thus compared, the interrater reliability kappa value was above .81 without training of the coders (Hruschka et al., 2004; Nili, Tate, & Barros, 2017). So, coding reliability was established.

4.9. Effectiveness of the design

The researcher regularly reflected on the effectiveness of the research design in bringing out the possible effects of expertise and perceived weakness on interpretation patterns.

It soon became apparent that the time limit of an hour and a half was enough for participants to feel free to choose between interpreting all or a few of stimuli. They could take their time during the selection of stimuli, assess perceived relationships between stimuli by sorting cards in groups or piles, and reshuffle stimuli in the course of the interview as interpretations developed.

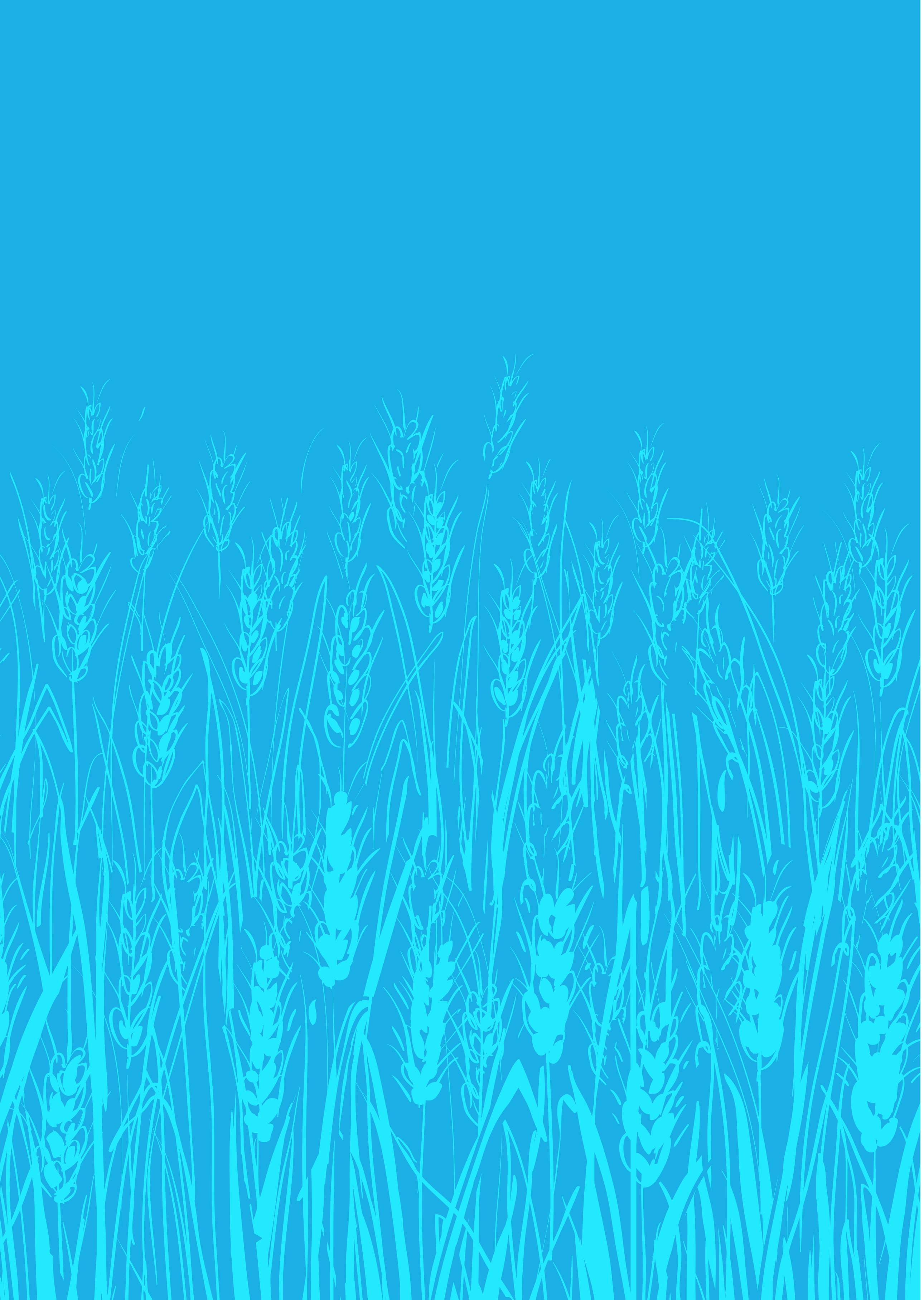
Variation in expertise profiles was indicated by two observed behaviors. Firstly, participants judged stimuli with a wide variety of heuristics. For instance, some would sort stimuli in piles of developments that were happening versus not happening, in layers of influence (personal, business or societal layers), or stimuli relationships (drivers, effects, and conditions). The variation in heuristics supported the variety in frame structure in the dissertation's first field study (see chapter 3). It also supported the cluster analysis of the expertise profiles in the sample (see section 4.3.). A second indication of variety in expertise emerged from the variety of the total number of stimuli that the participants interpreted in an hour and a half: participants interpreted as few as 5 or 7 stimuli, and others as many as 15 (see Table 11).

Of constant concern was the occurrence of perceived weakness, but reflection let two indications of the phenomenon surface. Firstly, some participants formed their opinion on a stimulus by returning to it more than once. When that occurred, interpretation of a stimulus took place in two or three iterations, separated by interpretation of other stimuli. This indicated that some stimuli triggered iterative interpretations and thus, that weakness was perceived. The second indication of perceived weakness emerged from the different strategies that participants used to link stimuli to their frames. Some would freely associate away from the stimulus, watering down the links between the stimulus and their associations to the point that no clear link remained at all. Others used strong links to company strategy as a selection criterion. They did not want to interpret seemingly unrelated stimuli because they felt these stimuli were irrelevant. Participants used salient elements from a stimulus and connected those to current strategy. Less salient elements were linked to analogous experiences. These strategies implied that participants tried to reduce weakness by avoidance (freely associating away), rejection (no link with the strategy), or matching (linking based on salience).

Three major interpretation patterns emerged from reflection on the interviews. The easiest recognizable pattern was linguistic. Some participants interpreted stimuli in fluent, well-crafted sentences, and others stuttered a lot, trailed their sentences, and needed a lot of silent breaks to collect their thoughts. The second pattern was structural: some participants built complex argumentations, and others made do with simply stating “I like this one”. The third pattern was spatial: some participants discussed stimuli as hypothetical possibilities that were far removed from their practice and made no reference to personal or business involvement. Others did express involvement when they showed curiosity, excitement, or feelings of urgency and relevancy.

The indications of variation in expertise and interpretation patterns, as well as the occurrence of perceived weakness validated the effectiveness of research design. Therefore, the experiment task remained intact. However, when insights started to emerge from the coding, minor changes were made to the closing interview in the second part of the sessions. These will be discussed in section 5.2.

In the next chapter, the coding process and the development of reliable variables based on the codes are presented.



5

VARIABLE DEVELOPMENT

It's not about envisioning; it's about seeing

Field Study I; Participant 2

The reviewed literature presented the weak signal process as successive stages and perceptual filters (see section 2.2.2.). The review also indicated that weak signal descriptions were too fuzzy to build a theoretical framework on the weak signal process. Cluster analysis summarized descriptions into six clusters, which were used to develop a new, comprehensive, weak signal definition. The definition defined weakness in the distance of a signal to the perceivers' frame of reference (see section 2.3.1.). The first field study validated the process model (see section 3.4.2.). Its findings on expert frames suggested that expertise played a significant role in the perception of weakness and the interpretation of signals (see section 3.4.3.). However, real-world examples showed that some experts predicted a development accurately and others did not. It was hypothesized that various expertise types might affect the weak signal process differently (see section 1.1. and 4.1.). So, the second field study was designed to explore the relationship between expertise types, perceived weakness, and process patterns. A stratified sample incorporated various types of expertise (see section 4.3.). An experiment task was developed that approximated the weak signal process model (see section 4.4.). Stimuli were designed to trigger perceived weakness (see section 4.5.). A grounded approach was chosen to let occurrences of task expertise, perceived weakness, and interpretation patterns emerge from the data (see section 4.6.).

Chapter 5 describes the technical details of the coding and the development of the variables for task expertise, perceived weakness, and interpretation patterns. Section 5.1. explains how the data was collected and coded. Section 5.2. reports how the coding process induced possible variables. Section 5.3. presents the statistical analysis to reach the final set of variables.

5.1. Data Collection

The experiment took place from December 2016 up and until March 2017. All sessions but one, were conducted by the same researcher to keep variation in the interviewer role to a minimum. One session was done in the presence of another researcher to check the influence of experimenter bias, which was evaluated as low (session 2).

Interviews were audiotaped and transcribed verbatim, including articulations such as “uhm”, stop words and stuttering, and syntax errors such as incomplete sentences or incorrect use of sentence structure.

The transcriptions were anonymized by replacing identifiers such as personal, company, brand, and product names with nouns like customer, company, brand, and product. Anonymous transcriptions were uploaded to NVivo software, version 12.2.0 for coding (Welsh, 2002). The fragments with articulations of the top-managers were included in the analysis; the utterings of the researcher were disregarded.

5.1.1. Data frame development

A grounded theory approach was used to code fragments for occurrences or indications of task expertise, perceived weakness, and interpretation patterns. Grounded theory is a systematic process for the collection and verification of data. The process consists of the constant comparing of text fragments that each represent one instance of a particular pattern. Multiple fragments are seen as a series so that each successive fragment can be used to extrapolate on the former. Extrapolation takes the shape of pattern formation, usually to develop theory (Glaser & Holton, 2004; Glaser & Strauss, 2009). In the field study, the constant comparative method was applied to develop a data frame suitable for multivariate analysis. This type of analysis can explore and visualize individual expertise profiles, weakness perceptions, and interpretation patterns simultaneously. Data frames for multivariate analysis consist of rows of observations and columns of variables.

The text fragments were coded for the steps of the experiment task they belonged to and classified in observation types (see section 4.4. Figure 20). This way, fragments exhibited the selection of certain stimuli to include in interpretation, or the interpretation of a stimulus whether selected or initially rejected by the participant, or articulations from the closing interview. The fragments in which a stimulus was interpreted were used as observations.

Each of the 20 participants was exposed to 15 stimuli. If each of them was to select all stimuli, a theoretical maximum of 300 observations was possible. A lower number of observations was reached because 14 participants selected fewer stimuli for interpretation and did not have enough time to interpret all of the rejected stimuli as well. Six participants were able to interpret all 15 stimuli during the hour and a half session; the others interpreted fewer stimuli. In total, 208 observations were included in the data set. These observations were separated into 159 observations of interpretation of stimuli that participants had selected, and 42 observations of stimuli that had been initially rejected. Furthermore, four participants conveyed their own scenarios that they felt were missing from the set of stimuli. In total, seven of these fragments were included in the observations (see Table 9).

Table 9: *Observations to include in multivariate analysis*

Participant ID	**Interpretation Types**			**Total**
	Selected Stimulus	*Rejected Stimulus*	*Conveyed by Participant*	
1	15	0	0	**15**
2	7	0	0	**7**
3	8	1	0	**9**
4	6	0	2	**8**
5	8	3	0	**11**
6	3	4	2	**9**
7	15	0	0	**15**
8	11	0	1	**13**
9	7	0	0	**7**
10	6	1	0	**7**
11	4	9	0	**13**
12	6	4	0	**10**
13	7	0	0	**7**
15	5	0	0	**5**
16	15	0	0	**15**
17	6	9	0	**15**
18	15	0	0	**15**
19	4	10	0	**14**

Table 9 continued:

Participant ID	Interpretation Types			Total
	Selected Stimulus	*Rejected Stimulus*	*Conveyed by Participant*	
20	7	0	0	**7**
21	4	1	2	**7**
Observations:	**159**	**42**	**7**	**208**

Several steps were taken to generate the variables. Firstly, observations were coded with its participant's scores for general expertise, industry expertise width and depth, and job expertise width and depth (see section 4.3. Table 9). These values were taken from the curricula vitae of the participants. Secondly, all fragments were coded for indications of task expertise, perceived weakness, and interpretation patterns (see section 5.2.). Thirdly, variables were developed from the codes (see section 5.3.).

5.1.2. Set-up grounded theory approach

Before coding could commence, the role of insights retrieved from literature and the first field study had to be determined. In a way, the coder had to off-load insights to become more open to the data. The constructivist approach of grounded theory views previous insights as another observation (Ramalho et al., 2015). Thus, the insights will be included in the analysis, but its framing is reduced. It entailed the framing of insights as imperfect and incomplete, and the use of insights as just another source of codes. The codes from literature were diluted with the codes that emerged from the analysis. In a later stage, codes were grouped in themes, merged or refined by constant comparisons.

Insights from literature were also put to use for the deliberate development of guiding questions for the coder so that the data could be systematically coded. Guiding questions strengthen the consistency of the coding process, as they frame the coder's perspective (Glaser & Holton, 2004; O'Reilly, 2012). Guiding questions were developed for task expertise, perceived weakness, and interpretation patterns (see Figure 23).

The guiding question for the coding of task expertise (mastery of weak signal detection and interpretation) was derived from literature on expertise. It was argued that task expertise developed from a process of skill acquisition, instead of formal training. Skill acquisition was separated into several stages. In the first stage, facts and rules were learned. In later stages, heuristic rules were formed and applied (Dreyfus & Dreyfus, 2017; Kuvaas, 2002). Therefore, excellent skills in weak signal

processing might manifest themselves in references to, for instance, task frequency and recency, knowledge of formal foresight methodologies, or the presence and formalization of foresight processes within the company. Hence, the first guiding question for the coder was: "What articulations of foresight can be interpreted as an incident of task expertise?".

Guiding Questions for the Coder

Task Expertise:

- What articulations of foresight can be interpreted as an incident of task expertise? Why?

Perceived Weakness:

- When surprise, unexpectedness or strangeness is articulated, of what is that a symptom?
- What is the main concern being faced by the participant when information is labeled as new?

Interpretation Patterns:

- How can the articulated thinking in this case represent a pattern? Why?

Figure 24: *Guiding questions for the emergence of codes from the data*

The guiding questions for perceived weakness were derived from a qualitative study by Lesca, Caron-Fasan, and Falcy (2012). The authors supplied the most comprehensive list of possible labels of weakness in the reviewed literature. They had asked a group of top-managers, who were actively involved in the weak signal process, to identify the criteria that could classify a signal as weak. The managers asked themselves why they interpreted certain information as weak. Recurrent remarks surfaced about aspects like the reliability of the information or the relevance of information. Three recurrent questions were directly linked to frame distance. These questions asked after perceptions of novelty, freshness, and surprise of information. These questions were transformed into two guiding questions. The first guiding question was: "When surprise, unexpectedness or strangeness is articulated, of what is that a symptom?". The second guiding question was: "What is the main concern being faced by the participant when information is labeled as new?". A list of Dutch synonyms for words expressing surprise, novelty, and freshness was developed to sensitize the researcher further to open coding. The list was used to have the coding software automatically search the transcripts for the occurrence of these words. These words were then highlighted to make sure that articulations of surprise were not overlooked during coding.

The guiding question for interpretation patterns was derived from literature on comparisons of experts and non-experts (see section 2.2.3.). It was found that expertise helped experts to keep signals and interpretation rules salient in their frame on which interpretation alternatives were developed (Bogner & Barr, 2000; Daft & Weick, 1984; Kiesler & Sproull, 1982). From this perspective, interpretation patterns could consist of comments on possible links between stimuli and the perceivers' frames, and argumentations about possible meanings of the stimuli. Arguably, expertise types and perceived weakness somehow altered these patterns. The guiding question to remain open to pattern recognition was: "How can the articulated thinking in this interpretation fragment represent a pattern? Why?"

After the development of the guiding questions, the coder could begin coding. The coding consisted of three stages. The first stage involved coding and code generation; the second stage involved code tree formation and refinement; the third reflections and the consultation of additional literature (see Figure 25).

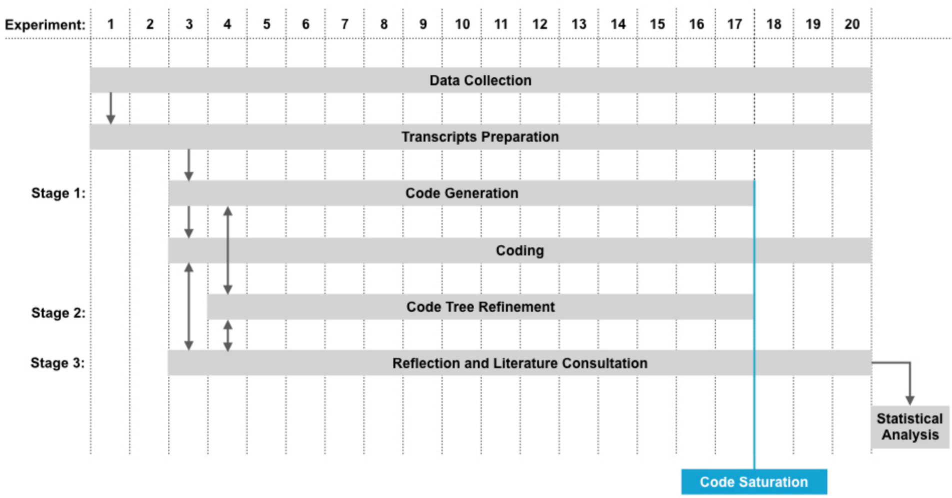


Figure 25: *Steps taken in data collection and analysis*

In the first stage, codes emerged from reading transcripts with the guiding questions in mind. For task expertise, the entire transcript was coded, including the selection task and closing interview fragments. The transcript was perused for articulations of knowledge of and engagement in a foresight task. This included mentions of methods by other companies like the Shell scenarios (Ramírez & Wilkinson, 2016) or the company's own foresight process if there was one. For perceived weakness, all interpretation fragments were perused to find articulations indicative of frame distance. This could include direct articulations such as "I did not know," or other articulations like stuttering or the use of stop words. For interpretation patterns, the interpretation fragments were combed through for articulations of links with the perceivers' frames and argumentation blocks such as claims, warrants, and backings.

In the second stage, a code tree was developed by the grouping of similar codes into branches. Four branches were formed: three branches were for the emerging codes for task expertise, perceived weakness, and interpretation patterns, and the fourth for the codes that classified a fragment. For instance, the branch Weakness (W) was formed by the grouping of fragments coded for expressions of uncertainty or certainty, such as: "I don't know if this [stimulus] will happen at all", and "I know for sure that this will become a reality" (see Table 10).

A code consisted of a letter for the branch, a code category number, and a code name. For instance: W.1.FullyAgreeing referred to the branch Weakness (indicated by W), the code category Stimulus certainty (indicated by the number 1), and the code itself (Fully agreeing). The code was attached to any fragment in which top-managers expressed certainty about their view on a stimulus. Likewise, item "P.4.DrivingForces" belonged to the branch Interpretation pattern (P), code category 4 (Argument complexity), and code Driving Forces. It was used to code the fragments in which a participant named driving forces to substantiate a claim about a stimulus. By naming codes this way, codes could be traced throughout coding and variable development and remained linked to the theoretical model underlying the study. No codes were deleted during the process.

The third stage contained reflections and consultations of additional literature on issues that had materialized. At first, this led to the expanding and refining of code categories. Later in the process, it led to the development of theoretical insights.

Table 10: Final version of the code tree

Code Tree		
Branch	**Code Categories**	**Codes**
Expertise Types (E)	E.1. General expertise	Age groups (5 groups)
	E.2. Industry expertise	Width
		Depth
	E.3. Job expertise	Width
		Depth
	E.4. Task expertise	Naming methods
		Issuing examples
		Implementing
		Delegating scanning
		Following procedure
		Recalling a-ha
Perceived Weakness (W)	W.1. Certain (stimulus certainty)	Fully agreeing
		Fully disagreeing
		Nuancing the stimulus
	W.2. No un/certainty	Neither
	W.3. Uncertain	Hard to interpret
	W.4. Mentality	Sudden awareness of aspect
	W.5. Foresight	Unknown stimulus
Interpretation Patterns (P)	P.1. Linguistic indicators	RepUhm (stuttering and uhms)
		Using stop words
		Faulty syntax
		Trailing sentences
	P.2. Non-salience (in frame)	Articulating thinking
	P.3. Salience (in frame)	Articulating knowing
	P.4. Argument complexity	Claiming opinion
		Creating analogy
		Naming benefits
		Naming consequences
		Driving Forces
		Perceiving impact
		Predicting future
		Stating preference
		Changing perspectives
		Issuing extra data
		Naming conditions
	P.5. Frame complexity	Linking stimuli
		Grouping stimuli
		Linking strategy
	P.6. Word count	Number of words
	P.7. Sentence count	Number of sentences
Classifications (C)	C.1. Interpretation sequence	1-15
	C.2. Interpretation type	Selection
		Interpreting selected
		Interpreting rejected
		Conveying own
	C.3. Industry type	Primary, secondary, tertiary, quaternary
	C.4. Participant ID	ID-1 to ID-21
	C.5. Stimulus sector	Politics, Economic, Societal, Legal, Technological

A stopping criterion of three sessions was adopted beforehand. This meant that the sessions were to stop whenever the coding of three sequential transcripts did not lead to new codes or changes in the code tree (Eisenhardt, 1989; Glaser & Holton, 2004; Glaser & Strauss, 2009; O'Reilly, 2012). So, saturation was reached at session 17.

Two additional measures were taken to verify saturation. First, a coherence check of the code tree by two researchers not involved in the coding, should not, and did not, lead to changes. Second, a literature search, based om the themes in the code tree, was done and analyzed to detect possible missing codes of themes. No codes had to be added.

5.2. Coding

Insights emerged through reflection on code counts and their meaning. For instance, the interpretation fragments of the first three sessions contained several rhetorical building blocks. Blocks consisted of claims like: "This [stimulus] is significant" and warrants like providing examples, naming driving forces, or using analogies to back a claim. Claims could occur on their own or in changing combinations. Reflection on the possible causes for the variation led to the assumption that experts used more complex rhetoric structures than non-experts. A more precise coding of rhetoric was required to allow this effect of expertise to emerge from the data, if it existed. So, literature on argumentation was consulted to flesh out the codes for rhetoric blocks. The Toulmin model for argumentation helped to recognize more elaborate rhetoric elements, such as grounds, qualifiers and rebuttals. The model was used to generate extra codes (Toulmin, 2003). Then, all fragments were coded for these extra codes, including the fragment from the first three sessions. Such emerging insights occurred for each branch of the code tree. However, perceived weakness and task expertise were much harder to recognize than interpretation patterns. These branches were subject to major adjustments during the code tree refinement stage. The major adjustments are discussed below to illustrate how the researcher dealt with her framing and bias, and the painstaking care in the development of variable categories. Both resulted from the consistent coding process.

5.2.1. Task expertise and the certainty problem

Task expertise was assumed to emerge from the data with the help of the guiding question: "What articulations of foresight can be interpreted as an incident of task expertise?" However, the researcher soon reached a point of total confusion between codes for task expertise and perceived weakness. When a participant articulated total certainty in his claim about a stimulus ("I *know* this is going to happen" -italics to visualize the verbal emphasis-), it could be coded as evidence of a strong signal, but also as the effect of superb skills. So, literature was consulted to get more clarity on task expertise.

In the literature, task expertise was viewed as a skill developed by practice (Ericsson & Smith, 1991). It was recognizable when superior performance in task completion occurred. It was likely that superior performance in the session would entail a super eloquent exposé of the meaning of a distant stimulus, its possible effects on the company ordered by likelihood and impact, and motivation of best responses to deal with these effects. The skill requirements for such a superior performance were any cognitive competencies to acquire and apply foresight knowledge fast. It was likely that task experts would be able to quickly slice and label their knowledge in many different ways to help them forge links between weak signals and their knowledge. Speed was deemed central to developing multiple iterations of interpretation and still be able to beat the competition to the market. Therefore, it was likely that superior skill could be recognized by articulations of knowledge, heuristics, and policies to speed up foresight, such as the delegation and formalization of the weak signal process. Seen in this light, articulations of certainty may be the result of task expertise, but not indicative for task expertise. Certainty can also stem from other causes, such as beliefs and thus it was assumed that certainty said more about perceived weakness, than about task expertise.

Following this insight from literature, several job descriptions for foresight specialists were read to become more sensitive to articulations of skill requirements. Rereading the transcripts with these ideas in mind led to the generation of six codes for task expertise: recent involvement in foresight, evaluation of the foresight of others, delegation of foresight to staff, supporting a formalized foresight process, naming of foresight methodologies, and recalling lightbulb moments on the relevance of foresight (see Table 10).

5.2.2. Perceived weakness and the "uhm" problem

In the previous sections, it was argued that weakness is not intrinsic to signals but that it is a perception of the perceiver. That meant the occurrence of weakness perceptions during the session could only be established afterwards. Participants were asked if they perceived signals as new, surprising, or non-familiar in the closing interview to gauge its occurrence or lack of it early. Besides asking participants directly, the coder also tried to recognize perceived weakness in the participants'

articulations. Both tactics felt like clutching at straws because weakness became recognizable only late in the analysis.

The first five participants declined that any of the stimuli had been new, unfamiliar, surprising, or distant in any other way. They only rarely articulated frame distance during the session task. This raised concerns about the effectiveness of the experiment. It was decided to share the concerns with the next three participants. After finishing the closing interview, participants were asked to reflect on the session to help find an explanation for the lack of (recognizable) weakness. They said that they skimmed cues and then matched a stimulus to similar issues in their company. They used the known issue to assess the stimulus. The importance of this explanation sunk in only later on, when it became clear that one of the proxies for weakness, uhmming, did not function.

An above average uhm frequency count in an interpretation fragment was first seen as an indication that weakness was perceived. It was reasoned as follows: if the distance between a stimulus and the frame was considerable, participants would have to think deeply to articulate their thinking, and uhmming would occur. The link between uhmming and thinking deeply was correct, but only rarely caused by weakness. Participant uhmmed foremost when they retrieved examples from memory to back their warrants and claims. In these cases, uhmming signified the retrieval of strong information from the frame. However, the belief in uhmming as a proxy for weakness was still strong, so the fragments with uhms were reexamined to learn more. The fragments with direct articulations of weakness were of particular interest. In these fragments, higher uhm frequency co-occurred with heavier stuttering. Thus, instead of uhmming, a stack of linguistic indicators was considered as weakness indicators. Literature on linguistics offered the use of stop words, trailing sentences, and incorrect grammar as indicators of uncertainty or wonder (Olson & Biolsi, 1991). These were added to the code tree. All fragments were reread to code these indicators if they appeared.

After three more transcripts had been coded, the effectiveness of the stack of linguistic indicators was reconsidered. The variation in code frequencies in fragments per participant, as well as between fragments of participants of various expertise profiles were considered. It resulted in the uneasy feeling that a relationship between perceived weakness and linguistic indicators was not so straightforward if there was one at all. Finally, the researcher's perspective shifted from linguistic *indicators* to linguistic *effects*. Uhmming was no longer seen as an indication that a participant was going to think deeply, it was seen as an effect of thinking deeply. Thus, the linguistic codes were no longer seen as weakness codes, but as interpretation pattern codes.

Around the same time in the coding process, it became clear that the frequency counts of articulations of interpretation difficulties (W.3.HardInterpret) were sparse. Up till that moment in the study, the participants were experts. The low frequency count was tentatively attributed to these high levels of expertise. The successive participants possessed lower expertise levels, so their transcripts were hunted for articulations of weakness with a hopeful heart but to no avail. The persistent low frequencies, the loss of linguistic stacks as an indicator, together with the fact that participants 7 to 9 had said that they interpreted a comparable salient issue within their frame instead of the stimulus, strongly suggested a change of course. It was contemplated that it may be more useful to ask participants to relay or rate weakness immediately after the interpretation of a stimulus. Yet, this felt like an intrusion of the thought process, so changes in the set-up were abandoned. Instead, the literature was consulted once more for indications of weakness. This resulted in the revelation that, besides articulated distance, the passing of signals through perceptual filters may also be articulated. Indeed, fragments were recalled in which a top-manager exclaimed sudden awareness of cues or effects of cues. So, studies on the perceptual filters were read to develop higher sensitivity for filter passages (Ansoff, 1975; Corner, Kinicki, & Keats, 1994; Dufva & Ahlqvist, 2015; Holopainen & Toivonen, 2012; Ilmola & Kuusi, 2006; Mendonca et al., 2012; Nadkarni & Barr, 2008; Starbuck & Milliken, 1988).

Weak signals that passed the first filter (foresight filter) into detection were likely to lead to a sudden awareness of novel information, which differed from the more literal articulated distance (W.3.HardInterpret) already in the codes. In case of a signal that passed the foresight filter, participants would say: “Is that so?”, “I can’t place this”. These fragments were coded with W.5.Foresight after the perceptual filter it represented. Weak signals that passed the second filter (mentality filter) into interpretation were likely to lead to a reevaluation of a known issue. For instance, participants would say: “It had not occurred to me that…”, or “Now that you confront me with…”, or they would use a passive voice and say: “That would be nice if…”. These fragments were coded with W.4. Mentality. The filter codes added to the frequencies of the weakness branch in the code tree, but they also untangled the instances of the code W.3.HardInterpret. The definition of this code became more precise: the filter codes were applied for articulations of sudden awareness, and W.3.HardInterpret was applied for articulations of lack of interpretive confidence.

Thus, the code categories under the weakness branch started to refer to distinct parts of the weak signal process (see Figure 26).

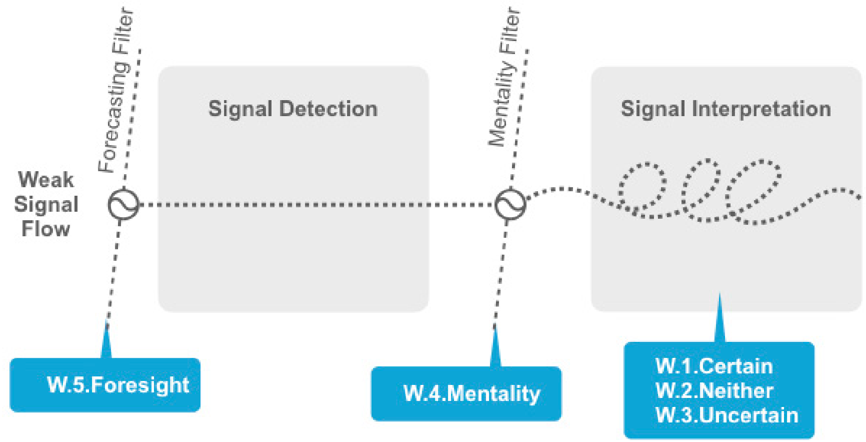


Figure 26: *Emerged codes for levels of perceived weakness*

The code categories seemed to refer to different weakness levels. For instance, a fragment belonging to the code category W.5.Foresight was completely new to the participant: thus, its distance to the perceiver’s frame was large. In contrast, a fragment belonging to the code category W.1.Certain was completely salient, thus had a very small distance to the frame, if any. The other code categories represented distances between these opposites (see Table 11).

Table 11: *Ordinal frame distances deduced from weakness codes*

Ordinal Frame Distances		
Code Category	**Salience Description**	**Deduced Distance**
W.1.Certain	Very salient stimulus	None
W.2.Neither	Neutral stimulus (not explicitly salient or non-salient)	None or small
W.4.Mentality	Salient stimulus triggering new interpretations	Moderate
W.3.Uncertain	Salient but unconfirmed interpretations	Large
W.5.Foresight	New, non-salient stimulus	Very large

5.2.3. Interpretation patterns

Eventually, seven characterizations of patterns were included in the code tree branch for Interpretation patterns. The highest number of code counts went to the word and sentence counts, and then to the linguistic patterns that first were part of the weakness branch, like “uhms” and trailing sentences. Less frequent characterizations reflected salience and non-salience, argument complexity, and frame complexity. Salient and non-salient patterns seemed to indicate the connection between a stimulus and knowledge in the reference frame during interpretation. Argument complexity referred to the number and type of argument building blocks that were used to communicate an opinion on a stimulus. Frame complexity referred to the relationships that participants reported. It emerged from episodes in which top-managers grouped stimuli, noted the influence of a stimulus on other stimuli, or related stimuli to their current strategy.

5.2.4. Code tree

After the analysis of the transcript of participant 17, no new codes were created, and code tree refinement had stopped. Thus, code saturation was reached after the session with participant 21.

The code tree was finalized with four branches. The expertise types branch held the categories for general, industry, job, and task expertise. The perceived weakness branch had five code categories for various weakness indications. The interpretation pattern branch held seven categories of patterns, and the classifier branch held the categories for observations, industry sectors, and participant ID (see Table 10).

5.3. From Codes to Variables

The emerged codes and their counts were used to create a data frame. The rows were formed with 208 observations, which were the fragments in which one stimulus was interpreted, or in which participants conveyed their own uncertain developments (see Table 11). The columns were formed with the codes, from here on called items.

The data frame had a high number of cells containing zeros. These indicated the absence of a phenomenon. For example, a zero for task expertise represented the lack or task expertise, or, in other words, the lowest score for task expertise (zeroes did not represent missing data).

The data frame was imported into SPSS Statistics (version 25.0.01 for Mac). Several significant correlations were found.

5.3.1. Statistical methods

Principal axis factoring (PAF) was chosen because it is an iterative type of factor analysis that refines commonalities between count data until they converge into factors. PAF can be conducted when data are of a comparable nature, and when variance in correlations is found. The data were centered and standardized for compliance with PAF assumptions.

The PAF analysis passed the minimum standard: all observations were included (N=208), the determinant was not zero, KMO was above .7, and the significance of Bartlett’s Test of Sphericity of .000 all indicated that PAF was appropriate (Hair, Black, Babin, & Anderson, 2010). The subsequent analysis consisted of two steps. First, sample adequacy was improved by removing the items with the lowest anti-image correlation, until all remaining items loaded higher than .5. Second, Varimax rotation was added to the criteria to develop uncorrelated factors. Only items loading higher than .5 were kept in accordance with the sample size (Hair et al., 2010, p. 117).

Next, Cronbach α was used for reliability testing of the items loading on factors.

5.3.2. Variable development

The variables for general, industry, and job expertise were derived from literature. Therefore, the PAF included only the codes for task expertise, perceived weakness, and interpretation patterns. The PAF resulted in seven factors that explained variance most. Two items loaded on two factors. The cross-loadings were eliminated by removing the least well loading item from its factor (see Table 12).

The development of variables from the factors is discussed below. First, the development of the variable for task expertise is presented (factor 2), then the development of the weakness index is presented (factor 6). The development of the variables for interpretation patterns are presented last (factors 1, 3, and 4). Factor 5 and 7 did not lead to the development of a new variable and are discussed in the interpretation patterns paragraphs.

Table 12: *Rotated factor matrix of factors constructed from principal axis factoring using Varimax with Kaiser Normalization; rotation converged in 9 iterations*

Rotated Factor Matrix							
Variable (z-scores)	**Factor**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Salient (P.3.)	.77						
Sentence (P.7.)	.60			.56			
Non-Salience (P.2.)	.57						
Predictions (P.4.)	.52						
Delegation (E.4.)		.82					
Method Naming (E.4.)		.63					
Process (E.4.)		.60					
Consequences (P.4.)			.64				
Syntax (P.1.)			.61				
Benefits (P.4)			.51				
Words (P.6.)				.71			
Rep-Uhm (P.1.)				.52			
Stop-words (P.1.)	.52				.60		
Claims (P.4.)					.57		
Certain (W.1.)						.89	
Uncertain (W.3.)						-.78	
Nuancing (P.4.)							.73
Interpretation of Factor:	Sense Making	Task Expertise	Application	No Flow	Not used	Weakness	Not used

Task Expertise

The three items loading on the second factor represented three of the conceptual codes for task expertise. When a participant said that weak signal detection was delegated to staff, the variable Delegation was applied. When a participant named a foresight method such as scenario planning or road mapping, the variable Method Naming was applied. When a participant had formalized weak signal interpretation as a systematic routine, the variable Process was applied. The three variables formed a reliable scale (α =.723). The scale was named *Task,* and created by summing the variables (see variable description in appendix E.6).

Weakness

The variable for perceived weakness was conceptually developed because it was evident that weakness codes referred to different concepts, like filters and stages, or knowns and unknowns. Thus, the formation of a unidimensional scale was out of the question, but factor loadings did influence the variable development. Weakness codes represented the presence or absence of articulations of weakness in an observation. Codes belonged to five distinct categories that each represented a

stimulus' distance to the frame of the perceiver (see section 5.2.2.). The categories were transformed into binary variables, each named after the category. The variables were to form an index of frame distance. Before the actual index was formed, the codes were included in the PAF as a check of the cohesion between the weakness codes and possible other codes.

The two items loading on the sixth factor represented the articulations of certainty and uncertainty about the meaning of a stimulus. The loadings on factor 6 had opposing directions: certainty opposes uncertainty. Thus, one of them should be reversed before the index was created. Since the purpose of the index was to indicate weakness, not strength, the included variables were expected to have the same direction as the variable *W.3.Uncertain*, and thus *W.1.Certain* was reversed. The item representing the forecasting filter (W.5.Forecasting) also loaded on the sixth factor, albeit below .5. The remaining items representing the codes W.2.Neither and W.4.Mentality did not load on factors at all. From these results, it was concluded that weakness items did not belong to other code categories, and thus, the index was formed.

Three variants were created to find the index that exhibited the best expression of the mutual distances within the index. The first variant consisted of a simple sum, the second a weighted sum, and the third of conditional grouping. Weighting and conditional grouping were done to accentuate the values of larger frame distances. The weighted sum correlated best, so this index was chosen (see variable description in appendix E.7).

Interpretation Patterns

The four items loading on the first factor represented four of the conceptual codes for interpretation patterns. Together, the items described the extensive (Sentence) application of salient (Salient) and non-salient information (Non-Salience) from the frame on the stimulus to extend it into the future (Predictions). The items referred to making sense of a stimulus when interpreted as a pattern. The factor items formed a reliable scale (α =.731). The scale was named *SenseMaking*, and was created by summing the items (see variable description in appendix E.8).

The three items loading on the third factor represented the conceptual codes that were applied when a participant articulated the fit of a stimulus with the company as negative (Consequences) or positive (Benefits). The variable Syntax was used for trailing sentences or sentences with bad syntax. The items were interpreted as the interpretation pattern typical for the application of a stimulus onto the company's situation. No wonder that bad syntax was part of the factor: it seemed an obvious effect of the first time, on-the-spot, evaluation of a stimulus.

The factor items formed a scale of questionable reliability (α =.631). Thus, variable formation was reconsidered. Two conceptual reasons in favor of the scale were decisive for its formation. Firstly, the factor seemed to represent a substage of interpretation, similar to the substages found in literature (see section 2.2.2. Figure 7). Together with *SenseMaking*, the factor may cover the interpretation stage more completely. Secondly, the factor may bring some substance the idea that perceived weakness could surge during interpretation (see sections 2.3.1. and 3.4.3. Figure 16). The scale was named *Application*, and was created by summing the items (see variable description in appendix E.9).

The two items loading on the fourth factor represented a code for the number of words in an observation (P.6.Words) and a code for the extent of stuttering and uhmming in an observation (P.1.RepUhm). The items seemed to refer to the flow of thought during interpretation: a smooth stream of words, interrupted by stuttering and uhmming. The factor items formed a reliable scale (α =.720). The scale was named *NoFlow*, and was created by summing the items (see variable description in appendix E.10).

The two items loading on the fifth factor represented a code for the number of stop words in an observation (P.1.StopWords) and a code for the claim that participants made about a stimulus (P.4.Claim). Cronbach α was unacceptable, so no scale was formed. The variables did not seem to add insight to *SenseMaking* and *NoFlow*, so these were dropped from the analysis.

The item on the seventh factor represented the code that was applied when participants were so knowledgeable on a stimulus, that they were able to nuance it with great detail (P.4.Nuancing). The code was conceptualized as an argumentation block, to back claims made about a stimulus. No other items had loadings above .5 for this factor, so the factor was dismissed. Like the items on the fifth factor, Nuancing did not seem to add insight to *SenseMaking* and *NoFlow*, so it was dropped from the analysis.

Thus, three pattern variables were developed. Each variable highlighted a distinct aspect of an interpretation pattern. Firstly, *SenseMaking*, which indicated the sense-

making part of the interpretation. Secondly, *Application*, which indicated the extent to which the interpretation was applied to the company situation. Thirdly, *NoFlow*, which indicated the flow of thought during interpretation. Together, the variables were capable of a multifaceted analysis of interpretation patterns.

5.4. Evaluation of the Variables

Statistical analysis led to the development of a variable for task expertise, a variable for perceived weakness, and three variables for interpretation patterns. Spearman's rho correlation coefficients of the variables revealed significant relationships, which implied that the variables were effective (see Table 13).

Specific correlations indicated that the variables measured the concepts adequately. Firstly, *Task* (task expertise) correlated negatively with *Weakness* (the level of perceived weakness), implying that task experts perceived less weakness (*rs* [208] = -.12, p = .04). This seemed plausible because task experts were familiar with the process and thus likely to feel comfortable with the stimuli. Furthermore, it is likely that high task expertise also lead to more knowledge about the developments that the stimuli described. The effect size was small according to Cohen (Cohen, 2013), which implied that the reduction of perceived weakness by task expertise was not directly observable. Considering that perceived weakness was a rather subtle, cognitive phenomenon, this was not surprising.

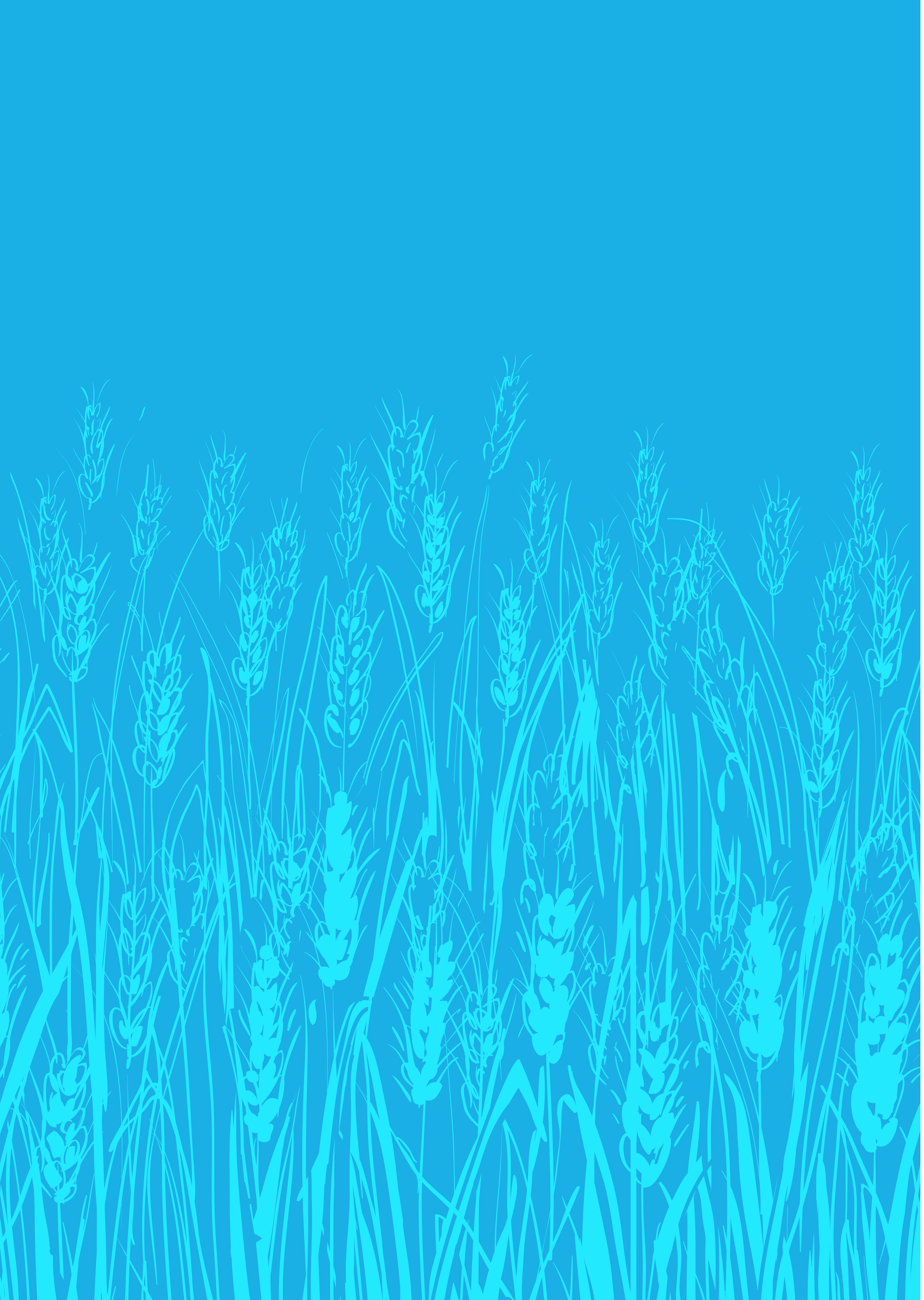
Secondly, *General* (general expertise) correlated to all three interpretation pattern variables, in contrast with the other expertise type variables. General expertise represented the most generic type of expertise, thus the widest frame. Therefore, it seemed plausible that general experts could use information from their frames to interpret stimuli (*SenseMaking rs* [208] = .26, *p* < .001) and apply them to their company (*Application rs* [208] = .20, p < .01), but do so with more stuttering and uhmming (*NoFlow rs* [208] = .15, p = .02) because they were generalists and not used to the task. The effect sizes for each of these correlations were small, indicating that effects were there, but not easy to observe.

Thirdly, the interpretation pattern variables correlated significantly to each other. This implied that the variables measured different aspects of the same concept, rather than different concepts. The effect sizes of the correlations between *NoFlow* and both *SenseMaking* and *Application* were large, which reflected the readily observable nature of *NoFlow* in uhmming and stuttering during the matching of stimuli with information in the reference frames. The effect size of the correlation between *SenseMaking* and *Application* was medium, which meant that it could be discerned through observation by a reasonably sensitive observer.

Thus, the variables were effective and adequate.

Table 13: *Spearman's rho correlation coefficients and Cohen evaluation of the effect sizes; significant correlations are in bold*

		Spearman's rho Correlations (N = 208)								
		General	***IndWidth***	***IndDepth***	***JobWidth***	***JobDepth***	***Task***	***Weakness***	***SenseMaking***	***Application***
IndWidth	Spearman's rho	**.13**								
	P Value	.03								
	Cohen's effect size	Small								
IndDepth	Spearman's rho	**.13**	**-.33**							
	P Value	.04	< .01							
	Cohen's effect size	Small	Medium							
JobWidth	Spearman's rho	**.42**	**.20**	**.25**						
	P Value	< .01	< .01	< .01						
	Cohen's effect size	Medium	Small	Small						
JobDepth	Spearman's rho	-.02	**.37**	**.47**	**.36**					
	P Value	.38	< .01	< .01	< .01					
	Cohen's effect size	-	Medium	Medium	Medium					
Task	Spearman's rho	**.15**	**-.31**	**.13**	**-.21**	-.09				
	P Value	.02	< .01	.03	< .01	.10				
	Cohen's effect size	Small	Medium	Small	Small					
Weakness	Spearman's rho	-.03	**.12**	-.06	**.16**	.05	**-.12**			
	P Value	.36	.04	.18	.01	.22	.04			
	Cohen's effect size	-	Small	-	Small	-	Small			
SenseMaking	Spearman's rho	**.26**	.03	.05	.08	-.01	-.08	**-.12**		
	P Value	< .01	.34	.26	.13	.45	.13	.04		
	Cohen's effect size	Small	-	-	-	-	-	Small		
Application	Spearman's rho	**.20**	-.02	**.26**	.10	.10	**.14**	-.09	**.45**	
	P Value	< .01	.42	< .01	.07	.08	.02	.11	< .01	
	Cohen's effect size	Small	-	Small	-	-	Small	-	Medium	
NoFlow	Spearman's rho	**.15**	**-.14**	**.23**	-.05	-.04	-.04	**-.19**	**.71**	**.54**
	P Value	.02	.02	< .01	.24	.26	.30	< .01	< .01	< .01
	Cohen's effect size	Small	Small	Small	-	-	-	Small	Large	Large



6

EXPERTISE TYPES, PERCEIVED WEAKNESS, AND INTERPRETATION PATTERNS – FIELD STUDY II

The more we let go of what we were used to, the better it went

Field Study II; Participant 4

This dissertation aimed to explore the weak signal process of top-managers and to find out more about the role of expertise in the process. After its first research step, the literature review, it seemed that foundational insights were missing because weak signals were so fuzzily described. This far on in the dissertation's research, the foundation was finally strong enough to venture into unexplored territories.

Weakness was defined as the distance between a signal and the perceiver's frame (see section 2.3.1.). The weak signal process stages and filters were validated (see section 3.4.2.). A relationship between weakness and interpretation patterns was found for two levels: strong and weak (see section 3.4.2.). The pervasiveness of expert frames on the process was also found (see section 3.4.3.), but it did not explain why some experts saw weak signals and other experts did not, and why some experts interpreted signals accurately, and others did not. A closer look at two real-world examples led to the hypothesis that distinct expertise types may have different effects on the process (see chapter 1).

Thus, the second field study set out to explore the role of expertise types in the process. The design of the field study included standardized, real-world-like stimuli, and an experiment task that closely resembled the weak signal process (see chapter 4). The variables to measure expertise types, perceived weakness levels, and interpretation patterns were developed, and the model of underlying variables and relationships was now operationalized with variables (see Figure 27).

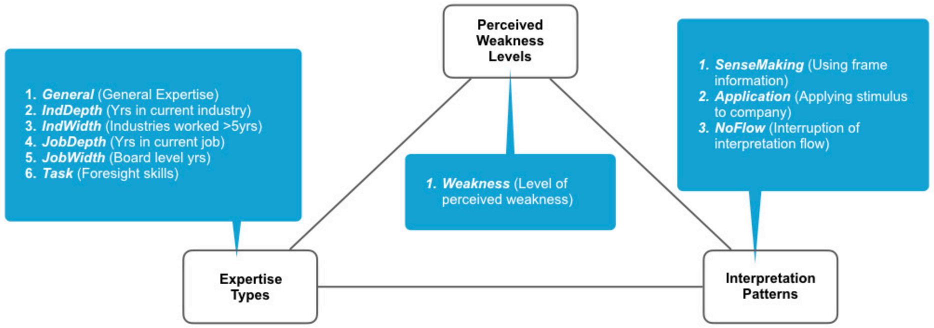


Figure 27: *Underlying model and variables*

The research questions were:

- Do different types of expertise influence interpretation patterns differently?
- Does the level of perceived weakness of a signal influence the interpretation patterns?
- Do the expertise types lead to different levels of perceived weakness?

Two types of statistical analysis were used to answer these questions. First, correlations indicated the strength and direction of the relationships between pairs of the variables for expertise types, level of perceived weakness, and interpretation pattern (see section 6.1.). Second, the data were treated with multiple factor analysis (MFA) to enable visual inspection of the relationships within and between groups of variables for expertise, weakness, and interpretation (Pagès, 2014) (see section 6.2.). The MFA was also used to evaluate the STRAWS method (see section 6.3.).

6.1. Correlations

A series of Spearman rank-order correlations were conducted to determine if there were any relationships between expertise types, levels of perceived weakness, and interpretation patterns. The Spearman rank correlation method was chosen for two

reasons. Firstly, most variables were not normally distributed (see variable descriptions in Appendix E). Secondly, the analysis of weak signal descriptions in literature and the reference frame complexity in our first field study suggested possible surges in perceived weakness levels during interpretation. This implied that the relationships between the level of perceived weakness on the one hand and expertise types and interpretations patterns on the other might not be linear. Thus, the Spearman rank-ordered method was more appropriate than the Pearson correlation coefficient and Kendall's tau coefficient for linear relationships (Hauke & Kossowski, 2011). A one-tailed test of significance indicated that there were several significant relationships. Table 13 displays the correlations (see Table 13). In the following sections, the significant correlations are discussed in the order of the research questions.

Although correlations do not express causality, this dissertation did interpret correlations causally on logical grounds. Participants brought their expertise to the experiment: it was already there before the experiment even started. Certain types of expertise might explain particular interpretation patterns. Thus, one could propose, or even hypothesize, that types of expertise could explain difference in interpretation patterns in line with the correlations between general expertise and interpretation ability as a whole, deep industry expertise and the connection between novel information and its applications to the specific situation of the company, and a supporting effect of task expertise of both general and deep industry expertise. The distinction between perceived weakness and interpretation exists at least theoretically. This dissertation sees perceived weakness as an act of rank ordering stimuli in terms of their closeness to the perceiver's frame of reference. Perceived weakness has been known to affect a stimulus' noticeability and ease of interpretation (Ansoff, 1979; Molitor, 1977; K. E. Weick, 1995). The rank-ordering of stimuli seemed to require less input than interpretation and might occur without understanding or explaining (Starbuck & Milliken, 1988). Therefore, it was assumed that the rank-ordering preceded interpretation. This way, correlations could theoretically indicate causality.

6.1.1. Expertise types and interpretation patterns

The expertise types are discussed from general to specific types. Per type, the statistically significant correlations with interpretation pattern variables are presented. Variation in the significant correlations suggest that expertise types did influence interpretation patterns differently.

General expertise

The Spearman's rho revealed three statistically significant relationships between general expertise and interpretation pattern variables. The level of general expertise related positively to the use of information in the frame for sense-making (*rs* [208] = .26, *p* < .001); the application of stimuli to the company (*rs* [208] = .20, *p* < .001); and to interruption of the flow of interpretation (*rs* [208] = .15, *p* < .02). The higher the level of general expertise, the higher the use of frame information, the more articulations about the application of a stimulus to the company appeared, and the more interrupted the flow of interpretation became (see Figure 28). The effect sizes of the correlations were small (Cohen, 2013).

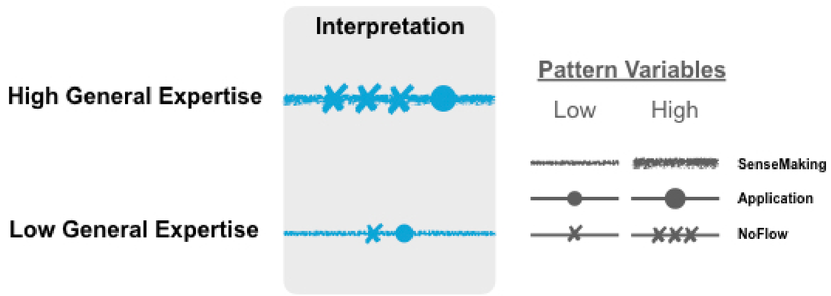


Figure 28: *Interpretation patterns for low and high general expertise include sense-making (rough line), application (dot applied to line), and interrupted flow (x-interrupted line).*

Width of Industry Expertise

The number of industries worked in for more than five years at board level (industry width) was significantly negatively related to interruption of the flow of interpretation (*rs* [208] = -.14, *p* < .02). The wider the industry expertise, the fewer times the flow was interrupted, thus the more fluent the interpretation (see Figure 29).

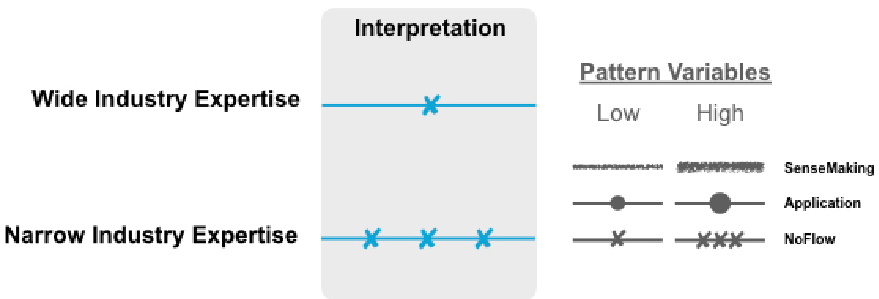


Figure 29: *Interpretation patterns for wide and narrow industry expertise include an interrupted flow (x-interrupted line).*

Depth of Industry Expertise

The number of years worked in the current industry (industry depth) correlated significantly and positively with the application of stimuli to the company situation (*rs* [208] = .26, *p* < .001) and the interruptions of the interpretation flow (*rs* [208] = .23, *p* < .001). The deeper the industry expertise, the more articulations appeared about the application of the stimulus to the company situation, and the more the flow were interrupted, thus the less fluent the interpretation (see Figure 30).

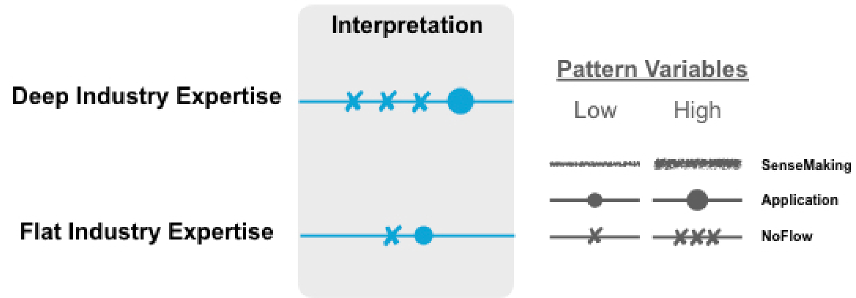


Figure 30: *Interpretation patterns for deep and flat industry expertise include patterns for application of stimuli to the company (dot applied to the line) and interrupted flow (x-interrupted line).*

Width and Depth of Job Expertise

Years worked at board level (job width) and years in the current job (job depth) were not significantly related to interpretation patterns.

Task Expertise

The level of task expertise was significantly related to the number of articulations about the application of a stimulus to the company (*rs* [208] = .14, *p* = .02). The higher the level of task expertise, the more articulations of stimulus application (see Figure 31).

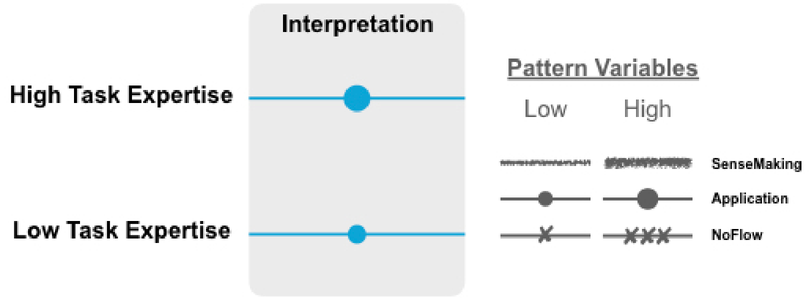


Figure 31: *Interpretation patterns for low and high task expertise include patterns for the application of stimuli to the company (dot applied to line)*

Expertise Types and Perceptual Filters

The significant correlations showed that general, industry and task expertise exhibited distinct combinations of interpretation pattern variables. Therefore, the correlations supported the first research question, as well as the more general notion in literature that expertise influenced interpretation (see section 2.2.3.). Literature also suggested that expertise widened perceptual filters, so that more signals from more categories were included in interpretation. The data included a count of the number of stimuli that each participant selected for interpretation (see Appendix E-14), so correlations between expertise types and number of selected stimuli could be calculated (see Table 14).

The correlation between general expertise and the number of selected stimuli supported the idea of the widening effect (*rs* [208] = .45, p < .01). With a medium size effect, this effect was observable by a sensitive observer. The positive correlation between general expertise and each of the interpretation variables (see section 6.1.1.) showed that it did raise interpretation patterns. The other expertise types had smaller or no effects on the number of selected stimuli and did not have a general size effect on the interpretation pattern variables. Therefore, it seemed that general expertise was responsible for the effect described in literature.

Table 14: *Significant correlations (Spearman's rho, one-tailed) between the variables and the number of selected stimuli*

Significant Correlations of the Variables with the Number of Selected Stimuli						
		General expertise	*Industry width*	*Job depth*	*Task expertise*	*Applica-tion*
Number of selected stimuli	Spearman's rho (one-tailed)	.48	.17	.24	.19	.14
	p Value	< .01	.01	< .01	< .01	.02
	Cohen's size effect	Medium	Small	Small	Small	Small

6.1.2. Levels of perceived weakness and interpretation patterns

The Spearman's rho revealed two statistically significant relationships between levels of perceived weakness and interpretation pattern variables. The level of perceived weakness related negatively to the use of information in the frame for sense-making (*rs* [208] = -.12, *p* =.04) and to interruptions of the flow of interpretation (*rs* [208] = -.19, *p* < .02). The higher the level of perceived weakness, the fewer information from the frame was used for sense-making and the fewer interruptions, thus the more fluent the interpretation (see Figure 32). Thus, levels of perceived weakness exhibited a distinct combination of interpretation patterns.

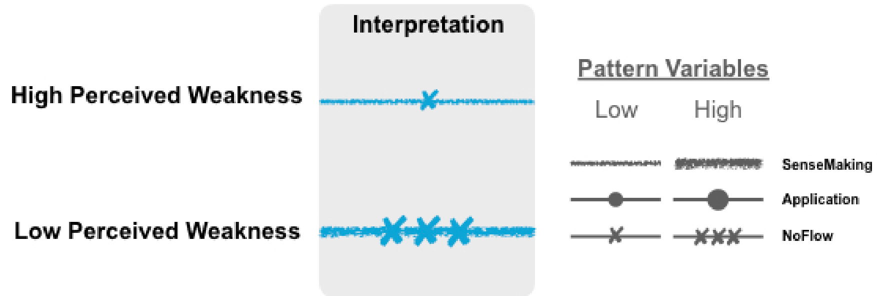


Figure 32: *Interpretation patterns for low and high levels of perceived weakness include patterns for sense-making (rough line) and flow (x-interrupted line)*

6.1.3. Expertise types and levels of perceived weakness

The Spearman's rho revealed three statistically significant relationships between expertise types and levels of perceived weakness. The number of years worked in an industry for more than five years at board level (industry width) and levels of perceived weakness correlated significantly and positively (*rs* [208] = .12, *p* =.04);

years worked at board level and perceived weakness correlated positively (*rs* [208] = .16, *p* =.01); and level of task expertise and perceived weakness negatively (*rs* [208] = -.12, *p* =.04). The wider the industry or job expertise, the higher the level of perceived weakness. The higher the level of task expertise, the lower the perceived weakness. Thus, distinct expertise types influence the level of perceived weakness differently.

The correlation between the level of perceived weakness and number of selected stimuli was not significant. Therefore, participants were not weakness averse or prone in their selections.

6.1.4. Research questions results

The research questions explored relationships between expertise types, perceived weakness, and interpretation patterns (see Figure 27). The first question looked into relationships between expertise types and interpretation patterns. Four expertise types had statistically significant relationships with one or more interpretation pattern variables: general, industry width, industry depth, and task expertise. Each of the expertise type variables led to a different pattern: general expertise led to an interrupted flow of sense making and application of stimuli. Industry width (multiple industries worked in for more than five years) was negatively correlated to interrupted flow (so the wider the industry expertise, the more fluent the interpretation). Industry depth (years worked in current industry) led to an interrupted flow during the application of a stimulus onto the company situation. Task expertise (foresight skill) just to application (see Figure 33).

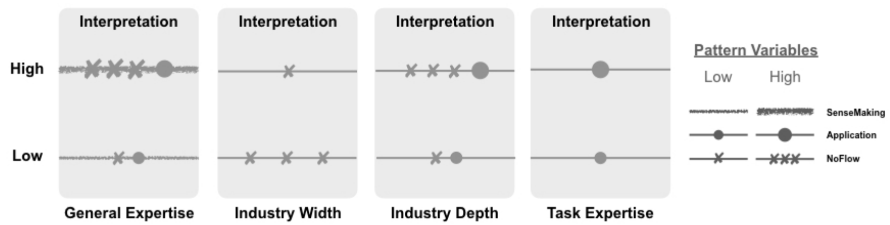


Figure 33: *Expertise types and significantly correlated interpretation patterns*

The different effects of expertise types on interpretation patterns suggest that expertise types might have specific benefits to the weak signal process. For instance, top-managers with high general expertise are likely to have a wider frame of reference. This means that they are able to match a wider range of weak signals to their frames and use similes to apply them to their company's situation. This does not imply that general experts find weak signal analysis an easy cognitive task. It involves deliberate thought and use of memory, hence the stuttering and uhmming. This will be discussed further in chapter 7.

The second research question looked into the relationship between perceived weakness and interpretation patterns. Perceived weakness was significantly but negatively correlated to sense making and interrupted flow. Thus, the higher the level of perceived weakness, the smoother the interpretation pattern. This was unexpected, as the distinction between strong and weak signal patterns in literature (see section 1.1.) suggested more interpretation effort for weaker signals.

The third research question looked into the relationships between expertise types and perceived weakness. Perceived weakness was significantly positively correlated with width of industry (industries worked in for more than five years) and width of job expertise (years worked at board level). It was negatively correlated to task expertise (foresight skill). In other words, top-managers with wider industry and job expertise perceived the stimuli as weaker that the others. This finding suggested that wider specific expertise included knowledge of possible different effects of a signal in different industry or job environments, which possibly increased awareness of signal unpredictability. Task experts perceived the stimuli as stronger, which suggested that these top-managers were more knowledgeable on the stimuli or felt more at ease with weak signals because they knew that they could rely on their skill to interpret them.

Each of the correlations between expertise types, perceived weakness, and interpretation patterns had a small effect size, which meant that it was too small to directly observe (Cohen, 2013). However, this did not imply that the effects were small in a cognitive sense. Like the famous misplacing of a single comma in a prediction of an ancient Greek priestess ("Return, not die in war" versus "Return not, die in war") which led to misunderstandings about victory or death, so can unobservable differences in cognition lead to large real-world effects. This means in managerial practice that the weak signal process is worth pursuing because of a tipping point effect: it helps to detect small changes in the environment with possible large effects in the future of the company. Weak signals may seem insignificant on first sight, so it seems counterintuitive to allocate resources to their detection and interpretation. That weak signal analysis helps to see large effects coming, by which time is gained for to make their company ready for these effects, can provide the rationale to do weak signal analysis despite their seemingly insignificance.

6.2. Multiple Factorial Analysis (MFA)

Participant expertise profiles varied in type and level simultaneously (see section 4.3.), which meant that their expertise profiles were multidimensional. Thus, bivariate correlations between expertise types and other variables did not fully describe the experiment process. An MFA was performed to simultaneously visualize the relationships between and within groups of variables for expertise types, perceived weakness, and interpretation patterns. Observations should be close if they had similar scores for the three groups. This way, the research questions could be answered for the group of expertise types, perceived weakness and the group of interpretation patterns.

An observation consisted of the interpretation of one stimulus. All participants had interpreted multiple stimuli. Thus, the data consisted of multiple observations with the same expertise profile and different levels of perceived weakness and interpretation patterns. A group of classifying variables with, for example, participant ID, could reveal if group variability could be contributed to the group variables or to the participant. Therefore, four groups were included in the MFA: expertise types (six variables), perceived weakness (one variable), interpretation patterns (three variables), and classifiers (four variables) (see Figure 34). The group classifiers included participant ID, observation type and sequence, and industry type. The first three groups were active in the construction of the axes to answer the research questions. The classifier group was only used to evaluate the experiment method (see section 6.3.).

The MFA treated each active group with a principal component analysis (PCA) and then compared the group PCAs to explore the relationships at a global level (Lê, Josse, & Husson, 2008; Pagès, 2014). The software package RStudio was used to do the MFA (version 1.1.442 – © 2009-2018 RStudio, Inc., Boston MA). The script is included in the appendix (see appendix F).

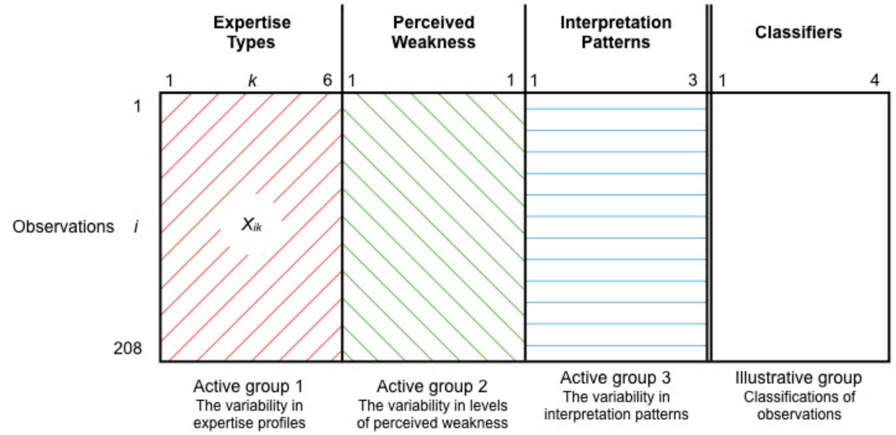


Figure 34: *Data table for the multiple factor analysis, where X_{ik}, is the value of observation i for variable k*

The MFA provided a solution with ten axes. The first two axes had an eigenvalue higher than one. The first axis explained 22.1% of the variance and the second 19.7%, so together they explained 41.7% (see Table 15). The two-axes solution was preferred because only three active groups were included in the MFA.

Table 15: *Eigenvalues and percentage of variance per axis*

Eigenvalues and percentages of variance			
Axis	Eigenvalue	Percentage of variance	Cumulative percentage of variance
1	1.20	22.07	22.07
2	1.06	19.66	41.73
3	0.82	15.12	56.85
4	0.74	13.70	70.56
5	0.58	10.71	81.27
6	0.37	6.89	88.16
7	0.30	5.55	93.71
8	0.15	2.75	96.46
9	0.12	2.21	98.67
10	0.07	1.33	100.00

The MFA plots visualized the covariance in two ways. The global view gave an overview of the trajectories of the variable vectors through the global point cloud of observations (see section 6.2.1.). The partial view showed how the three group

PCA's contributed to the global point cloud (see section 6.2.2.). This dissertation used the visual inspection of the global plot to interpret the correlations and the partial plot as a check on the interpretation of the global plot.

6.2.1. Global view

Figure 35 shows the correlations of the variables per group to the global axes (see Figure 35). Visual inspection of the correlation plot was used to answer the research questions.

Expertise Types and Interpretation Patterns

The group expertise type variables showed the covariation within the group. Task expertise opposed the other expertise types, which suggested that high levels of general and specific expertise (industry and job width and depth) did not lead to high task expertise. It set task expertise apart as a non-industry or job-related skill. These four expertise type variables were almost orthogonal to the interpretation pattern variables, thus showing a negligible influence on interpretation. Only *Industry Depth* and *General Expertise* were close to the interpretation pattern variables, but the vector length of *General Expertise* indicated that this was the only variable of the two that was well correlated to the global axes (see Figure 35a).

The group interpretation pattern variables were close as the three variables covaried in the same direction. The closeness indicated a general size effect of interpretation. The vector of the *SenseMaking* variable was closest to the correlation circle, which showed its high correlation to the second global axis. Therefore, *SenseMaking* was used to explain the behavior of the interpretation pattern group (see Figure 35a).

Visual inspection of Figure 35b showed that *General Expertise* was most responsible for increases in interpretation (see Figure 35b).

Perceived Weakness and Interpretation Pattern Variables

The direction of the vector for perceived weakness was opposite to the interpretation pattern variables (see Figure 35b). Therefore, perceived weakness decreased along with a general size increase in interpretation patterns.

Expertise Types Variables and Perceived Weakness

Perceived weakness opposed task expertise and was positioned almost orthogonal to general expertise (see Figure 35c). This suggested that task expertise, which represented foresight skills, had an opposite effect on perceived weakness in

comparison with the other expertise types. General expertise had no effect on perceived weakness. This was interpreted as follows: task expertise reduced perceived weakness, general expertise did not influence it, and the other types increased it.

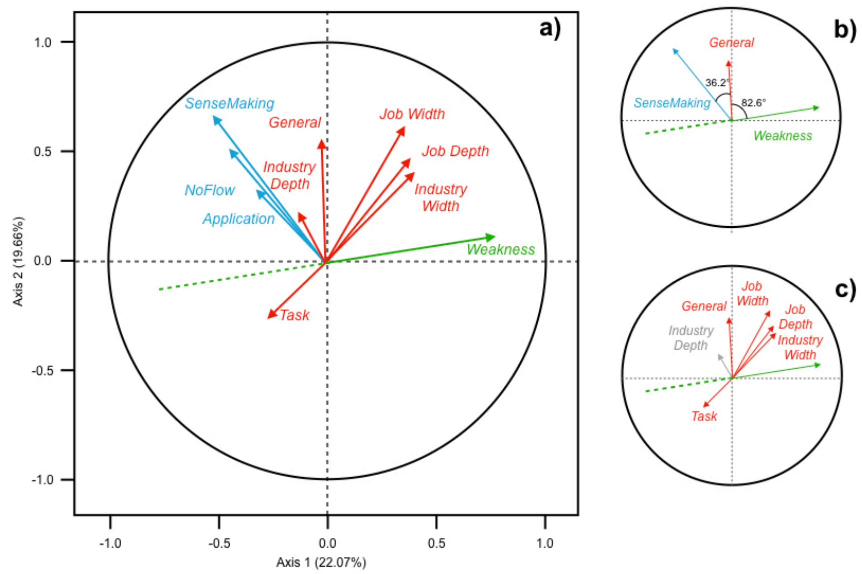


Figure 35: *Correlations of the active variables to the MFA axes; variables color-coded per group (a); isolated vectors for general expertise, perceived weakness and sense making and their angles (b); and isolated vectors for all expertise variables and perceived weakness (c)*

6.2.2. Partial view

Each of the PCAs on the three active groups resulted in a point cloud of observations. This meant that an observation was represented in three group point clouds. The global view of the point cloud was based on the three group clouds simultaneously: it held the mean points of each set of three group points per observation. The partial view of the global point cloud displayed an observation's three partial points and its mean point. When partial points were close to the mean point (low within-individual-inertia), an observation's position was relatively stable across the three PCAs. A long distance between partial points and their mean suggested a discrepancy in the observation between its three describing aspects (expertise type, weakness, and interpretation pattern). Figure 36 shows the partial and mean points for two observations typical for the axes of the global point cloud (see Figure 36). Visual inspection of the plot was used to check the interpretation developed from the group view in the previous section (see Figure 36).

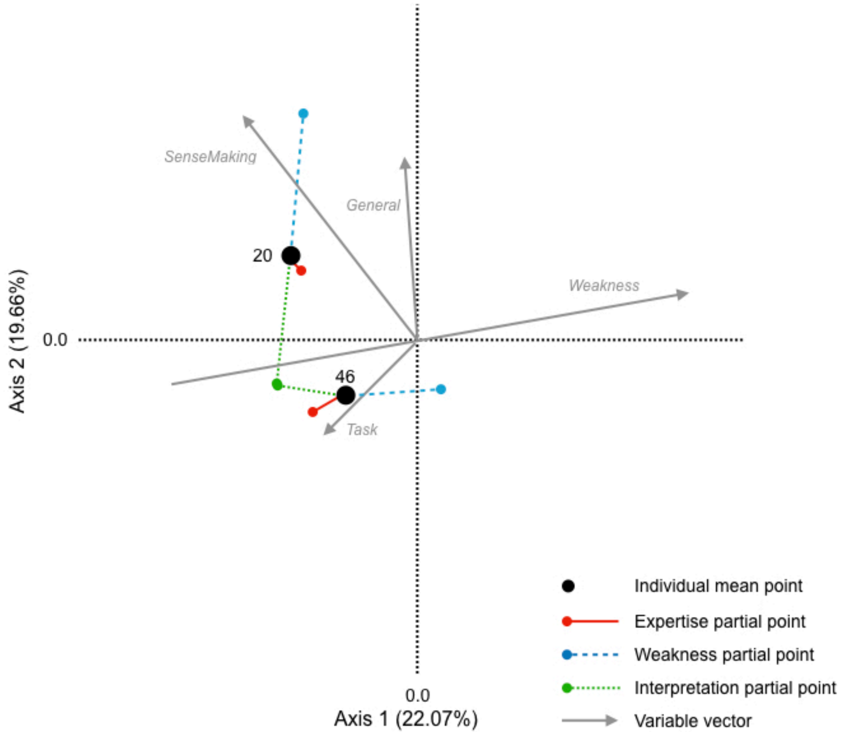


Figure 36: *Partial and mean points of observations 20 and 46; variable vectors (grey) were superimposed on the partial plot as a visual reminder of their trajectories*

The two observations with the lowest within-individual-inertia for both axes were most representative for the global structure. Observation 20 had a within-individual inertia of .0 for the first and .06 for the second axis; observation 46 had a within-individual inertia of .11 for the first and .0 for the second axis.

The red partial points representing the expertise types present in an observation were close to the mean points of the observations. The position of the mean points was influenced most by the larger distance of the partial points for perceived weakness and interpretation. Both observations were similar from the point of view of the perceived weakness group: the two green partial points for perceived weakness were superimposed on the same coordinates. The observations had the same low level of perceived weakness (*Weakness* = 1 or hardly weak). However,

observation 20 was done by a participant with high general expertise (*General* = 4), and observation 46 by a participant with medium general expertise (*General* = 3). The high general expertise resulted in a high interpretation pattern, and the medium general expertise in a low pattern.

The participant of observation 20 possessed lower task expertise than the participant of observation 46 (*Task* = 1 and *Task* = 2 respectively), which pointed out that the possession of task expertise is not a requirement for high interpretation.

In short, the partial point analysis confirmed the interpretation of the global view.

6.3. Evaluation of the STRAWS Method

The group with classification variables contained variables to identify the participants to which observations belonged (*Participant*), whether observations were interpretations of selected, rejected, or conveyed stimuli (*ObsType*), the sequence of observations per participant (*ObsSeq*), and industry type of the company that the participant was currently leading (*IndType*) (see Table 16). The group was used to evaluate the STRAWS method. The variable vectors were estimated by using the information in the active observations and the variables were not used to construct the MFA axes. Coloring the global point cloud per classification variable with different colors for the categories visualized the spread of observations in the cloud for a variable.

Table 16: *Classification variables and their categories*

Classification Variables		
Variable	**Description**	**Categories**
Participant	Classification of observations per participant	Participant ID 1 to 20
ObsType	Classification of observations in type of stimulus interpretation	Selected, Rejected, Conveyed
ObsSeq	Ordering of observations per participant in sequence of interpretation	First to Fifteenth
IndType	Classification of observations in industry sector that the company of the participant belonged to	Primary, Secondary, Tertiary, Quaternary

The variable that identified the participants to which observations belonged (*Participant*), as well as the variable for industry sector (*IndType*) confirmed the variance required for the analysis of expertise types and perceived weakness (subsection 6.3.1.). The variable that identified the sequence of observations per participant (*ObsSeq*) confirmed that levels of perceived weakness were not influenced by sequence (subsection 6.3.2.). The variable that identified the type of observation (*ObsType*) confirmed that participants were not biased in favor of confirming information (subsection 6.3.3.).

6.3.1. Evaluation of variance

Figure 37a presents the MFA factor map with the observations, color-coded for the variable *Participant*. The categories of this variable represented the ID number of participants. This way, the observations of a participant belonged to the same category. Their mean point was calculated and shown as a larger point within the set a participant's observations. A confidence ellipse was drawn around each mean point to accentuate the relative distance between the categories. The spread of the mean points along both axes visualized the variance in the data. This way, the spread of the *Participant* categories along both axes showed that variance occurred and thus that the relationships as defined in the research questions could be analyzed (see Figure 37a).

Figure 37b presents the observations point cloud color-coded for industry sector (*IndType*). Industry sector was included in the classification variables so that a possible effect of, for instance, complexity and dynamism of distinct sectors may become visible. Literature suggested that the exposure to specific industry environments could influence perceived uncertainty within the environment as a result of different perceptions of the level of unpredictability of developments within industry environments (Duncan, 1972). In our first field study a difference occurred between participants from the high-tech sector (quaternary) and the other sectors. The participants from the high-tech sectors did not recall weak signals (see section 3.4.1.). This was attributed to the focus of these participants on emerging technologies.

If such an effect were to exist in the second field study, it would show as a distinct horizontal spread of *IndType* categories, with the category Quaternary at the left and the other categories as the right. Figure 36 (left) shows a slight spread of the categories along both axes and the spread along the first axis was not as expected. It was plausible that the slight spread was caused by the category sizes and the values for expertise types. The category Tertiary was by far the largest (127 observations). It was situated close to the origin. The smaller categories were spread along the axes as a result of their values for various expertise types. In the sets of observations per participant, values for expertise type did not vary, while they did vary for the other variables. The categories Secondary and Quartiary were closest together because these categories were created from participants with similar levels of general expertise

and width of job expertise. The category Primary was situated lower on the second axis because these participants had lower levels of general expertise and higher levels of depth of industry expertise (see section 4.3. Table 9). However, the mean points for the categories were relatively close to the origin. Thus, it was concluded that industry sector did not describe the spread very much. This means that perceived weakness occurs in any industry, regardless of their complexity and dynamism.

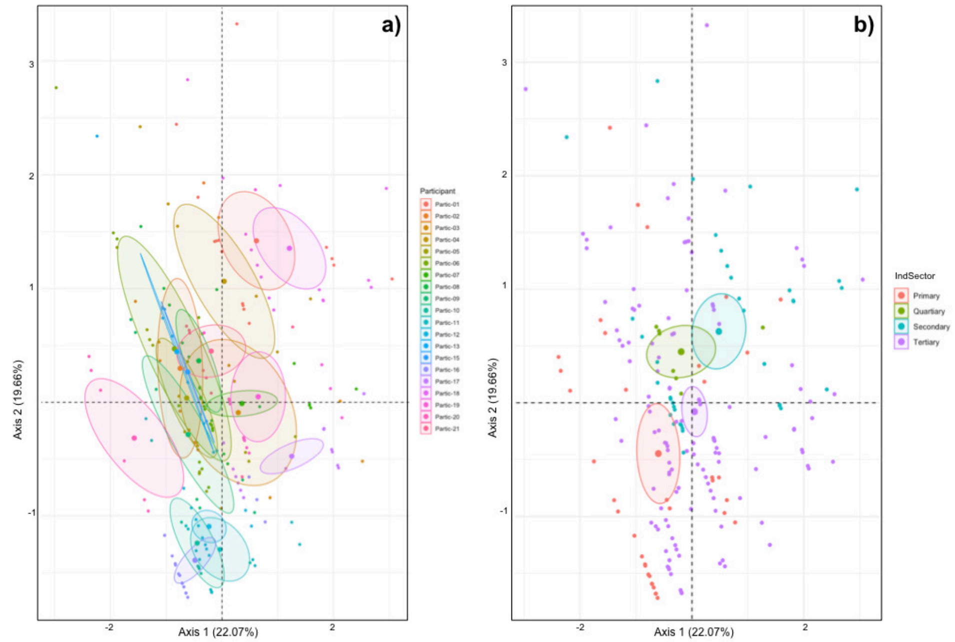


Figure 37: *Spread of observations for participant ID (a) and industry sector (b)*

6.3.2. Evaluation of the experiment task

The experiment task consisted of the interpretation of several standardized stimuli representing developments in several segments of the environment. This way, task repetition was to trigger multiple levels of perceived weakness per participant (see section 4.4.). However, task repetition could also lead to a learning curve or to increasing anxiety, leading to an undesired stepwise decrease or increase of perceived weakness levels per repetition.

The lack of stepwise decrease and increase in levels of perceived weakness was visualized by comparison of the factor map with observations color-coded for the variable for observation sequence per participant (*ObsSeq*) and for levels of perceived weakness (*Weakness*), both presented in Figure 38. The categories First to Fifteenth were not in sequence along the first axis (see Figure 38a), to which the variable for levels of perceived weakness was highly correlated (see Figure 38b).

Another effect did materialize: participants who interpreted more stimuli had a higher variation in levels of perceived weakness. This was visualized by the larger distance to the origin of the mean points of the categories Thirteenth, Fourteenth, and Fifteenth, as well as the larger ellipses drawn around these mean points (see Figure 38b).

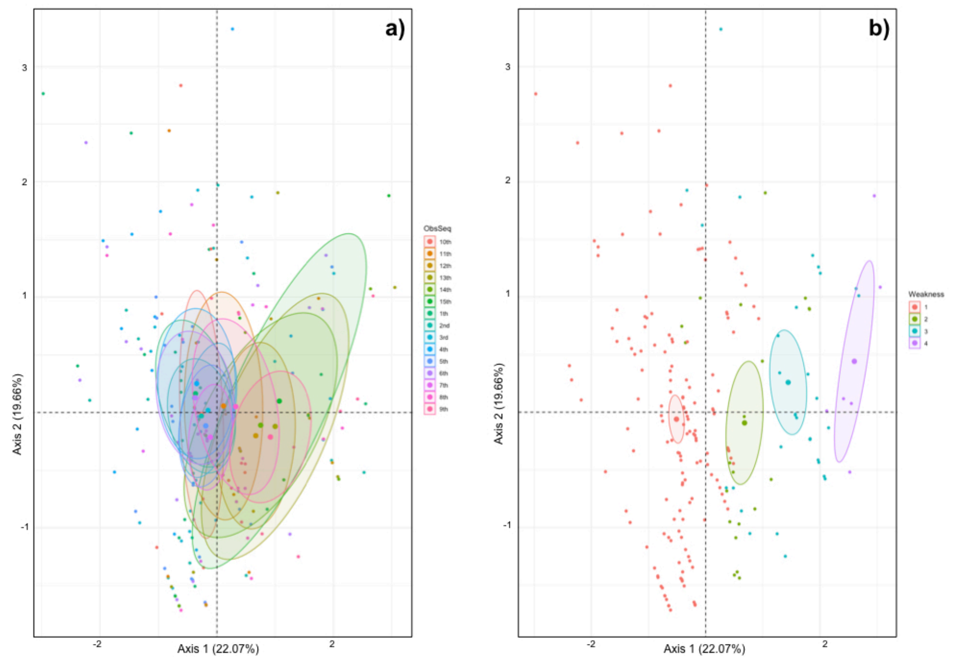


Figure 38: *Factor maps of observation sequence (a) and levels of perceived weakness (b)*

6.3.3. Evaluation of the presence of undesired bias

It was assumed that undesired biases as uncertainty aversion, confirmation bias, or experimenter bias would skew the findings towards lower levels of perceived weakness during the interpretation of selected stimuli. Participants were prompted to interpret rejected stimuli after the interpretation of selected stimuli to avoid the

skew (see section 4.4.), but that did not prevent possible biases from occurring.

No considerable tendencies to select less weak stimuli were visible in the comparison of the factor maps with observations color-coded per type (*ObsType*) and with the level of perceived weakness (*Weakness*), both presented in Figure 39. The variable for observation type categorized observations in interpretations of stimuli that participants had selected (Selected), interpretations of stimuli initially rejected (Rejected) and similar developments that participants conveyed of their own accord (Conveyed). Figure 39a visualized the categories spread of the categories foremost along the second axis, with the mean point of Rejected (green) below the origin and the mean points of Selected (blue) and Conveyed (red) above the origin. The category Rejected (green points) was situation below the origin, indicating that these observations had the lowest interpretation patterns. The category Selected (blue points) was the largest and contained high spread along the sense-making variable, which explained its mean point's position close to the origin. The position of Conveyed (red points) reflected the lengthy train of thought that this type of observation exhibited. This ranking along the interpretation pattern vector is highly plausible, because it reflected that participants had more knowledge about the conveyed developments than about rejected stimuli. However, this did not mean that conveyed developments could not be perceived as weak (see red point at the right side of the first axis), or rejected stimuli as strong (see green points at the left of the first axis).

So, the STRAWS method was tested for undesired experiment effects, and the findings presented in 6.3. show these did not occur. That means that the STRAWS method was reliable.

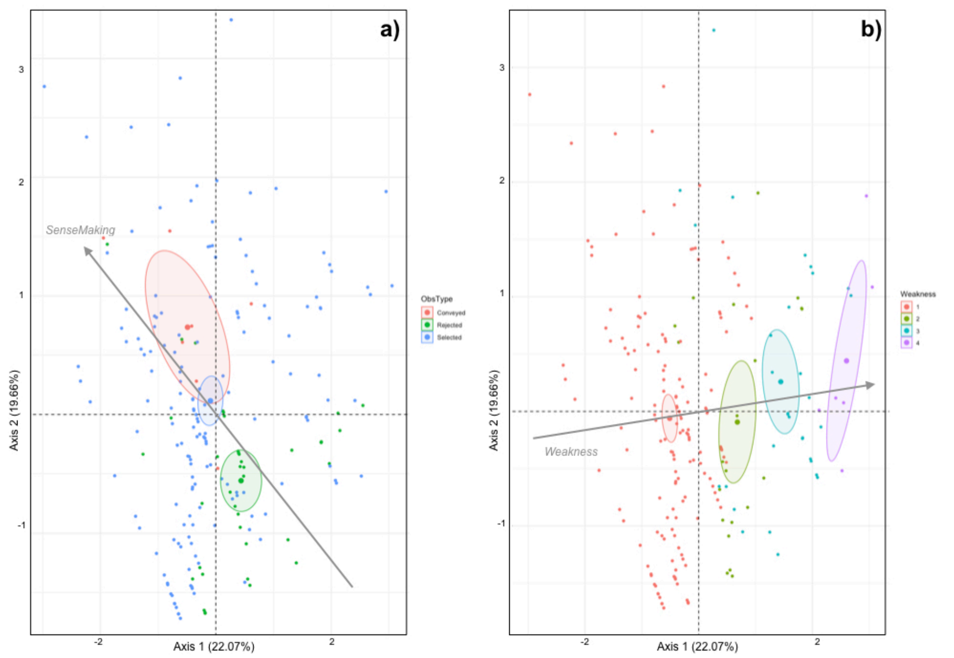


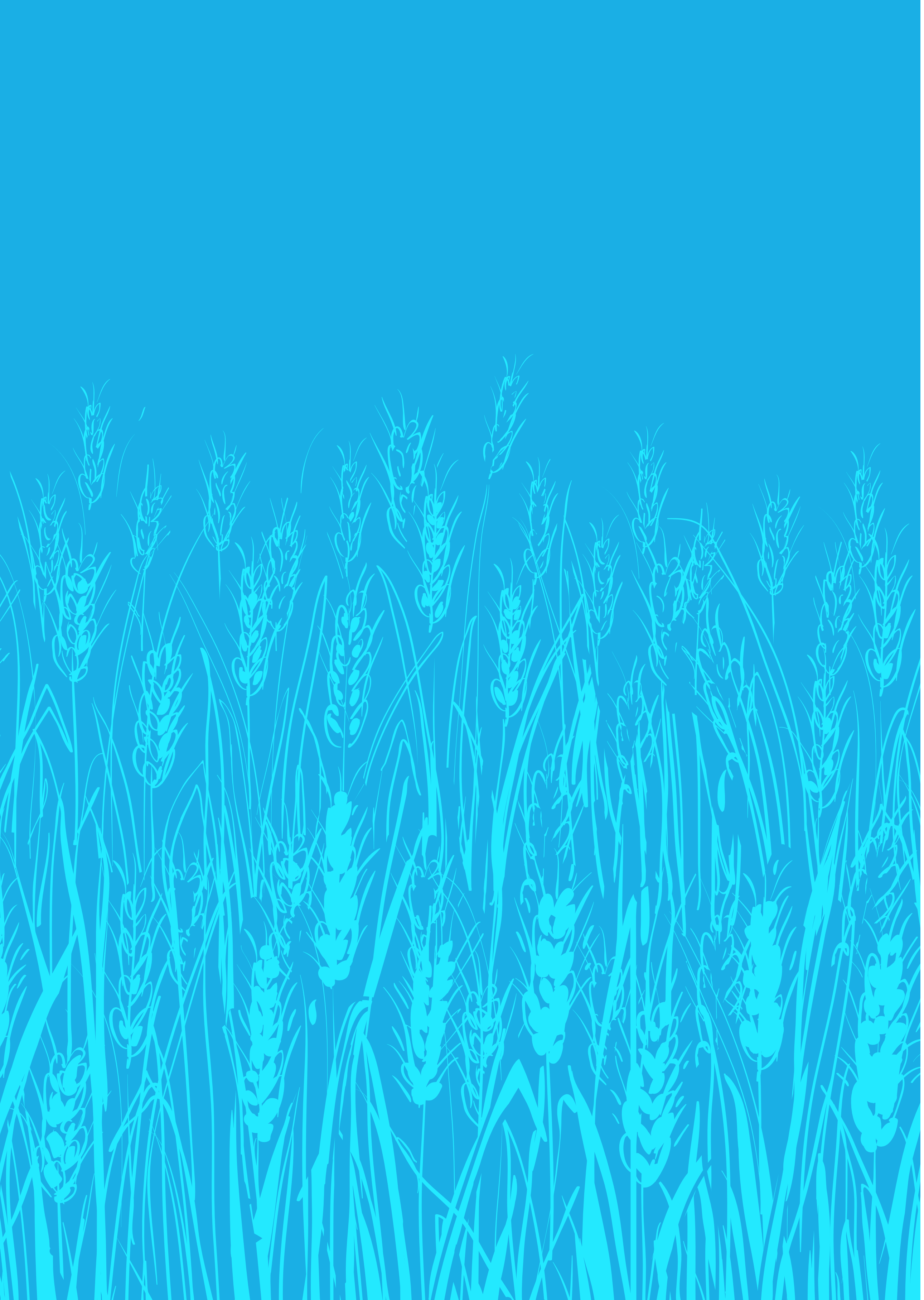
Figure 39: *Factor maps of observation types, vector for the SenseMaking variable superimposed for illustration purposes (a) and levels of perceived weakness (b)*

6.4. Back to the Research Questions

Correlations and visual inspection of the MFA plots were consistent in their support of the research questions. Firstly, expertise types influenced expertise patterns differently. General expertise increased sense making, application of stimuli to the company and interrupted flow, thus having the largest effect. Industry depth affected application and interrupted flow, industry width affected interrupted flow negatively, and task expertise affected application, but to a small extent. This meant that general expertise was most responsible for extensive interpretation.

Levels of perceived weakness reduced sense making and interrupted flow of interpretation. This meant that very weak signals were easily interpreted as not important, because there was so little known about them that they could not be linked to the company at all. In those cases, a short “I don’t think this is relevant” sufficed. Such a short and smooth interpretation pattern resembles a strong signal pattern. This meant that the relationships between perceived weakness and interpretation is likely to be non-linear.

Expertise types influenced perceived weakness levels differently. Industry width (multiple industries worked in for more than five years) and job width (number of years worked at board level) increased perceived weakness, while task expertise decreased perceived weakness. This meant that wider specific expertise types such as industry and job width most likely increased awareness of the interpretation difficulty of a signal, and that task expertise increased confidence in interpretation accuracy.



7

DISCUSSION AND CONCLUSIONS

Then they asked: "Please, tell how the economy will perform in the next four years". That is, of course, a non-sense question.

Field Study II; Participant 1

The scientific contributions of this dissertation are threefold. The new weak signal definition helps to solve the problem of fuzzy weak signal descriptions and the subsequent lack of validation in weak signal research. The STRAWS method consists of guidelines and tools to investigate the weak signal process for multiple levels of perceived weakness. It also brought new theoretical insight into the role of expertise in the weak signal process.

The findings underpinning these contributions are discussed in the following sections. First, the basics of weak signal research are discussed. Then the STRAWS method is examined in section 7.2. The theoretical findings are debated in section 7.3. The scientific relevance of these findings and their limitations are discussed in section 7.4. The managerial relevance is presented in the shape of recommendations for top-managers in section 7.5. The section is concluded by suggestions for future research.

7.1. Basics of Weak Signal Research

Weak signals referred to a fuzzy concept that described a variety of signal types or the many aspects that made the signal weak. Types could include phenomena like trends (Thorleuchter & Van den Poel, 2015), the information behind trends (Yoon, 2012), or shocks (Barreto, 2012). Weakness originated from, for instance, low information quality (Saritas & Smith, 2011), high impact uncertainty (Kuvaas, 2002), or paradoxical information (Liebl & Schwarz, 2010). The range of signal types and origins made it conceivable that studies investigated different concepts at worst, or different levels of perceived weakness at best. For instance, a study on low quality trend information may result in relatively lower levels of weakness because trends are rather salient, even when badly reported. In comparison, a study on the cause of paradoxical shocks may raise levels of perceived weakness due to its paradoxical character, even though it used the comfort of hindsight to collect data.

Clarity of the weak signal concept is essential so that levels of perceived weakness can be rated and findings can be validated for the correct level. A new weak signal definition was derived from cluster analysis of the reviewed descriptions to remedy the fuzziness (see section 2.3.1.), and a field study was developed to validate the weak signal process and pattern (see section 2.3.2.).

7.1.1. Weak signal definition

The literature review resulted in 68 weak signal descriptions containing various combinations of 30 keywords (see appendix B for the data table). A cluster analysis was used to elicit groups of keywords that were responsible for most of the variation in the definitions. A new definition was created based on the clusters (see section 2.3.1.).

The dissertation uses the following weak signal definition:

> **The perception of strategic phenomena detected in the environment or created during interpretation that are distant to the perceiver's frame of reference**

The most striking finding was the emergence of a cluster that referred to a seemingly random set of signals that, once interpreted, disrupted the interpreter's frame (cluster 6). It is this cluster that explained weakness levels in a measurable way: the distance of new information to information already in the frame.

Distance expressed weakness more precise than the usual terms like ambiguity (Barreto, 2012), incompleteness (Blanco & Lesca, 1997), or unfamiliarity (Wang & Chan, 1995). At first glance, these terms may seem similar, but each of them tells a slightly different story. Ambiguous or incomplete information presupposes that there is information available. However, scholars also mentioned signals that are merely sensed or felt (King, 1984). In those cases, there is no information consciously available. Limiting weakness to ambiguity or incompleteness could exclude vital weak signals. Unfamiliarity, like frame distance, refers to information that the perceiver has not recognized or has not been exposed to, but it can also refer to known, strange information. In this sense, unfamiliarity is not as precise as distance to the perceiver's frame. Thus, a more exact definition could clarify the concept and explain how results should be interpreted.

The new definition was applied to both of the dissertation's field studies so that the occurrence of perceived weakness could be established. In the first field study, 13 expert top-managers recalled critical situations and the new information leading up to them. During recall, they articulated frame distance almost literally. For instance, participant 13 said: "you want [knowledge] that goes further than the usual". Participant 7 said: "This [knowledge] did connect, but not overlap" (replacement of information with which participants can be identified in brackets). In the second field study, 20 top-managers of mixed expertise types and levels interpreted multiple weakness triggering stimuli while thinking out loud. Again, participants articulated distance almost literally. For instance, participant 2 said: "This [signal] is a long way from my usual [business]". Participant 5 said: "[Signals] that were far four years ago, are now [reality]". Thus, frame distance was recognizable in the articulations, and it did indicate weak signals.

The scientific implications of the new definition are threefold. Firstly, cluster analysis summarized the keywords into six clusters that explained the variance, while retaining most of their meaning. The keywords from the reviewed descriptions are traceable to a cluster. The new definition was built on the clusters and so formed a framework to which the descriptions can connect. Shared keywords can help to validate findings, and also to separate findings that are only seemingly connected. This way, weak signal research can be organized in a meaningful framework of validating studies.

Secondly, the new definition allows for the proper attribution of results in weak signals studies. Hitherto, the level of perceived weakness was only rarely determined. Instead, weak signals were retrieved from the sample or outside experts, and may or may not have been weak in the eyes of the study participants. Measuring perceived frame distance requires that researchers make sure that their stimuli are indeed perceived as weak by the sample. This avoids the attribution of strong signal findings to the weak signal process.

Thirdly, viewing weakness in terms of distance can extend weak signal research from foresight into decision-making. When weakness is the distance dimension of information in and outside the frame of reference, then both can be expressed in numbers such as available facts. The smaller the distance, the denser (higher number of facts) and the more concrete the information is likely to be. The larger the distance, the less dense, and the more abstract the information. Inversely, the more concrete, the denser, and the smaller the distance of information. These possible relationships turn distance into a strategic dimension. When there is more concrete information, interpretation is easier and likely to lead to opportunistic decision-making. When information is more abstract, it is harder to make it actionable, and decision-making is likely to be postponed or to be more conservative. Thus, distance can reverse decision-making from opportunistic to conservative and back, which means that distance can be used as a parameter in the evaluation of decision alternatives (Fiedler, 2007). This also has exciting managerial implications because it points to distance as a means to objectify the perception of weak signals as well as reducing risk aversion caused by anxiety about uncertainty and change. As such, distance supports the collaboration in diverse teams because it can connect viewpoints otherwise negatively perceived as, for instance, risky, untrue, or subversive. And so, top-managers should include perceived frame distance as a criterion for focused search (larger distance) and for decision-making (smaller distance), as well as frame viewpoints during interpretation in terms of relative distance.

7.1.2. Validation of weak signal process stages and filters

The reviewed literature described the weak signal process with four stages, each separated by a perceptual filter. The first, preliminary stage consisted either of the recognition of the problem for which weak signals were required, or the preparations for search. The signals from the environment that fitted the first stage passed the first perceptual filter. The filter was called forecasting filter, and it consisted of the method and criteria the perceiver used for search. After passing the forecasting filter, signals landed into the detection stage, where the perceiver became aware of them. The second filter, called mentality filer, sat in between detection and interpretation. It consisted of the beliefs and knowledge that perceivers used to interpret signals. After passing the mentality filter, signals landed into the interpretation stage. This stage had two steps: first, a preliminary assessment of relevance and then further analysis to develop meaning. The third filter, called power filter, sat in between interpretation

and action. It consisted of the loss and distortion of signal information caused by interaction about signals (see section 2.2.2.). The reducing effects of power filters on signal inclusion were for instance caused by groupthink or self-interest. Framing viewpoints in terms of relative distance may help counter these effects, because the deliberate framing in distances can keep help defer judgments to a more opportune moment as well as move judgments away towards more neutral territory.

The problem with this process was that it belonged to both strong and weak signals. Only the pattern that a signal followed through the process distinguished weak from strong signals. Weak signals could be rejected by each of the perceptual filters and required a more intense interpretation stage. Strong signals would flow seamlessly through the filters into action. Thus, findings from studies with a fuzzy weak signal definition still adhered the same overall process, while the distinct features of a weak signal process may not surface. Therefore, it was uncertain if the weak signal process as described resembled a stronger process or a weaker process.

The dissertation's first field study was performed to make sure that the weak signal process and signal patterns were as described in literature, while simultaneously exploring the role of reference frames in the process. The field study repeated the design of two earlier studies to validate the process, but this time with explicit evidence that weakness was perceived. The field study found evidence of all stages and filters, but also of adjustments to the process (see section 3.4.2.). The adjustments reduced the negative limiting effects of the perceptual filters on signal inclusion by stipulating search parameters and sources, as well as the involvement of seminal people within the organization, with different perspectives all the while deferring judgment on a signal (see Figure 40).

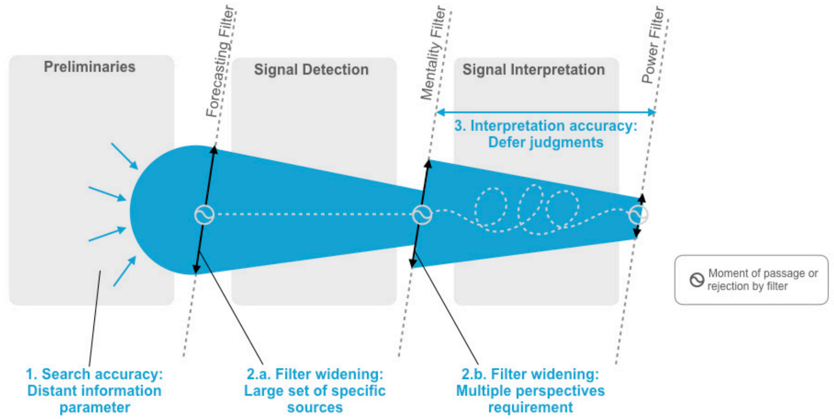


Figure 40: *Adjustments to the weak signal process in blue*

For the management practice, the findings imply that companies can increase search and interpretation accuracy by removing some of the cognitive barriers in their foresight process. For instance, explicit attention to distant information can be included in foresight assignments. A relevant list of valuable sources can be developed over time, when referencing and evaluation of sources becomes a standard step in foresight. Organizing special the occasional cross-functional session to interpret findings improves interpretation, especially when cognitive diversity is included as a criterion for participation.

Remarkably, when top-managers stipulated search parameters, they referred to frame distance. For instance, participant 2 said to look for information they did not recognize that was dissonant to the shared logic of the company. In other words: the findings validated the process, but specified the filters to include distant signals, which altered the weak signal pattern into a broader, longer pattern. This way, the accuracy of detection and interpretation was raised.

The finding of the adjustments was almost more important than the validation of the process. Interestingly, foresight scholars have recently been focusing on the development of complex methodologies to widen perceptual filters to reach the same effect as these simple adjustments (Derbyshire, 2017; Khan & Quaddus, 2004; Meissner & Wulf, 2013). For instance, scenario planning includes the exploration of distinct environmental segments to remedy the presumed narrow sightedness of the industry focus of top-managers. In light of the new definition and process findings, these methodologies may not be as effective. Such widening of focus may reduce the effects of perceptual filters, but also confound weak signals. For instance, weak signals may originate from within the industry focus but are overlooked because of their distance to the perceiver's frame. A widening of focus does not directly remedy that. Furthermore, widening the focus extends detection to include plenty of information that may be new, but also irrelevant. In other words: accuracy of weak signal detection and interpretation is improved by process improvements rather than the improvement of the quality of information or enlarging the quantity of information. Hence, the validation of the process strengthened the foundation of weak signal research. The adjustments to the process raised the significance of the role of the filters in the process. Narrow perceptual filters protect top-managers from information overload and low signal to noise ratios, but also cause collateral damage by missing relevant and urgent weak signals. Specific process adjustments help to widen perceptual filters, but in a targeted way. Instead of just widening filters to let in more signals and noise, filters are adjusted to only add relevant distant signals to the mix and to keep noise to a minimum.

In combination with the new definition, the adjustments pointed towards new possibilities in the refinement of foresight methodologies, as well as a focus for future research. Benefits of methodologies may be easier to measure, improve, and validate when the new information they bring in is seen in terms of the frame distance. Insights from measurable effects of perceptual filters in terms of variation of frame distance may help to research the factors that contribute to the detection of the right signals at the right time.

The adjustments also had managerial relevance. Besides guidelines to improve foresight processes, the findings revealed a distinct beneficial aspect of diversity. Diversity in the workplace is often advertised to increase aspects like productivity, profit, and employee engagement. If diversity is interpreted as cognitive diversity, increased decision accuracy can be added to that list of benefits. Cognitive diversity presumes that the same information will be at different frame distances so that together, a cognitively diverse team can interpret more weak signals with more ease more accurately (Bogner & Barr, 2000; Eisenhardt, 1989; Lyles & Schwenk, 1992). Discussions framed in various distances can shorten the shared distance as parts of one viewpoint can close the distances in others, without getting bogged down in arguments over beliefs.

7.2. Tools: the STRAWS Method

From the outset, scholars have introduced weak signals as an emerging phenomenon with multiple weakness levels. The weakest signal was merely sensed. It was the feeling that a phenomenon may become very important to the company, without knowing how, when, or why. When more concrete information emerged, weakness levels decreased stepwise. Steps included information about the origin of the signal, estimations of the effect of the company's responses, or operational results that reflected the first impact (Ansoff, 1975).

The decreasing character of perceived weakness required research designs capable of triggering and measuring multiple levels of perceived weakness. However, the reviewed designs treated weakness as binary: stimuli were either strong or weak. Stimulus weakness was based on participant self-assessments before studies commenced. The occurrence of weakness was seldom checked during or after the experiment. Thus, the designs functioned as a rather blunt instrument.

Refinement of research designs meant tackling at least the following three problems. Firstly, stimuli cannot *be* weak, only *perceived* as weak by participants. Thus, stimuli must trigger perceptions of weakness, instead of containing weakness. Secondly, the actual occurrence of perceived weakness must be verified so that results could be attributed to perceived weakness. Thirdly, levels of perceived weakness must be discernable, to learn more about the gradual emergence of weak signals.

Hence, a standardized format for stimuli was developed with the intention to trigger perceived weakness. Stimuli consisted of trend scenarios of five conflicting and ambiguous cues, based on real-world global trend extrapolations in 5 distinct environmental sectors. Top-managers interpreted several stimuli while thinking out loud. Multiple stimuli were required to up the chance that multiple levels of perceived weakness were triggered. The thinking out loud technique was used to collect articulations of frame distance, which were used to develop a perceived weakness index with multiple levels (see chapter 4). Together, stimuli, task, and index formed the STRAWS method: scenario triggered rateable articulations of weak signals (see Figure 41).

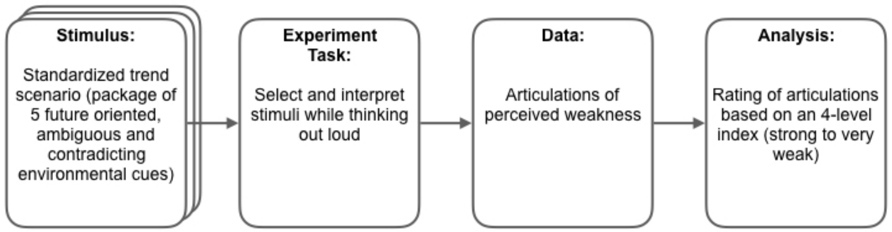


Figure 41: *The STRAWS method*

The STRAWS method was applied and evaluated in the second field study. The stimuli did trigger multiple levels of perceived weakness in all of the 20 participants. Evaluation of the task showed that task repetition had no negative effects on levels of perceived weakness per participant: no stepwise increase or decrease in levels, so no learning curve or growing anxiety was present (see section 6.3.). Correlations of the weakness index with expertise variables showed expected directions. It correlated significantly and positively with width of industry and job expertise, and negatively with task expertise. The correlations implied that the wider view caused by working in multiple industries for more than five years, or by many years worked on board level increased perceived weakness, and that foresight skill decreased it. This seemed plausible, as wider views may have led to more knowledge about multiple interpretations and effects of distant phenomena, while skill in dealing with distant information may reduce anxiety caused by distance or increase confidence in that stimuli could be interpreted and interpreted accurately. Thus, the index did measure the intended concept (see section 5.3.).

Especially the stimulus format and the perceived weakness index may have beneficial implications to research on weak signals. Standardized stimuli may raise the validation of findings across studies and within studies. The weakness index contributes to a clearer understanding of the difference between strong and weak signals. The index can be used to confirm the presence of perceived weakness in the sample, as well as separate findings for the various weakness levels. Alone or in combination with the new definition, stimulus format and index can strengthen the theoretical framework underpinning weak signal research.

The flexibility of the method contributes to its strengthening power. In the dissertation's field study, the STRAWS method was used to explore interpretation patterns typical for levels of perceived weakness and expertise. However, the method is not limited to that goal. It can easily be adapted to accommodate pattern comparisons in other stages of the weak signal process. Furthermore, the method can be adapted to fit larger samples for the benefit of comparing and contrasting sample splits, such as various management levels or types of experts. In those set-ups, the method can be fully digitized for online application by the random showing of stimuli, the subsequent recording of interpretations, and transcription of recording into texts. Finally, the stimulus format stipulates the design of a cue package, which is not bound to specific content. Thus, researchers can fit contents to their goals, while still trigger perceived weakness.

7.3. Theory on Expertise Types

The dissertation's central question was how the weak signal process works for top-managers. Top-managers can be considered as experts on the weak signal process for several reasons. Top-managers are responsible for strategy, which represents the course of a company into the future so that it can withstand change. Thus, top-managers are likely to be exposed to weak information and able to deal with ambiguity and unfamiliarity. Second, the word 'top' in top-manager suggests that they manage the weak signal process successfully or else they would probably not or no longer work at top-level.

The weak process consisted of four stages and three perceptual filters, but the dissertation focused on the middle part of the process. The preliminary stage was replaced by stimuli, and the last perceptual filter and stage were omitted because these represented the interaction part of the process. In the dissertation, the process consisted of the forecasting filter, the detection stage, the mentality filter, and the interpretation stage (see Figure 42).

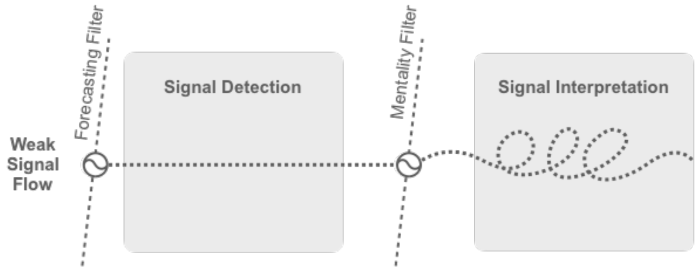


Figure 42: *Explored stages and filters of the weak signal process*

Literature suggested that the flow of weak signals through the process was different for experts. Experts had a wider forecasting filter so that they could detect more signals. Experts also had a wider mentality filter so that they could develop multiple interpretation alternatives simultaneously (see section 2.2.3.). In contrast, experts and top-managers possessed different types of expertise. The dissertation operationalized expertise in general expertise, width and depth of industry expertise, width and depth of job expertise, and task expertise so that possible variance could be explored.

Thus, the field study's underlying model consisted of relationships between expertise type, perceived weakness, and interpretation pattern (see Figure 43). The first research question explored the relationship between expertise types and interpretation patterns (see Figure 43, line 1). The second explores the relationship between the level of perceived weakness and interpretation patterns (see Figure 43, line 2). The third the relationship between expertise type and the level of perceived weakness (see Figure 43, line 3).

The experiment (field study II) with 20 top-managers resulted in 208 observations of interpretation, which were coded for task expertise, perceived weakness, and interpretation patterns. Principal axis factoring of the emerged codes resulted in five variables: task expertise, weakness, sense-making (the use of frame information to make sense of a stimulus), application (the application of a stimulus to the company environment) and interrupted flow (the extent to which the flow of interpretation was interrupted by stuttering and uhmming). The data was then organized in a table containing 208 rows of observations, six columns of expertise type variables, a column for the perceived weakness index, and three columns for the interpretation pattern variables. The data table was used to reveal Spearman's rho correlations and multivariate relationships between the groups of variables (multiple factor analysis).

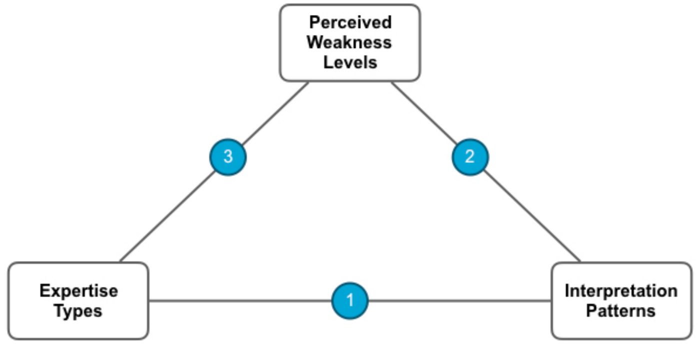


Figure 43: *The model of relationships that the expertise study explored*

7.3.1. Expertise types and interpretation patterns

In the reviewed studies, it was argued that expertise showed in more extensive interpretation, but that seemed to be only partially true. The dissertation revealed two ways in which expertise types influenced interpretation patterns.

Firstly, general, industry, and task expertise influenced the extent of interpretation pattern types sense-making, application, and interrupted flow. *Sense-making* referred to the extent to which information from the participants' reference frames was used to make sense of a stimulus. *Application* referred to the application of a stimulus on the participants' company. *NoFlow* referred to the amount of stuttering and uhmming that interrupted the flow of interpretation.

Industry width was negatively correlated, while general, industry depth, and task were positively correlated to pattern types. (see section 6.1.). The patterns were visualized to accentuate the variation (see Figure 44).

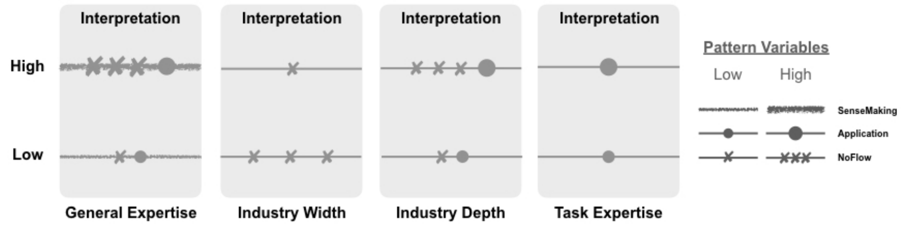


Figure 44: *Expertise types and related patterns*

Secondly, correlations between expertise types and the number of selected stimuli showed that general expertise had the most widening effect on perceptual filters, and that other types had smaller or no effects on filters.

Thirdly, the MFA pointed out that different expertise types had different effects on the overall interpretation size.

This implied that expertise is relevant for interpretation, but for particular reasons, as was hypothesized. General experts may have the most to contribute to the overall process. Their wider frame will help to make sense of signals that might otherwise be rejected or remain unseen, and help to apply signals to the company's situation for assessments of impact. Wide industry expertise may not help at all, even though their interpretations were more fluent. Specialist expertise, such as industry depth or task expertise, may have most to contribute in the interpretation stage, when signals must be applied (see Figure 45). This may explain the success of the expert top-managers' adjustments to the process, who deliberately included multiple sources and viewpoints in the process of people with special expertise.

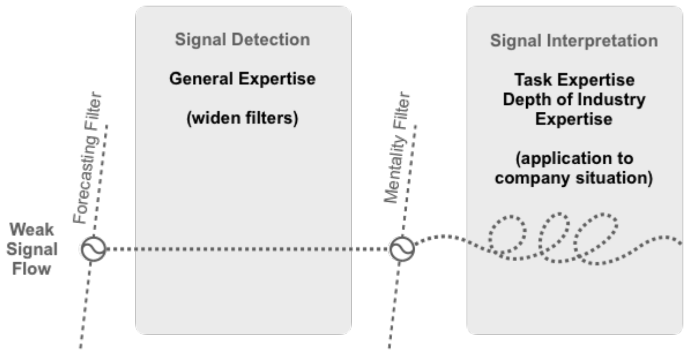


Figure 45: *Expertise types and positive contributions to the weak signal process*

Looking back on Peter Schiff's ongoing battle with other experts about the effect of the housing market crisis on a possible recession (see Chapter 1): these experts had deep industry knowledge, thus deep frames, which differed in the beliefs about the meaning of dept. In this case, opposing deep industry frames led to an impasse, instead of the deferral of judgment and the collection of other viewpoints like our expert top-managers of the first field study would have suggested. The example could be interpreted as another call for cognitive diversity in the weak signal process. Thus, it can be hypothesized that expertise types have distinct merits and pitfalls in the interpretation of weak signals. Furthermore, their effect may differ per process stage and filter. Research on these hypotheses is valuable for the strategic deployment of talent and teams dedicated to foresight. Finally, combined expertise types in management teams may explain the variation of interpretation accuracy between competing companies. When delegating or formalizing foresight processes in their company, top-managers should consider the composition of a team of people with various expertise types. The team composition should follow the development of meaning, so that general experts are more involved in detection and industry experts in interpretation. Furthermore, findings suggest that the top-manager should not refrain from taking part in foresight, as his uniquely wide overview is instrumental in seeing the right signals in the detection stage of the process.

7.3.2. Perceived weakness levels and interpretation patterns

Literature had stated that weak and strong signals flow differently through the process. If weak signals made it through the filters into interpretation, multiple iterations were required to make sense of them (Camillus & Datta, 1991). In contrast, strong signals flowed seamlessly through all stages and did not require much interpretation. Hence, it was likely that weaker signals would trigger higher values for interpretation patterns than stronger signals.

The reviewed studies applied signals as a binary variable: a signal was either weak or strong, and the interpretation pattern was either extensive (weak) or not (strong). This was interpreted as a positive relationship: the weaker the signal, the more extensive the interpretation (see Figure 46, left).

In contrast, the weakness index in this study correlated negatively with two interpretation pattern variables: sense-making and interrupted flow (see section 6.1.). The negative correlation pointed out that a high level of perceived weakness resulted in a fluent, less extensive interpretation, while low levels resulted in more sense-making, which was more interrupted by stuttering and uhmming (see Figure 46, right).

This reversed relationship between literature and our findings suggest that perceived weakness is not linearly related to interpretation. Very weak signals and strong signals may present a similar seamless and fast interpretation pattern, so deliberate attention should be paid to the frame distance of a signal. When distances do not emerge from the interpretation, strong and very weak signals can come across similarly. That way, misinterpreted signals can drop from the process or pass into the action stage for the wrong reasons and with possible detrimental effects of missed emerging impacts.

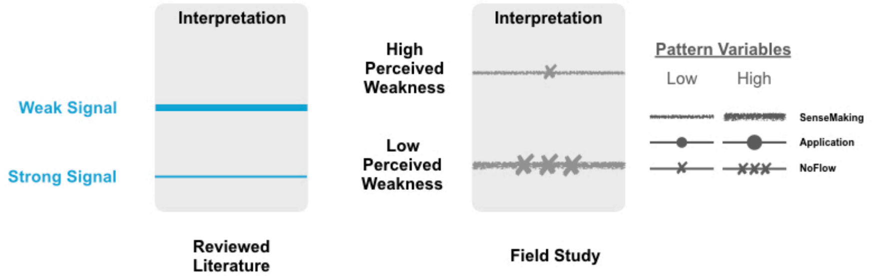


Figure 46: *Visualization of interpretation patterns described in the reviewed literature (left) and by the correlations in the field study (right)*

It seems logical that interpretations of very weak signals were less extensive. Indeed, very weak signals are well outside the frames of their perceivers. Thus, perceivers had less information to pull out of their frame that may help them interpret very weak signals. It is also plausible that interpretations of hardly weak signals were more extensive than very weak ones. Hardly weak signals are at least partially represented in the frame. Thus, perceivers had more information available to retrieve from the frame for sense-making. Retrieving information from memory, especially when it is not wholly salient, can be accompanied by stuttering and uhmming during articulations.

Assuming that both the reviewed literature and the field study were correct, the positive and negative relationship lead to the hypothesis that perceived weakness and strength are two separate factors instead of each other's opposites. Weakness and strength may contribute to interpretation in two separate ways, similar to Herzberg's two-factor theory of motivation. This theory explains that job satisfaction depends on two unrelated factors: satisfaction and dissatisfaction. For instance, an employee who gets a raise is not more satisfied with his job, just less dissatisfied. Similarly, a weak signal that becomes stronger may get closer to the perceiver's frame, thus extending interpretation. In contrast, a strong signal that becomes stronger does

not extend interpretation, just a quicker passage into action because it is already interpreted. Further testing of the weakness index and two-factor variations is required to substantiate this hypothesis so that perceived weakness can be better isolated in statistical analysis and more can be learned about its effects on interpretation.

Furthermore, the extensive weak signal pattern from literature and the two patterns from the field study indicated at least two possible explanations. First, the more extensive pattern from literature may actually represent a mean of patterns of varying levels of perceived weakness. Second, the more extensive pattern from literature may indicate that the stimuli in the reviewed studies triggered lower levels of perceived weakness. Either way, the finding indicates that the disaggregation of perceived weakness in multiple levels is feasible and may help to discover new ways to detect weaker signals earlier and more accurately.

At least, the foresight field should not maintain the binary difference between weak and strong signals without a clear motivation. New studies should not use earlier findings and approaches without scrutinizing them for the weakness level they represent. In their stimuli development, they ought to include weaker signals and not resign to weak signals already inside the frames of the sample.

7.3.3. Expertise types and levels of perceived weakness

There are no findings to present from the reviewed literature on the relationships between expertise types and levels of perceived weakness. In this dissertation, three significant correlations were found. Width of industry and job expertise correlated positively while task expertise correlated negatively to perceived weakness. The theoretical implications of these findings become apparent when we consider the effect of frames on the perceptual filters in the process. The reviewed literature suggested that the frame determines the number and type of signals that pass perceptual filters. It was also suggested that the forecasting and mentality filters must be wide to let a sufficient number of weak signals pass (Ilmola & Kuusi, 2006).

Studies on the role of expertise on the weak signal process that compared experts to novices found that experts include more weak signals into detection and interpretation. During interpretation, experts can more easily link weak signals to their prior frame and thus are able to do more iterations than novices. Studies attribute these effects to the finding that experts have more complex frames than novices. The complexity of the prior frame is seen as a significant determinant of weak signal analysis (Bateman & Zeithaml, 1989; Daft & Weick, 1984; Dutton, 1993;

Huff, 1990; Kiesler & Sproull, 1982).

When both literature and correlations are considered accurate, the opposing direction of the correlations may suggest that the difference between these expertise types stem from relative differences in width and depth of reference frames. General expertise represented a wider, flatter filter and depth of industry expertise a narrower, deeper filter. The frames of general experts consisted of more signal categories so that weak signals were more easily linked to the frame and detected. The frames of industry specialists were narrower and deeper in comparison. The frames consisted of fewer signal categories but had more signals per category so that detected signals were more easily applied to the company or industry. The positive correlation between general expertise and perceived weakness in our second field study suggested that the relative flat filters of general experts were able to included new weak signals within the signal categories already in their reference frames. Following this line of reasoning, the narrow, deep filters of industry experts may have been able to include weak signals in new categories (outside the categories already in their reference frame). Task expertise (foresight skill) may represent a widening and deepening effect on perceptual filters, thus reducing the numbers of signals still perceived as weak.

This dissertation's first field study focused on expert top-managers. It resulted in the emergence of several frame structures that exhibited different levels of complexity and dynamism. The overlay of the frame structure on the weak signal process made clear that experts can have static, simple frame structures, especially when they are focused on interpretation. Expert top-managers who focused on weak signal detection had more complex, dynamic frames than those who focused on interpretation. Top-managers seemed to structure their frames strategically as if they knew that structure determined their sensitivity for weak signal detection. This supported the assumptions on the effect of the width and depth of filters. For instance, one of the participants in the first field study was a top-manager with almost fifteen years of industry expertise, in his second year of leading a company at the forefront of emerging technologies, and an investment horizon of decades. In terms of the second field study, this top-manager was an industry specialist, supposedly with a narrower, but very deep frame, thus including fewer signal categories. His frame structure represented a simple model of the environment, thus including fewer links and less dynamism. Both increased the number of signals perceived as weak: those outside the frame categories, those within categories but unlinked or not interpreted as dynamic. This top-manager explicitly expressed delight in signals that he could not easily place. Distant signals challenged his interpretation skills and helped him to increase feelings of urgency in his staff, so that he could get them to join his vision and strategy (see section 3.4.3. figure 15). In other words, a narrow, deep frame with a simple structure helped him to perceive more signals as distant, which he liked and needed to make the company more resilient.

Thus, the dissertation's findings seem to imply that expertise contributes to the organization and density of signals within the frame structure. Combinations of expertise types and frame structures can explain the variance of perceptual filter effects on the process.

Four directions for future hypotheses can be developed from the findings. Firstly, general expertise types may contribute to wider (more signal categories) and flatter (fewer signals per category) filters. This way, general expertise types increase the number of weak signals to detect. Secondly, specific expertise types may contribute to narrower, deeper filters. This way, specialist frames increase the number of interpretation alternatives to develop on detected signals. Thirdly, the focus of the frame on detection may increase width and depth (more complexity and dynamism), and the focus on interpretation may decrease width and depth (less complexity dynamism) of the filters. This way, sensitivity to weak signals is maintained at a high, manageable level. Finally, task expertise may represent the optimum filter width and depth for successful weak signal processing. Adding task expertise to group interpretation may deepen the wider filters of general experts and widen the filters of specialists.

Even at this exploratory stage, managerial relevance can be elicited because the findings bring substance to the concept of cognitive diversity. Besides its beneficial role to raise the effectivity of the weak signal process, cognitive diversity also has gained in meaning. The idea that multiple perspectives increase interpretation accuracy is often implemented in cross-functional teams or team composition based on variation in gender and cultural backgrounds. This may or may not result in cognitive diversity, because even cross-functional teams or teams with otherwise diverse backgrounds can still share dominant logic. Implementation of diversity in expertise type and frame distance can help to remedy this. In other words: companies can benefit from having a cognitive divers team keeping an eye on weak signals, so that they can become aware of emerging changes.

7.4. Relevance of the Thesis and its Limitations

The insights that served as the basis for this thesis were derived from four fields: foresight, sense-making, strategic choice, and entrepreneurship research (see section 2.2.). Shared and complimentary findings were used to develop the theoretical basis of this dissertation. The dissertattion's findings are relevant for each field because it integrates and extrapolates findings from each field into new theory on how the weak signal process works. All fields may find our findings on weakness levels helpful to classify their work in terms of signal weakness or to expand their work to include higher levels of perceived weakness. Foresight scholars may also benefit from the practicalities of a new weakness definition, index, and stimulus design. Sense-making scholars may find our view on the effect of the load of the prior frame with specific expertise types on sense-making helpful in their retrospective work on individual belief systems. Strategic choice may be interested because frame distance may help explain how choices between alternatives are made. Finally, entrepreneurial research may want to explore the findings on reference frames as a part of research on the state of alertness that entrepreneurs require to become aware of new opportunities. Furthermore, the thesis relevance transcends these fields to adjacent lines of research that have a different view on what makes information weak.

Only recently, in the early years of our century, the work on a theory of strategic surprise in economic terms developed into theoretical frameworks (Golman & Loewenstein, 2015; Gray, 2005; McDaniel & Driebe, 2005; Thompson, 2018). The frameworks suggest that strategic surprises are caused by a fundamental lack of information, which means that the lack of information is inherent to the environment and that full, complete information does not exist. A fundamental lack of information compels ongoing interpretation on the part of top-managers. While this dissertation deals with weakness as a perception, the theory of surprise indicates that weakness is an inherent trait of any environmental information used as input for strategic processes and decisions. In both views, the level of weakness can be measured in the distance of information to the perceiver's frame. Weakness originating from frame distance or by fundamental incompleteness may lead to similar processes and outcomes, which means that these theories can benefit from each other's insights as well.

Although this dissertation was focused on top-managers, its relevance transcends the corporate domain. Foresight originated in the domain of policymaking, and weak signal analysis has been fostered in that domain under the influence of for instance the Cold War, and now through globalization and rapid change. That way, weak signal research forms a link between the field of perceived uncertainty and foresight, and both fields could benefit from each other's research. First attempts to link the fields have been forged in the uncertainty field and deserve the attention of

foresight scholars (Van Dorsser, Walker, Taneja, & Marchau, 2018). This dissertation borrowed from the uncertainty field the idea that complexity and dynamism may describe the structure of the reference frames of managers and that structures may be particular for levels of perceived weakness. Defining weak signals in terms of distance to the frame led to the insight that different levels may lead to different interpretation patterns. The step from different interpretation patterns to different actions seems obvious, considering the different levels of perceived uncertainty and their specific strategies. This thesis illustrates how the field can build on one another, which is valuable in fields that both recognize the increasing change rates and information overwhelm in the environment.

7.5. Recommendations for the Managerial Practice

Several managerial implications of the research have already been noted throughout this dissertation. With two caveats, the most important recommendations for top-managers are listed below. Caveats are that the dissertation's findings were specific for our sample of Dutch CEOs, albeit that the sample included a large variety of expertise profiles, industries, and company sizes. Signals were limited to environmental phenomena and did not include weak signals from within the company. Caveats have been taken into account by deliberately positioning the findings as recommendations to use as the top-manager sees fit.

First of all, weak signals occur in any industry, regardless of the industry's complexity and dynamism (see section 6.3.2.). This means that there are no exemptions from partaking in weak signal analysis on the grounds of perceived industry certainty or lack of volatility.

Secondly, the tipping point effect of weak signals (small signal, large potential impact) has dual relevance. Weak signals can help companies to gain the time needed to prepare companies for future impact (see section 6.1.4.). As such weak signal analysis plays the role of preventive medicine. That way, weak signal analysis deserves the allocation of company resources despite their seemingly insignificance in the present. It also means that weak signal analysis will allow top-managers to take the time and defer judgment on weak signals until their meaning becomes clearer, all the while sensitizing the company to their existence. Doing the analysis while deferring judgment may buy the time to help employees adjust to change and to include them in discussions about the company's future. Inclusion is likely to increase commitment and as well as feelings of urgency, thus gaining momentum for change.

Thirdly, weak signal analysis itself does not need to involve complex methodologies or expensive expert consultants (see section 7.1.2). Complex methodologies do their work: they help to increase weak signal inclusion in strategic processes, but include extra noise as well. Foresight experts can help reduce perceived weakness and facilitate interpretation, but expertise types already in the company can also be quite sufficient for competent weak signal analysis. Instead of using complex methodologies, it can be done with the implementation of a relatively simple process of search and interpretation. Wide sweeps of the usual business environment, but focused on distant signals may suffice. If foresight processes already exist, simple improvements in search parameters (distance) and sources may already improve the process. A careful selection of co-workers to help detect and interpret weak signals can increase process accuracy too. The organization of occasional meetings of a cognitive diverse team to interpret search results improves interpretation accuracy (see section 3.4.2.). Cognitive diversity means that people with different expertise types, who perceive different levels of perceived weakness in the same signals, can work together to develop interpretation alternatives. Cognitive diversity can also help to escape from diametral beliefs caused by equally deep expertise in cognitive homogeneous teams. Preferable, general expertise is used during search and interpretation, because this expertise type helps to include more weak signals in the process and to develop multiple alternatives. Industry expertise can help during interpretation to apply signals to the company which makes signals actionable. Foresight skill can reduce perceived weakness and facilitate discussion, so that others can help interpret more easily (see section 6.1.). The caveat here is the importance of general expertise. This means that the top-manager cannot invest out of the process, because his overall view is crucial for the process accuracy.

Fourthly, managers must disregard possible misgivings about team members who stutter and uhm a lot, or use bad syntax. These interruptions of their flow of thought do not always mean that they interpret signals less accurately or decisively, but that they are heavily involving their memory and reference frame in the process (see section 5.2.2.).

Finally, framing weak signals in terms of distance to the shared beliefs in the company will turn weakness from a lack of information to a decision tool. Distance framing can remove tension from discussions about beliefs, because discussion no longer focuses on who interprets a signal right, but on when the company can start acting on a signal (when distance is reduced to a certain stage). Furthermore, distance also describes the type of action to be taken. Longer distances mean more search and

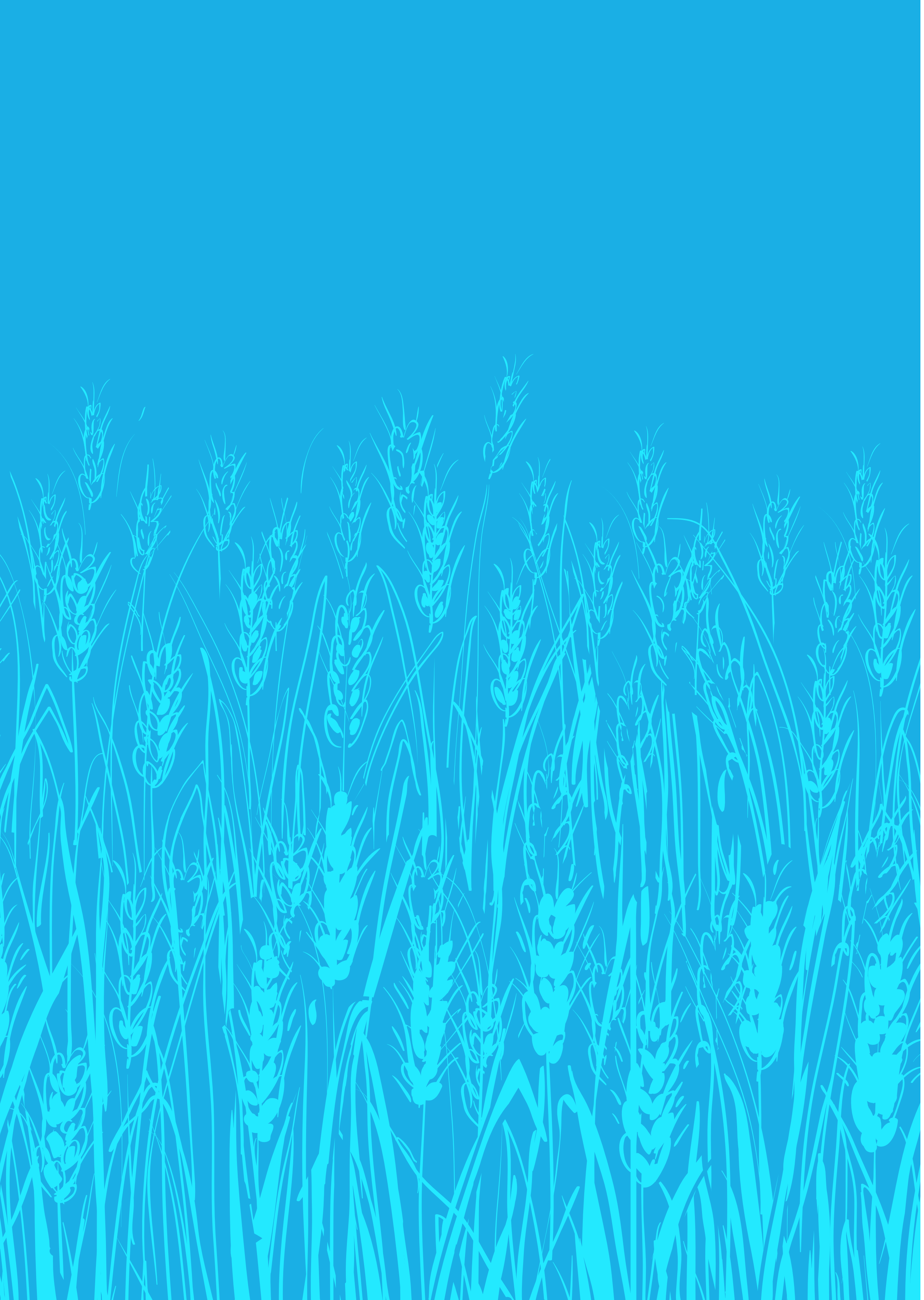
conservative judgments, while shorter distances mean more opportunistic action.

In short, top-managers are crucial to the weak signal process: it starts with their awareness of the role of weak signals as preventive medicine. Their wider expertise will ensure the inclusion of weak signals once top-managers are aware of distance as a search parameter. Finally, using the weak signal process strategically not only helps to detect threats and opportunities early, but can also help to rally the employees behind change.

7.6. Future Research

The discussion of the findings already included several attractive directions for future research. First of all, the new definition can be viewed as a means to build a framework of findings in weak signal research. The analysis would raise the validation of findings, bring more insights into the cohesion of the field and its gaps. Secondly, digitization of the STRAWS method would bring a quantitative validation of the dissertation’s findings within reach, as well as the extension of the findings to multiple countries and management levels. Thirdly, the findings on expertise types and frame structure led to several interesting topics for future research with the concept of cognitive diversity as a common denominator. Research on these topics is valuable for the strategic deployment of talent and teams dedicated to foresight. For instance, weakness in terms of frame distance may be seen as a dimension of decision-making behavior: the shorter the distance, the denser and more concrete the information, and the more opportunistic the decision-making behavior.

If the concept frame distance were to be adopted by foresight scholars and practitioners, more organizations would become aware sooner of disruptive developments. Together, we may reduce their negative effects and perhaps even turn them into new opportunities. In that case, straws that tell the wind will not only predict storms but also a fresh breeze over fertile empirical grounds.



EPILOQUE

This is what I believe in. Maybe it will lead to nothing. I mean, maybe I'm very wrong. Is quite possible.

Field Study II; Participant 6

I have described the research concisely and structured but that does not reflect the process at all. Weak signal research is complicated because it has paradoxical qualities. For instance, how can managers even perceive weak signals when perception is programmed to its opposite? Perception excludes information that cannot be connected to insights already the prior frame, so perceiving very weak signals is an impossible task. Secondly, rejected signals have the same effect as no signal, namely no effect, which implies that a signal can only be a signal after its perception. Furthermore, only relevant signals can be perceived as weak because irrelevant signals are discarded before they even pass the perceptual filter. However, relevance is already an interpretation. Finally, the interpretation of a weak signal immediately reduces its weakness because the act of interpretation is an act of knowledge creation. These paradoxical qualities required several leaps in insight before a working research set-up was reached. Leaps invariable resulted from setbacks and dead ends. For the benefit of future research, I want to record one of the 'failures' as well. Indeed, dead ends and detours are also findings that can help the progress of other scholars.

The assumptions about weakness underwent significant shifts as the research progressed. At the start of the research, I thought it was likely that signals from the company environment were objectively weak. Inherently weak information, such as the first introductions of new technologies onto the market, seemed to bamboozle top-managers into biased decision-making. The ambiguity and incompleteness of that information would trigger biases and that the difference between good and bad judgments would be determined by the types of biases in play, not by its absence or presence. I derived this assumption from several studies showing that overestimation helped managers to get new technologies from the lab onto the market, while the confirmation bias would increase a manager's blindness with regards to the same technology. One of the first things I did was to survey a set of managers about the biases they had noticed in a recent strategic discussion about new information. The survey soon made clear that managers could experience many different biases during the making of one decision, and that the same biases could be present during recognition and rejection of technology. So that was the end of bias as a determining factor.

I still wanted to pursue the idea that some cognitive trait determined the process. With bias out of the way, I thought that perhaps predictability of environmental change interfered with weak signal interpretation. Studies on environmental uncertainty said that decisions were contingent on environmental uncertainty. Most importantly, this field drove the point home that bad decisions can stem from a mismatch between objective uncertainty and perceived uncertainty. Lengthy exploration of the uncertainty literature did not bring insights into the role of the signal itself. So, the field was exited but with a pearl of new insight that cognition did play a role, only in a slightly different shape. The rest, as they say, is history.

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If ever there was a mise en abyme or Droste effect in Dutch, it was the research for this dissertation. Weak signals turned out to be a very weak concept, but after seemingly endless recursive iterations, the work finally has come to an end. It was truly a transformative experience.

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Last but not least, this dissertation would not have seen the light of day if it was not for the patience and love of my husband George. He had to suffer the brunt of a candidate being stuck, and the hyperactivity of a candidate on a roll, while trying to make sense of half-baked ideas because he wanted to. George, I thank you from the bottom of my heart.

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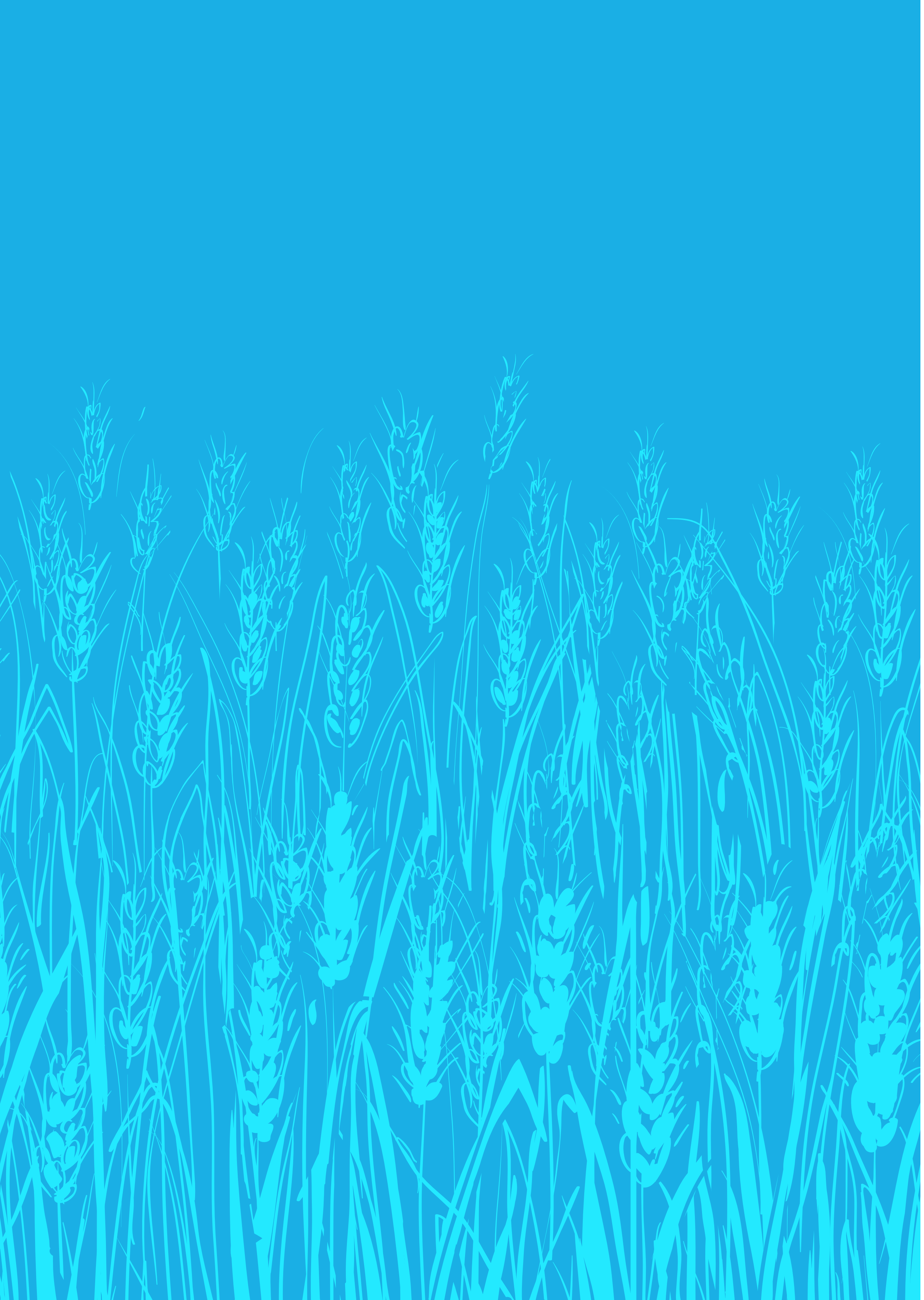

APPENDICES

Appendix A. Master List Seminal Papers
Appendix B. Keywords Weakness Descriptions (Chapter 2)
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Appendix A. Master List Seminal Papers

Master List Seminar Papers	
Reference	**Times Cited (Google Scholar; August 30, 2019)**
Aguilar, F. J. (1967). Scanning the Business Environment. New York: Macmillan.	2884
Ansoff, H. I. (1975). Managing strategic surprise by response to weak signals. California Management Review, 18(000002), 21–33.	2128
Auster, E., & Choo, C. W. (1994). How senior managers acquire and use information in environmental scanning. Information Processing & Management, 30(5), 607–618.	190
Ilmola, L., & Kuusi, O. (2006). Filters of weak signals hinder foresight: Monitoring weak signals efficiently in corporate decision-making. Futures, 38(8), 908–924.	159
Lesca, N., Caron-Fasan, M. L., & Falcy, S. (2012). How managers interpret scanning information. Information & Management, 49(2), 126-134.	40
Milliken, F. J. (1990). Perceiving and interpreting environmental change: An examination of college administrators' interpretation of changing demographics. Academy of Management Journal, 33(1), 42–63.	684
Nadkarni, S., & Barr, P. S. (2008). Environmental context, managerial cognition, and strategic action: an integrated view. Strategic Management Journal, 29(13), 1395–1427. https://doi.org/10.1002/smj.717	557
Weick, K. (1979). Cognitive processes in organizations. In Research in organizational behavior. Greenwich, CT: JAI Press.	1127

Appendix B. Keywords Weakness Descriptions (Chapter 2)

Outside-frame	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Trend creating	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Random	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Unpredictable	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n
Peripheral	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	n	n	n	y
Frame-effect	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n
Dynamic	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	y	n	n
Discontinuous	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	y	n	n	n
Novel	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	y	n	n	n	n	n	n	n	n	n
Complicated	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n
Small	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	y	y
Uncontrollable	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Constrained	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Confounding	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Interconnected	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Ambiguous	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	y	y	n	n	y	n	n	n	n	n	n	n
Significant	n	y	n	n	n	y	n	y	n	y	y	n	n	n	y	y	n	n	y	y	y	n	n	y	n	n	n	n
Unique	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
DM-process	n	n	y	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Ill-defined	n	n	n	n	y	y	n	n	y	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n
Internal	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n
New-source	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
ThreatOpp	n	y	n	y	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	y	y	n	n	n	n
Impact	y	n	y	y	n	y	y	y	y	y	y	n	y	n	y	n	n	n	n	n	y	n	n	n	n	y	n	n
Emerging	y	y	n	y	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	y	y	n	y	n	y	n	y
Environment	y	n	n	n	n	n	n	n	n	n	y	n	n	n	n	y	n	n	n	n	n	y	n	n	n	n	n	n
Problems	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Phenomena	y	y	n	n	n	y	y	y	y	n	n	n	y	y	y	y	n	y	n	y	y	y	n	y	y	n	n	y
Indicators	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Information	y	n	y	n	n	n	n	n	n	n	n	n	n	y	n	n	y	y	y	n	n	n	n	n	n	n	n	y
Year	1967	1975	1977	1980	1980	1983	1984	1987	1987	1988	1989	1989	1990	1993	1993	1995	1995	1996	1999	2000	2002	2003	2004	2004	2004	2004	2004	2004
Author	Aguilar	Ansoff	King	Ansoff	Lyles and Mitroff	Dutton et al	Daft and Weick	Dutton and Duncan	Dutton and Jackson	Lyles and Thomas	Stubbart	Murphy	Milliken	Auster and Choo	Dutton	Costa	Wang and Chan	Choo	Forbes	Bogner and Barr	Kuvaas	Blanco and Lesca	Brown	Day and Schoemaker	Haeckel	Kajanto et al	McKay and McKiernan	Menon and Tomkins

Appendix B. Continued

Author	Hiltunen	Ilmola and Kuusi	Anderson and Nichols	Cunha and Chia	Hiltunen	McEwen	McKenzie et al	Mendonça et al	Rohrbeck et al	Rossel	Schoemaker and Day	Kuosa	Liebl and Schwarz	Battistella and De Toni	Mayer et al	Murphy	Saritas and Smith	Barreto	Heinonen and Hiltunen	Lesca et al	Mendonça et al	Yoon	Elimimian and Edevbie	Groddeck and Schwarz	Schoemaker et al	Schwarz et al	Maitlis and Christianson
Outside-frame	n	n	n	n	y	n	n	y	n	n	n	y	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n
Trend creating	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Random	n	n	n	y	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n
Unpredictable	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y
Peripheral	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Frame-effect	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	y
Dynamic	n	n	n	n	n	n	n	n	n	y	y	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n
Discontinuous	n	n	n	n	n	n	n	y	n	n	n	n	y	y	n	n	n	n	n	n	y	n	n	y	n	n	n
Novel	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	y	n	n	n	n	n	n
Complicated	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Small	y	y	n	y	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	y	n
Uncontrollable	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Constrained	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Confounding	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n
Interconnected	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Ambiguous	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	y
Significant	y	n	y	n	n	y	y	n	n	n	n	n	n	n	y	n	y	y	n	n	n	y	n	n	n	y	n
Unique	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
DM-process	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n
Ill-defined	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	y	n	n	n	n	n
Internal	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	n
New-source	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
ThreatOpp	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n	y	n	n	y	y	y	n	n	n	n	n
Impact	n	n	y	n	n	y	n	n	n	n	n	n	n	n	n	n	y	y	n	n	n	n	y	n	n	y	y
Emerging	y	y	y	n	y	n	n	n	y	y	y	n	n	n	n	n	y	y	y	y	n	n	y	n	y	y	n
Environment	n	n	n	n	y	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	y	n
Problems	n	n	n	n	y	y	n	n	n	n	n	n	n	n	n	n	n	n	y	n	n	n	y	n	n	n	y
Phenomena	y	y	y	n	y	n	n	y	y	y	n	y	y	n	n	y	y	y	n	n	y	y	n	y	n	y	y
Indicators	y	n	n	n	y	n	n	n	y	y	n	n	y	n	n	n	y	n	y	y	y	y	n	y	n	n	n
Information	n	n	n	n	n	n	n	n	n	y	y	y	n	n	n	y	n	n	n	n	y	n	n	n	y	n	n
Year	2006	2006	2007	2007	2008	2008	2009	2009	2009	2009	2009	2010	2010	2011	2011	2011	2011	2012	2012	2012	2012	2012	2013	2013	2013	2013	2014

Appendix B. Continued

Author	Thorleuchter et al	Akrouchi et al	Carbonell et al	Cevolini	Loza-Aguirre et al	Vahidi-Motti and Masoumi	Vandersteen	Kim and Lee	Rowe et al	Tapinos and Pyper	Lin et al	Bertoncel et al	Nunes and Da Silva
Outside-frame	n	y	n	y	n	n	n	n	n	n	n	n	n
Trend creating	n	n	n	n	n	n	n	n	n	n	n	n	n
Random	n	n	n	y	n	n	n	n	n	n	n	n	n
Unpredictable	y	n	n	n	n	n	n	n	n	n	n	n	n
Peripheral	n	n	n	n	n	n	n	n	n	n	n	n	n
Frame-effect	n	n	n	n	n	n	n	n	n	n	n	n	n
Dynamic	n	n	n	n	n	n	n	n	n	n	n	n	n
Discontinuous	n	n	y	n	n	n	n	y	n	n	n	n	n
Novel	n	n	y	n	n	n	n	n	n	n	n	n	n
Complicated	n	n	n	n	n	n	n	n	n	n	n	n	n
Small	n	n	n	n	n	n	n	n	y	n	n	n	n
Uncontrollable	n	n	n	n	n	n	n	n	n	n	n	n	n
Constrained	n	n	n	n	n	n	n	n	n	n	n	n	n
Confounding	n	n	n	n	n	n	n	n	n	n	n	n	n
Interconnected	n	n	n	n	n	n	n	n	n	n	n	n	n
Ambiguous	n	n	n	n	n	n	n	n	y	n	n	n	n
Significant	n	n	n	n	n	y	n	y	n	y	n	y	n
Unique	n	n	n	n	n	n	n	n	n	n	n	n	n
DM-process	n	n	n	n	n	n	n	n	n	n	n	n	n
Ill-defined	n	n	n	n	n	n	n	n	n	n	n	n	n
Internal	n	n	n	n	n	n	n	n	n	n	n	n	n
New-source	n	n	n	n	n	n	n	n	n	n	n	n	n
ThreatOpp	n	n	y	n	n	n	n	n	n	n	n	n	n
Impact	y	y	n	n	y	n	y	n	y	y	y	n	n
Emerging	n	y	y	n	n	n	n	y	n	n	n	y	y
Environment	n	n	n	n	y	n	n	n	n	n	n	n	n
Problems	n	n	n	n	n	n	n	n	n	n	y	n	n
Phenomena	y	y	y	n	n	y	y	y	y	y	n	n	y
Indicators	n	y	y	n	y	y	n	y	n	n	n	y	n
Information	n	n	n	y	y	n	n	n	n	n	n	n	y
Year	2014	2015	2015	2016	2016	2016	2016	2017	2017	2017	2018	2018	2019

Appendix C. R Script Cluster Analysis (Chapter 2)

A two-step cluster analysis was performed on the weak signal keyword data table (see Appendix B). Keywords were treated as categorical variables that indicated the presence of attributes in weak signal descriptions. The analysis started with a multiple correspondence analysis (MCA) containing all dimensions. The results of the MCA were clustered in groups with hierarchical clustering using the Ward criterion. A complete description of the research procedures employed in the cluster analysis can be found in Lê, Josse, and Husson (2008).

The data set consisted of 68 rows of weak signal descriptions and 30 columns of keywords (see data frame in Appendix B). The keywords were active in the analysis. Three extra variables containing research discipline labels, year of publication, and paper ID were used for illustration purposes (not active, but present in the analysis). No outliers were removed.

For the analysis in RStudio (Version 1.1.442 – © 2009-2018 RStudio), the Factominer and Factoextra packages were activated to perform the MCA and the clustering.

The following script was followed to explore the effect of the combination of 4 research disciplines and temporal foci on the variety in keywords.

```
# Performing MCA
res.mca <- MCA(X2019_weak_signal_keywords, ncp = 15, quanti.
sup=31, quali.sup = c(32,33), graph = TRUE)

#Apply hierarchical clustering, setting the number of clusters to 4 to allow
for the possibility of clusters per discipline
res.hcpc <- HCPC (res.mca, graph = FALSE, min = 4, max = 4)

#Visualizing the results
fviz_cluster(res.hcpc, geom = "point", main = "Factor map")

# Description by variables
res.hcpc$desc.var$test.chi2

# Description by variable categories
res.hcpc$desc.var$category
```


The following script was followed to cluster keywords for the new definition:

```
# Performing MCA
res.mca <- MCA(X2019_weak_signal_keywords, ncp = 15, quanti.
sup=23, graph = TRUE)

#Apply hierarchical clustering, setting the number of clusters by clicking
on the tree
res.hcpc2 <- HCPC (res.mca, graph = TRUE)

#Visualizing the results of the clusters
fviz_cluster(res.hcpc2, geom = "point", main = "Factor map")

# Description by variables
res.hcpc2$desc.var$test.chi2

# Description by variable categories
res.hcpc2$desc.var$category
```

Appendix D. Stimulus Materials in Dutch (Chapter 4)

Sector	Source	Title	Short description	Cue 1) Anchoring	Cue 2) Driver	Cue 3) Barrier	Cue 4) Positive impact	Cue 5) Negative impact
Technological	https://www.gartner.com/doc/3142020?ref=un-authreader&sr-cId=1-3478922254	**Machines bepalen het informatie aanbod**	Technologie is in staat om proactief informatie te verzamelen, verbanden te leggen en de resultaten in begrijpelijke taal te vertellen	Machines stellen al nieuwsberichten en productaanbevelingen samen, laten websites zich aan de lezer aanpassen en optimaliseren advertenties.	Verbeteringen in data-integratie en voorspellende algoritmes laten machines doordringen tot alle facetten van zakelijke informatie.	Tegelijkertijd bemoeilijkt de exponentiele groei van ongestructureerde data de selectie van de juiste informatie uit de brei van gegevens.	Gerobotiseerde informatie kan marktsegmentatie en communicatie sterk verbeteren,	maar ook klanten veel minder afhankelijk maken van expertise.
	https://www.gartner.com/doc/3142020?ref=-unauthreader&sr-cId=1-3478922254	**Menselijke hulp voor slimme apparaten**	Apparaten die aan het Internet hangen kunnen aangeven dat er onderhoud nodig is	Auto's hebben al contact met de garage en stellen reparatie-afspraken voor en beveiligingsbedrijven krijgen meldingen als een alarm onderhoud nodig heeft. Dit jaar tellen de verbonden systemen van auto's wereldwijd al 600 miljoen onderdelen.	Het aantal apparaten met een Internetverbinding stijgt explosief. Waarschijnlijk is bijna de helft intelligent genoeg om monteurs om hulp en ondersteuning te vragen.	Tegelijkertijd wordt veel herstelwerk door middel van automatische updates weggewerkt en kunnen sommige monteurstaken door robots gedaan gaan worden.	Slimme apparaten bieden zoveel gemak dat er grote schaalvoordelen te behalen zijn voor de bedrijven die hier koploper in kunnen worden.	Maar de lawine van onderhoudsverzoeken kan ook leiden tot een enorme hoeveelheid achterstallig onderhoud omdat het huidige aantal onderhoudsbedrijven de vraag niet aankan. Veel (cruciale) apparaten zullen slecht werken, fouten maken, of ermee ophouden.
	https://www.gartner.com/doc/3142020?ref=un-authreader&sr-cId=1-3478922254	**Algoritmes doen autonoom zaken**	Algoritmes bewaren, verzamelen en spenderen geld en zijn contractpartner in zakelijke, juridische, economische en financiële systemen	Algoritmes zijn al actief op de aandelenmarkten. Hier is een deel van aan- en verkoop geautomatiseerd om zo snel mogelijk van voordeel te kunnen profiteren. Deze algoritmes werken alleen nog niet autonoom.	Blockchain algoritmes (software die decentraal en open is, zodat iedereen real-time data kan beheren) kunnen daarvoor zorgen. De technologie verbetert en verspreidt zich doordat digitale geldeenheden zoals bitcoin breder geaccepteerd raken en zich in de richting van machtige platforms ontwikkelen.	Tegelijkertijd groeit de wetgeving die dit soort constructies probeert te reguleren. In sommige landen is het gebruik ervan strafbaar.	Blockchain kan gebruikt worden voor allerlei typen databases. Gebruikers beheren zelf, decentraal, de data waardoor die beter beschermd is tegen cyber aanvallen. Het proces is transparant en goedkoop omdat allerlei overhead wegvalt.	Maar traditionele rolpatronen gaan verdwijnen: alle partijen worden zowel gebruiker, producent, aanbieder en vrager.
Political	https://www.dni.gov/index.php/about/organization/glob-al-trends-2030	**Machtsverschuiving naar private partijen**	De macht verschuift van nationale overheden naar andere instituties, zoals NGO's, multinationals, universiteiten, miljardairs en megasteden	Veel landen kennen al hybride constructies, waarbij de overheid op diverse niveaus samenwerkingen aangaat met private partijen en wetenschappelijke instellingen.	Door Internet overstijgt de publieke opinie de landsgrenzen en zowel de elites als de groeiende middenklassen zijn het steeds vaker en meer eens over grote uitdagingen, zoals armoede, milieu en anti-corruptie. Private partijen zitten steeds meer samen in internationale netwerken en raken gewend om samen te werken, terwijl overheden geremd worden door verkiezingen.	Tegelijkertijd zijn democratische overheden, net als het stijgend aantal autoritaire regimes, gehecht aan hun onafhankelijkheid en invloed.	Publiek-private samenwerking over de grenzen heen kan een enorme impuls betekenen voor economische groei.	Maar als private partijen de macht krijgen kan het gebruik van gevaarlijke en ontwrichtende technologieën niet meer door overheden worden gecontroleerd.

Appendix D. Continued

Sector	Source	Title	Short description	Cue 1) Anchoring	Cue 2) Driver	Cue 3) Barrier	Cue 4) Positive impact	Cue 5) Negative impact
Political	https://www.dni.gov/index.php/about/organization/global-trends-2030	**Landen clusteren op welvaartsniveau**	De landen met economische groei zoeken elkaar op, terwijl de landen zonder groei naar de periferie van de markt verschuiven	De EU functioneert bijvoorbeeld niet helemaal als één markt en de rijke landen stellen steeds strengere eisen aan de andere leden.	Verdergaande inmenging en samenwerking van rijke landen kan paal en perk stellen aan de conflicten in de wereld, terwijl bilaterale relaties worden versterkt.	Tegelijkertijd hoeft de VS minder energie te importeren, waardoor zij minder als 'politieman' de verhoudingen in de wereld hoeven reguleren. Desintegratie van economische blokken neemt dan onder invloed van nationaal populistische druk verder toe.	Een EU met twee groepen kan er voor zorgen dat de sterkere landen sneller groeien en daardoor als geheel meer veerkracht en weerbaarheid krijgen.	Maar de EU kan ook verder desintegreren. Na de Brexit volgt wellicht de Grexit, met grotere gevolgen voor de economie dan de val van Lehman Brothers in 2008.
	https://ec.europa.eu/futurium/en/content/deep-shift-technology-tipping-points-and-societal-impact-global-agenda-council-future	**Directe democratie en multi-actor consultatie**	Informatietechnologie heeft de samenlevingen wereldwijd veranderd en zal ook tot veranderingen van overheden leiden	De publieke opinie vraagt de overheid om openheid en transparantie, kennisdeling en efficiency. Burgers oefenen druk op de overheid uit via alle digitale kanalen die tot hun beschikking staan, terwijl informatie wordt gelekt of niet goed beschermd.	Technologie draait de verhouding tussen overheid en burger om: van top-down naar bottom-up. Burgers kunnen onmiddellijk reageren op de overheid en meteen gelijkgestemden vinden om actie te ondernemen en te protesteren. Het referendum is maar een begin.	Tegelijkertijd kunnen overheden uit zelfbescherming hun toevlucht nemen tot restrictieve maatregelen. Onder het mom van privacy en veiligheid wordt toegang tot informatie aan banden gelegd.	Als overheden burgers meer toegang geven tot kennis en invloed kunnen burgers nieuwe systemen voor waardecreatie scheppen.	Maar de verschuiving van macht naar de burger kan ook leiden tot het recht van de sterkste, als social media het gevoel onvrede van enkelen versterkt en minderheden irreële oplossingen proberen af te dwingen.
Economic	http://www.oecd-ilibrary.org/development/securing-livelihoods-for-all_9789264231894-en	**Activiteitenportfolios vervangen banen**	Door robotisering verdwijnt de fulltime baan en moeten mensen een portfolio van betaalde activiteiten ontwikkelen om in hun onderhoud te voorzien	Drie van de grootste werkgevers in de wereld zijn al een substantieel deel van de medewerkers aan het vervangen met robots.	Activiteitenportfolios worden mogelijk gemaakt door drie gelijktijdige ontwikkelingen. Ten eerste de technologische ontwikkeling, zodat mensen overal en altijd kunnen werken; ten tweede dat het basisinkomen uit belastingen wordt betaald; en ten slotte de maatschappelijke omslag van macht naar zelfontplooiing die de nieuwe generaties laten zien.	Tegelijkertijd kunnen robots kosten sterk terugbrengen, waardoor allerlei industrieën kunnen groeien en zo juist meer banen opleveren. Robots hebben bovendien mensen nodig om te kunnen functioneren: iedere robot moet gemaakt en onderhouden worden.	Efficiency kan sterk toenemen, waardoor teams van robots en mensen kunnen werken aan oplossingen voor grote maatschappelijke uitdagingen.	Maar goedkope robots kunnen ook de lagere en middenklassen op de arbeidsmarkt verdringen en dat kan tot onrust en onlusten leiden.
	http://www.shareable.net/blog/the-we-economy-value-creation-in-the-age-of-networks	**We-economy: platforms als business model**	De "we-economy" wordt gedomineerd door startups die zich snel ontwikkelen omdat ze als platform voor vraag en aanbod functioneren. Hun business modellen zijn erop gericht op een bijdrage te leveren aan de oplossingen van maatschappelijke uitdagingen	Nieuwe spelers als Airbnb, Uber, Alibaba en Nest zijn succesvol. Nieuwe startups kunnen hun voorbeeld navolgen. Bovendien rapporteert de OESO een stijgende belangstelling voor "social impact investing".	De ontwikkeling naar de we-economy wordt gedreven doordat platforms geen kosten hoeven maken en dus makkelijk kunnen opschalen. Platforms gedijen als de groei van gebruikers gepaard gaat met groei van aanbieders en hulpmiddelen: het fenomeen heeft monopolistische neigingen.	Tegelijkertijd betekent dit voor bestaande bedrijven dat zij alle onderdelen van het business model moeten veranderen. Protectionisme ligt meer voor de hand. De kans dat restrictieve regels de we-economy remmen is daarom groot.	Als de we-economy doorzet gaan de traditionele rolverdelingen op de schop: klanten worden experts en co-creators, concurrenten worden partners en de afbakening tussen industrieën zal vervagen.	Maar platformpartners zijn ook sterk afhankelijk van elkaar en het succes van individuele partners is daardoor steeds moeilijker door het bedrijf zelf te beïnvloeden.

Appendix D. Continued

Sector	Source	Title	Short description	Cue 1) Anchoring	Cue 2) Driver	Cue 3) Barrier	Cue 4) Positive impact	Cue 5) Negative impact
Economic	https://en.wikipedia.org/wiki/Off-the-grid, http://www.shtfplan.com/headline-news/regulated-out-of-existence-off-gridders-forced-back-on-the-grid-camping-on-own-land-illegal_09272015	**Off-grid: autonome systemen**	Het afkeren van traditionele socio-economische modellen leidt tot de vorming van autonome systemen en gemeenschappen, die zonder hulp van de bestaande spelers kunnen functioneren	In de wereld leven inmiddels meer dan 1,7 miljard mensen off-grid. In landen als de VS is hun aantal in de afgelopen 10 jaar met 33% jaarlijks gegroeid. De beweging zoekt meer ruimte, minder overheidsbemoeienis en waarlijke onafhankelijkheid.	Nieuwe, betaalbare, technologieën stellen gemeenschappen in staat om in hun eigen behoeften te voorzien: van energie, water, voedsel en onderdak tot medische kennis en toebehoren. Off-grid systemen zijn bovendien efficiënter en produceren minder afval dan de on-grid systemen.	Tegelijkertijd nemen overheden maatregelen die het off-grid leven onmogelijk maken, zoals het verbod op kamperen in sommige zones of het niet afgeven van bouwvergunningen voor lokale grids.	Als het aandeel off-grid groeit, slinken de nadelige effecten van bijvoorbeeld nationale stroomuitval voor het maatschappelijk functioneren aanzienlijk. De maatschappij wordt als geheel veerkrachtiger.	Maar een sterke toename van de off-grid beweging zet het groeimodel van de huidige economie in veel industrieen ook weer onder druk.
Social	http://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/the-consumer-sector-in-2030-trends-and-questions-to-consider	**Real-time persoonlijke gratificatie**	Door toenemende technologische mogelijkheden verwachten consumenten dat aanbieders steeds sneller en beter op hun persoonlijke wensen anticiperen	Social media marketing, 3-D prototyping en apps verhogen de verwachtingen die consumenten hebben van bedrijven in de gratificatie van hun latente behoeftes.	Omdat de middenklasse wereldwijd groeit, komen er steeds meer consumenten bij die mobiel Internetten. Dit zijn mensen die gemak zoeken en persoonlijk benaderd willen worden met versimpelde keuzes.	Tegelijkertijd maken hyperconcurrentie en afvlakkende groeiscenario's het steeds moeilijker voor bedrijven om zich aan te passen aan steeds veeleisender consumenten.	De combinatie van technologische ontwikkeling en veeleisende consumenten zorgen ervoor dat nieuwe markten en contactmomenten met consumenten ontstaan en ontwikkelen.	Maar dat betekent ook dat bedrijven naast de traditionele vaardigheden moeten gaan investeren in data-analyse, nieuwe competenties en andere manieren van distributie.
	http://virtual-addiction.com/ en http://www.techaddiction.ca/internet_addiction_statistics.html	**Effecten van toenemend Internetgebruik**	De afhankelijkheid van mensen van communicatie-technologie is nu al groot, maar dat is een fractie van de afhankelijkheid die we in de toekomst zullen hebben	In de VS heeft al 1 op de 8 Amerikanen last van dwangmatig internetten, dat leidt tot depressie, sociale isolatie, prikkelbaarheid, liegen, lage productiviteit en moeheid. In China, Taiwan en Korea liggen de cijfers hoger.	Er komen steeds meer wearables en andere voorwerpen met een internetverbinding op de markt, terwijl Wi-Fi overal toegang verschaft. Verveling behoort tot het verleden, traditionele sociale silo's bestaan niet meer en de wereld ligt real-time aan onze voeten (vingers).	Tegelijkertijd hebben we minder parate kennis en algemene ontwikkeling (dat Googlen we), vermindert schrijfvaardigheid en neemt het concentratievermogen af door multitasking in meerdere media.	Online activiteiten kunnen teamwork en creativiteit stimuleren en kennisvergaring vergemakkelijken, waardoor bedrijfsprestaties verbeteren. Daarnaast bevordert computergebruik de visuele intelligentie en oog-hand coördinatie van mensen.	Maar een groeiende groep mensen met een afhankelijkheid of een aversie kan ook het tegenovergestelde effect hebben: stroevere sociale interactie en dus minder productief teamwork.
	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4603674/	**Bijhouden van technologische vooruitgang**	Cognitieve taken in het dagelijks leven en op het werk nemen toe. Het leven wordt complexer en we kunnen het minder goed met routine af.	De cognitieve competenties van mensen worden sinds 1971 gemeten en laten wereldwijd een stijgende trend zien in lezen en rekenen.	Per generatie neemt het IQ wereldwijd met twee à vier IQ punten toe door betere gezondheidszorg en onderwijs.	Tegelijkertijd kennen niet alle bevolkingsgroepen en regio's dezelfde toename in IQ. Cognitieve vermogens en mentale snelheid nemen in de Westerse wereld juist relatief af.	Toename van het IQ kan de samenleving helpen ontwikkelen door groei van functionaliteit, productiviteit en door politiek-culturele ontplooiing.	Maar toenemende heterogeniteit in de gemiddelde cognitieve vermogens van landen kan leiden tot een verminderde innovatiekracht in die landen.

Appendix D. Continued

Sector	Source	Title	Short description	Cue 1) Anchoring	Cue 2) Driver	Cue 3) Barrier	Cue 4) Positive impact	Cue 5) Negative impact
Legal	http://www.futurist-speaker.com/business-trends/four-key-trends-driving-the-future-of-patents/	**De patent revolutie**	Het aantal patentaanvragen neemt exponentieel toe, maar intellectueel eigendom staat steeds meer onder druk door digitalisering	Het Internet stelt gebruikers in staat om copyrights te negeren door data te gebruiken, te hergebruiken en te misbruiken, omdat data makkelijk beschikbaar is en de pakkans laag is.	Nieuwe technologieën maken nieuwe patenten mogelijk. Bijvoorbeeld: nu we geur kunnen definiëren en meten kan er ook patent op geuren en aroma's worden aangevraagd. De groei in patenten kan dus nog verder toenemen.	Tegelijkertijd kunnen "patent trolls", holdings die bestaande patenten opkopen en toezien op de naleving van die patenten, zoveel patenten vertegenwoordigen dat zij grote bedrijven en industrieën naar hun hand kunnen zetten. De kosten hiervan worden steeds minder goedgemaakt doordat illegaal gebruik ook groeit met het toenemen van Internetters.	De functie van patenten kan in elk geval gedeeltelijk door social innovatie worden overgenomen. Door online publiek te betrekken bij vraagstukken, wordt het publiek co-creator van innovaties. Daardoor kan de loyaliteit van gebruikers toenemen.	Maar het zijn juist de stevige boetes op patentschendingen die gebruikers weerhouden om kennis te delen en betrokken te willen zijn bij sociale innovatie.
	http://www.fichl.org/fileadmin/fichl/documents/FICHL_11_Web.pdf	**Nieuw recht voor nieuwe technologieën**	De regulering van stamcelonderzoek, klonen, synthetische biologie en genomics vraagt om een nieuwe definitie van mens-zijn en van de rechten en plichten die daarbij horen	De filosofische vraag wat mens-zijn betekent houdt ons al eeuwen bezig, en is sinds de jaren '70 is door IVF en euthanasie verder gepolariseerd. De nieuwe technologieën benadrukken de noodzaak om deze vraag opnieuw te beantwoorden.	De meeste landen hebben ontwikkelingen in deze technologieën aan strenge banden gelegd, zodat er zeer beperkt met levend menselijk materiaal kan worden geëxperimenteerd.	Tegelijkertijd heeft nationale wetgeving geleid tot zwarte handel in de benodigde materialen voor onderzoek en therapieën. Het gemak waarmee mensen en bedrijven over staatsgrenzen heen kunnen stappen, maakt dat individuele wetgeving tekort schiet om de illegaliteit aan te pakken.	De technologieën voor bio-engineering kunnen antwoorden geven op verschillende uitdagingen: van het positief beïnvloeden van de gezondheid en gemiddelde levensduur van mensen, waardoor ziektekosten van individuen en verzekeraars afnemen, tot het opruimen van milieuverontreiniging en het vervangen van fossiele brandstoffen.	Maar hightech is ook high-risk: de technologieën kunnen relatief gemakkelijk worden gedupliceerd door staten die zich niet aan de afspraken houden. Met veiligheidsrisico's (nieuwe epidemieën), ethische risico's (manipulatie van mensen in lichamelijke en geestelijke zin), en economische risico's (zoals verdringing van traditionele landbouw) tot gevolg.
	http://www.fichl.org/fileadmin/fichl/documents/FICHL_11_Web.pdf	**Bescherming van toekomstige generaties**	Onder het strafbaar stellen van daden tegen toekomstige generaties valt het veroorzaken van grootschalige, langdurige en grote schade aan ecosystemen, het onthouden van essentiële bronnen nodig om te overleven of het veroorzaken van vergaande polarisatie tussen naties.	De verdragen die nu via de VN worden gesloten op gebieden zoals klimaat, vluchtelingen en ontwikkelingshulp vormen het begin van een nieuw onderdeel van het internationaal recht: misdaden tegen toekomstige generaties. De eerste organisaties en denktanks op dit gebied zijn nu enkele jaren actief.	Internet, toenemende internationale handel en andere drivers van globalisering zoals demografische ontwikkelingen (de grijze golf in de ontwikkelde wereld en een geboorteoverschot in de zich ontwikkelende landen) beïnvloeden de nationale rechtssystemen. Daarnaast is het internationaal recht zelf ook in ontwikkeling onder invloed van instabiliteit in de wereld.	Tegelijkertijd is de instelling van een nieuw hof niet zonder problemen. Als we de ontwikkeling van het International Criminal Court bekijken, heeft die door de trage en geldverslindende voortgang problemen op het gebied van geloofwaardigheid en de noodgedwongen selectie van zaken leidt tot vragen over legitimiteit.	Hoewel internationaal recht zich in economisch opzicht heeft gefocust op harmonisatie van regels, kan de bescherming van toekomstige generaties ook leiden tot een focus op diversiteit binnen samenlevingen.	Maar nieuwe regels kunnen de verdeling en ontwikkeling van rijkdom en geld sterk gaan beïnvloeden en bijvoorbeeld de geldhoeveelheid in de economie mee bepalen.

Appendix E. Descriptives Variables (Chapter 4)

Descriptions of the variables included in the second field study's PCA (Chapter 6); N=208, no missing data.

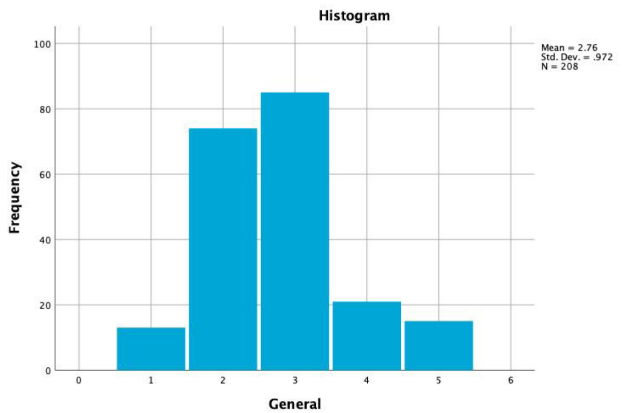
1. *General Expertise*

Ordinal variable with 5 categories, derived from Ericsson & Smith (Ericsson & Smith, 1991), referring to the age-group that a participant belonged to, in the month and year in which the experiment took place.

Statistics	
Mean	2.760
Median	3.000
Std. Deviation	.972
Skewness	.552
Std. Error of Skewness	.169
Kurtosis	.164
Std. Error of Kurtosis	.336
Minimum	1
Maximum	5

Frequencies

Age group	Label	Frequency	Percent	Valid Percent	Cumulative Percent
[36-40)	1	13	6.3	6.3	6.3
(46-50)	2	74	35.6	35.6	41.8
(51-55)	3	85	40.9	40.9	82.7
(56-60)	4	21	10.1	10.1	92.8
(61-65]	5	15	7.2	7.2	100.0
	Total	208	100.0	100.0	

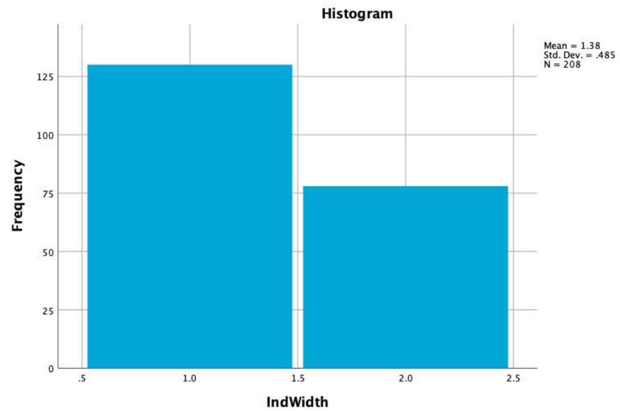


2. *IndWidth*: Number of industries worked in for over 5 years

Dichotomous variable, derived from Ericsson & Smith (Ericsson & Smith, 1991), referring to the number of industries worked in for more than five consecutive years, up and until the year that the experiment took place.

Statistics	
Mean	1.38
Median	1.00
Std. Deviation	.485
Skewness	.520
Std. Error of Skewness	.169
Kurtosis	-1.746
Std. Error of Kurtosis	.336
Minimum	1
Maximum	2

	Frequency	Percent	Valid Percent	Cumulative Percent
1	130	62.5	62.5	62.5
2	78	37.5	37.5	100.0
Total	208	100.0	100.0	

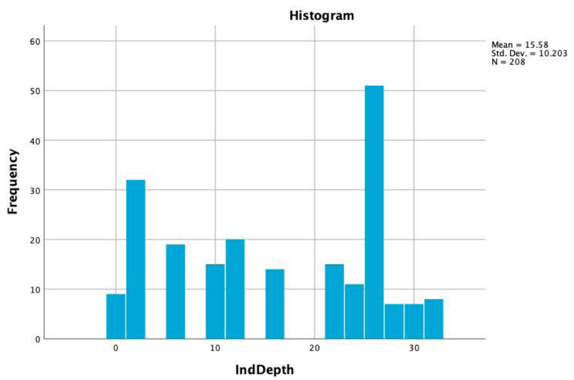


3. *IndDepth*: Years worked in current industry

Discrete variable, derived from Ericsson & Smith (Ericsson & Smith, 1991), referring to the number of years worked in the current industry, up and until the year that the experiment took place.

Statistics	
Mean	15.58
Median	15.00
Std. Deviation	10.203
Skewness	-.119
Std. Error of Skewness	.169
Kurtosis	-1.506
Std. Error of Kurtosis	.336
Minimum	0
Maximum	31

Frequencies				
	Frequency	Percent	Valid Percent	Cumulative Percent
0	9	4.3	4.3	4.3
1	7	3.4	3.4	7.7
2	25	12.0	12.0	19.7
5	7	3.4	3.4	23.1
6	12	5.8	5.8	28.8
9	15	7.2	7.2	36.1
11	20	9.6	9.6	45.7
15	14	6.7	6.7	52.4
21	15	7.2	7.2	59.6
23	11	5.3	5.3	64.9
25	36	17.3	17.3	82.2
26	15	7.2	7.2	89.4
28	7	3.4	3.4	92.8
30	7	3.4	3.4	96.2
31	8	3.8	3.8	100.0
Total	208	100.0	100.0	

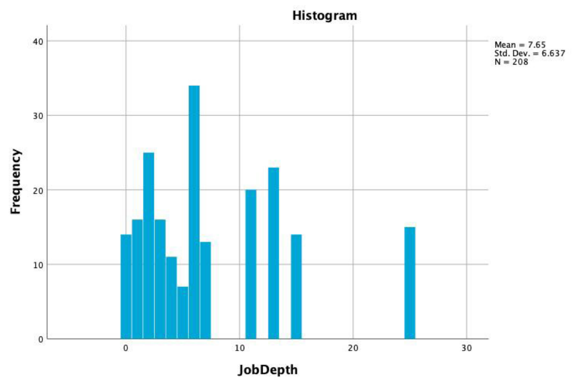


4. *JobWidth*: Years in current job

Discrete variable, derived from Ericsson & Smith (Ericsson & Smith, 1991), referring to the number of years worked in the current job, up and until the year that the experiment took place.

Statistics	
Mean	16.49
Median	17.00
Std. Deviation	7.942
Skewness	.310
Std. Error of Skewness	.169
Kurtosis	-.430
Std. Error of Kurtosis	.336
Minimum	1
Maximum	32

Frequencies				
	Frequency	Percent	Valid Percent	Cumulative Percent
1	7	3.4	3.4	3.4
6	15	7.2	7.2	10.6
7	12	5.8	5.8	16.3
9	13	6.3	6.3	22.6
10	7	3.4	3.4	26.0
11	14	6.7	6.7	32.7
15	17	8.2	8.2	40.9
16	14	6.7	6.7	47.6
17	35	16.8	16.8	64.4
18	18	8.7	8.7	73.1
21	11	5.3	5.3	78.4
25	22	10.6	10.6	88.9
31	8	3.8	3.8	92.8
32	15	7.2	7.2	100.0
Total	208	100.0	100.0	



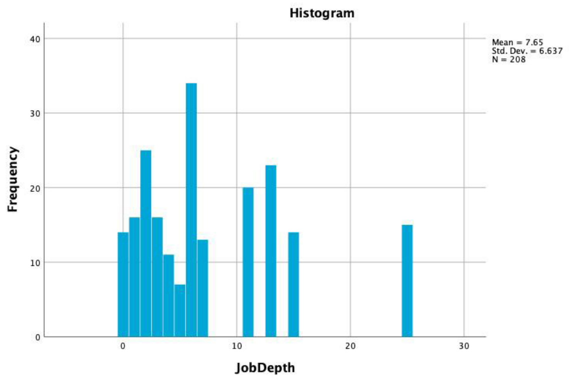
5. *JobDepth*: Number of years worked at board level

Discrete variable, derived from Ericsson & Smith (Ericsson & Smith, 1991), referring to the number of years worked at board level up and until the year that the experiment took place.

Statistics	
Mean	7.65
Median	6.00
Std. Deviation	6.637
Skewness	1.170
Std. Error of Skewness	.169
Kurtosis	.890
Std. Error of Kurtosis	.336
Minimum	0
Maximum	25

Frequencies

	Frequency	Percent	Valid Percent	Cumulative Percent
0	14	6.7	6.7	6.7
1	16	7.7	7.7	14.4
2	25	12.0	12.0	26.4
3	16	7.7	7.7	34.1
4	11	5.3	5.3	39.4
5	7	3.4	3.4	42.8
6	34	16.3	16.3	59.1
7	13	6.3	6.3	65.4
11	20	9.6	9.6	75.0
13	23	11.1	11.1	86.1
15	14	6.7	6.7	92.8
25	15	7.2	7.2	100.0
Total	208	100.0	100.0	



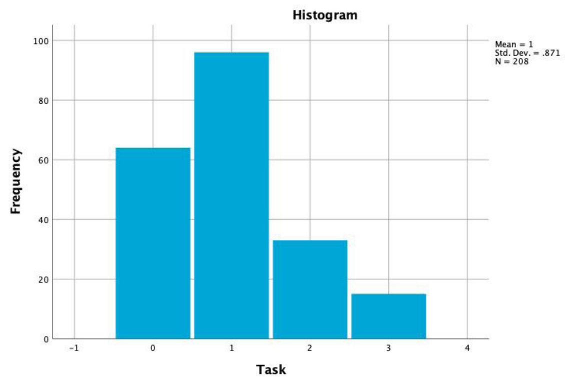
6. *Task:* Task Expertise

- Sum of three items:
  - E.4.MethodNaming (naming of foresight methodologies)
  - E.4.Process (presence of formalized weak signal interpretation routines)
  - E.4.Delegation (detection was delegated to staff)
- Recoded to improve distribution
- Ordinal scale (α =.723)

Statistics	
Mean	1.00
Median	1.00
Std. Deviation	.871
Skewness	.674
Std. Error of Skewness	.169
Kurtosis	-.115
Std. Error of Kurtosis	.336
Minimum	0
Maximum	3

Frequencies

	Label	Frequency	Percent	Valid Percent	Cumulative Percent
0	None	64	30.8	30.8	30.8
1	Fundamental	96	46.2	46.2	76.9
2	Intermediate	33	15.9	15.9	92.8
3	Advanced	15	7.2	7.2	100.0
Total		208	100.0	100.0	

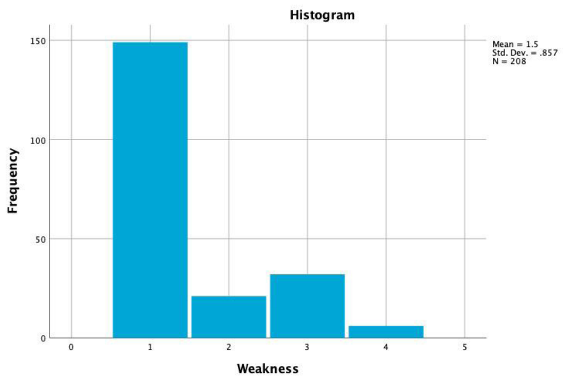


7. *Weakness*: Perceived Weakness

- Weighted sum of five items
  - W.1.Certain.R: reverse coded W.1.Certain (explicit agreement or disagreement with stimulus)
  - W.2.Neither (absence of explicit certainty and uncertainty in the opinion about a stimulus)
  - 2* W.3.Uncertain (explicit doubt about the meaning of a stimulus)
  - 3* W.4.Mentality (passing of information through the mentality filter in the shape of sudden awareness of novel effects or impact of a stimulus)
  - 4* W.4.Foresight (passing of information through the foresight filter in the shape of previously unknown information)
- Recoded to improve distribution
- Ordinal index

Statistics	
Mean	1.50
Median	1.00
Std. Deviation	.857
Skewness	1.457
Std. Error of Skewness	.169
Kurtosis	.743
Std. Error of Kurtosis	.336
Minimum	1
Maximum	4

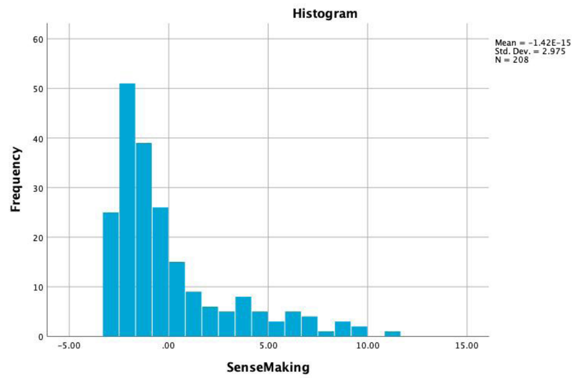
Frequencies					
	Label	Frequency	Percent	Valid Percent	Cumulative Percent
1	Strong	149	71.6	71.6	71.6
2	Hardly weak	21	10.1	10.1	81.7
3	Weak	32	15.4	15.4	97.1
4	Very weak	6	2.9	2.9	100.0
Total		208	100.0	100.0	



8. *SenseMaking*: Using the knowledge from the prior frame for interpretation

- Sum of four items:
  - P.3.Salient (use of salient information from frame)
  - P.7.Sentence (number of sentences in observation)
  - P.2.NonSal (use of non-salient information from frame
  - P.4.Predictions (articulation of future state of stimulus)
- Discrete variable (α =.731)

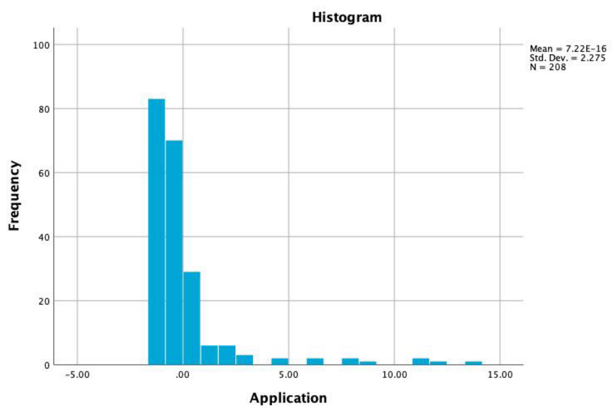
Statistics	
Mean	.000
Median	-1.129
Std. Deviation	2.976
Skewness	1.585
Std. Error of Skewness	.169
Kurtosis	1.971
Std. Error of Kurtosis	.336
Minimum	-2.821
Maximum	11.537



9. *Application:* Application of stimulus onto company situation

- Sum of three items
  - P.4.Consequences (articulation of consequences of stimulus)
  - P.1.Syntax (number of trailing sentences and sentences with bad syntax)
  - P.4.Benefits (articulation of benefits of stimulus)
- Discrete variable (α =.631)

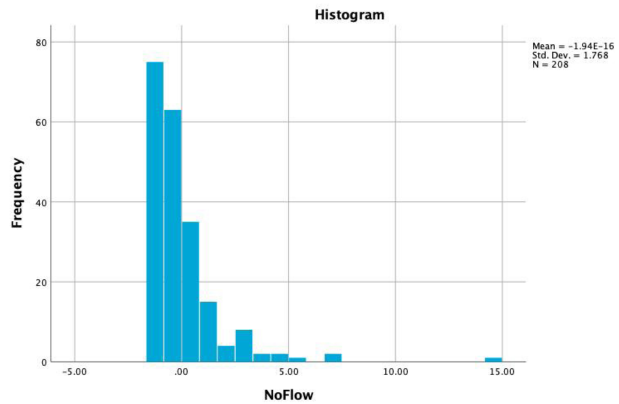
Statistics	
Mean	.000
Median	-.707
Std. Deviation	2.275
Skewness	3.877
Std. Error of Skewness	.169
Kurtosis	16.328
Std. Error of Kurtosis	.336
Minimum	-1.071
Maximum	13.623



10. *NoFlow*: Interpretation pattern interruption

- Sum of two items
  - P.6.Words (number of words in observation)
  - P.1.RepUhm (occurrences of stuttering and uhmming in observation)
- Discrete variable (α =.720)

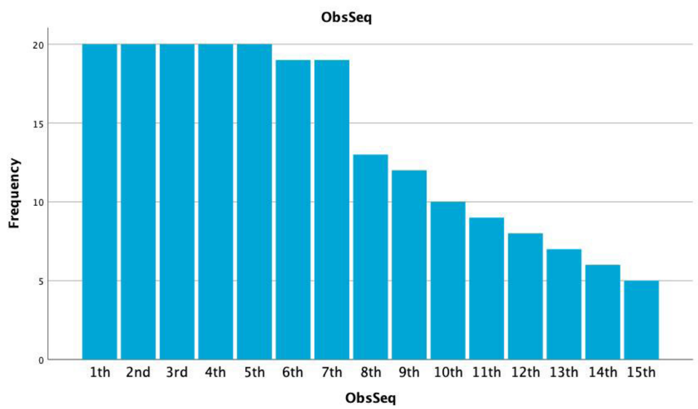
Statistics	
Mean	.000
Median	-.477
Std. Deviation	1.768
Skewness	4.118
Std. Error of Skewness	.169
Kurtosis	26.762
Std. Error of Kurtosis	.336
Minimum	-1.402
Maximum	14.980



11. *ObsSeq*: Sequence of Observations

Nominal variable with 15 categories referring to the sequence of observations from a participant

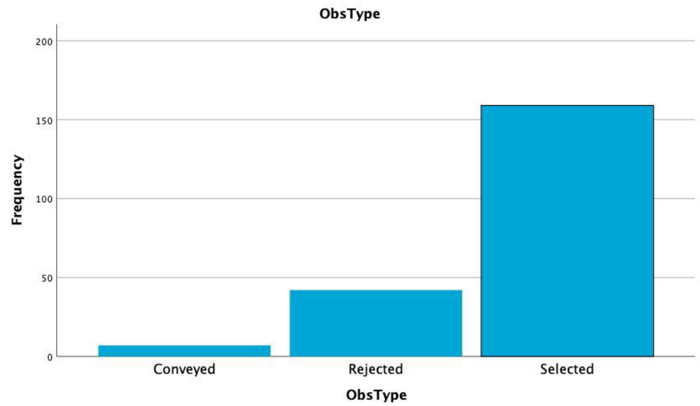
	Frequency	Percent	Valid Percent	Cumulative Percent
1th	20	9.6	9.6	9.6
2nd	20	9.6	9.6	19.2
3rd	20	9.6	9.6	28.8
4th	20	9.6	9.6	38.4
5th	20	9.6	9.6	48,0
6th	19	9.1	9.1	57.1
7th	19	9.1	9.1	66.2
8th	13	6.3	6.3	72.5
9th	12	5.8	5.8	78.3
10th	10	4.8	4.8	83.1
11th	9	4.3	4.3	87.4
12th	8	3.8	3.8	91.2
13th	7	3.4	3.4	94.6
14th	6	2.9	2.9	97.5
15th	5	2.4	2.4	100
Total	208	100	100	



12. *ObsType*: Type of Observation

String variable with three categories referring to the type of fragment: interpretation of a selected stimulus (Selected), interpretation of a rejected stimulus (Rejected), signals that the top-managers conveyed themselves (Conveyed).

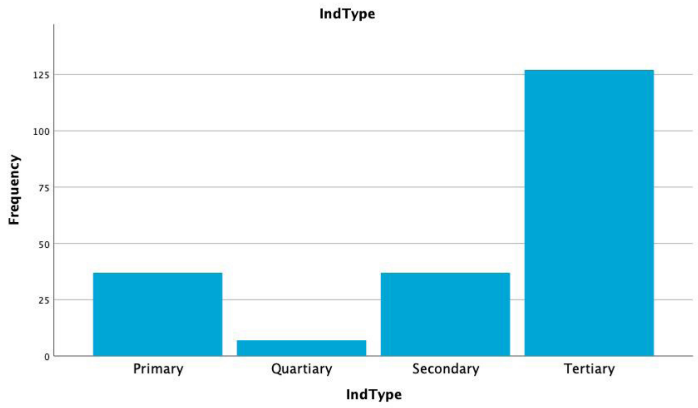
	Frequencies			
	Frequency	Percent	Valid Percent	Cumulative Percent
Conveyed	7	3.4	3.4	3.4
Rejected	42	20.2	20.2	23.6
Selected	159	76.4	76.4	100.0
Total	208	100.0	100.0	



13. *IndType*: Industry type

String variable with 4 categories referring to types of industry activity: extraction of raw materials (primary), manufacturing (secondary), services (tertiary), and high-tech (quartiary).

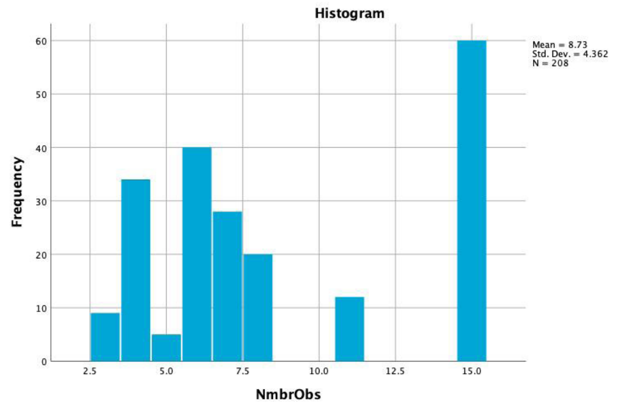
	Frequencies			
	Frequency	Percent	Valid Percent	Cumulative Percent
Primary	37	17.8	17.8	17.8
Quartiary	7	3.4	3.4	21.2
Secondary	37	17.8	17.8	38.9
Tertiary	127	61.1	61.1	100.0
Total	208	100.0	100.0	



14. *NmbrObs*: Number of stimuli that participants included in selection

Nominal variable referring to the number of stimuli that participants selected at the beginning of their session.

	Frequencies			
	Frequency	Percent	Valid Percent	Cumulative Percent
3	9	4.3	4.3	4.3
4	34	16.3	16.3	20.7
5	5	2.4	2.4	23.1
6	40	19.2	19.2	42.3
7	28	13.5	13.5	55.8
8	20	9.6	9.6	65.4
11	12	5.8	5.8	71.2
15	60	28.8	28.8	100
Total	208	100	100	



Appendix F. R Script MFA (Chapter 6)

A multiple factor analysis (MFA) was conducted to explore the global relationships between expertise types, perceived weakness, and interpretation patterns. The data set contained 208 rows of observations of top-manager interpretation of a stimulus and 15 columns of variables in four groups. The first group contained six variables for expertise types; the second group contained one variable for perceived weakness; the third group contained three interpretation pattern variables; the fourth group contained four classification variables. The first three groups were active in the MFA, the fourth was illustrative. No missing data and no outliers. A complete description of the research procedures employed in the MFA can be found in (Pagès, 2014).

R version 3.5.0 (2018-04-23) -- “Joy in Playing”
Copyright (C) 2018 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin15.6.0 (64-bit)

#Load packages Factominer and Factoextra
> library(“FactoMineR”, lib.loc=”/Library/Frameworks/R.framework/Versions/3.5/Resources/library”)
> library(“factoextra”, lib.loc=”/Library/Frameworks/R.framework/Versions/3.5/Resources/library”)

#Import Data Frame
X2019_aug_PCA.sav

#MFA including group plot
> res.mfa <- MFA(X2019_aug_PCA, group =c(6,1,3,1,4), type=c(“s”, “s”, “c”,”c”,”n”), name.group=c(“expertise”,”weakness”,”interpretation”,”ID”, “class”), num.group.sup = c(4,5),graph = TRUE)

 # Eigenvalues
> res.mfa$eig
> fviz_eig(res.mfa, addlabels = TRUE)

 # Group statistics: Lg; RV; Correlations; Coordinates; Cos2
> res.mfa$group$Lg
> res.mfa$group$RV
> res.mfa$group$cor

> res.mfa$group$coord
> res.mfa$group$cos2

 # Variables
> res.mfavarcor
> plot(res.mfa, axes = c(1,2), choix=”var”, habillage = “group”, invisible = “quanti.sup”)

 # Cloud of observations
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, col.ind = “#00A6D6”, Repel=TRUE)

 # Factor maps color-coded per variable, including confidence ellipses
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “ObsSeq”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “ObsType”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “Weakness”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “IndType”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “Participant”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “General”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “IndWidth”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “IndDepth”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “JobWidth”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “JobDepth”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))
> fviz_mfa_ind(res.mfa, invisible=”quali.var”, habillage = “Task”, addEllipses = TRUE, ellipse.type=”confidence”, repel = TRUE, geom=c(“point”))

 # List of within-individual-inertia per observation for both axes
> options(max.print=999999)
> res.mfaindwithin.inertia

 # Partial points observations with highest and lowest within-individual-inertia on both axes

```
fviz_mfa_ind(res.mfa, partial = c("20", "15","46","51"), geom=c("point"))
```

Appendix G. Curriculum Vitae

Barbara Liesbeth van Veen (1968)

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Netherlands

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Mobile: +3161 - 187 1413
barbara@futuristbarbara.com

Profile

Pragmatic, enthusiast consultant, specialized in future cognition and tailor-made corporate foresight processes. Possesses over ten years of experience as a foresight specialist and public speaker in multiple industries. Advocates evidence-based decision-making in cognitive diverse teams to increase foresight accuracy.

Experience

Since 2012 FuturistBarbara.com

Founder / Independent foresight specialist

- Foresight process redesign and development of futuristic perspectives for mid-sized companies and industry associations
- Conceptualized and developed 1,000 m2 space exhibition to complete the NASA - a Human Adventure Exhibition, at the Royal Dutch Jaarbeurs (July - December 2013), 130,000 visitors
- Public educational speaker; Topic: "The Future and Decision Making". Keynote at professional conferences on employment, health care, hospitality and retail
- Published writer in trade journals such as *Adformatie* (Future of Advertising), *2015 And Beyond* (Future Self), *H Ticino* (Future of Entrepreneurship)

Since 2001 Het Veranderbedrijf

Founder / Strategic Marketer

- Competitive repositioning, brand innovation, and above the line marketing strategy for firms in Dutch markets
- Persuasive environments aimed at business transformation and innovation: Meeting Moods, and Super Nova for Royal Dutch Jaarbeurs (interactive meeting rooms compelling the 5 senses with interior design using color saturation, shape and texture, timbre and rhythm, and natural flavors and aromas)
- Director of the Media Plaza Foundation (September 2008 - March 2013). Educated around 1,000 entrepreneurs yearly on emerging communication technologies

- Public Speaker, topic: “The Year 2050”, and “The Future of …”
- Virtual collaboration trainer dispersed teams independent of place and time
- Scenario planning in hospitality, financial services, housing, construction, and industry organizations for hospitality and employment

1999 - 2001 Hermes (VOF)
Partner / Professional Conference Organizer

Major conferences:

- For 12 consecutive years the annual congress The Hague Telecom (City of The Hague) for 400 influencers in telecom on the latest trends, (2 within Hermes, 10 within Veranderbedrijf)
- National Real Estate Manifestation (1998)
- UNESCO Diplomatic Conference Armed Conflict The Hague (1999),
- UN Climate Top Rotterdam (2000)
- OPCW (UN on prohibition of chemical weapons), The Hague (2000)
- Permanent Forum on Pharmaceutical Crime, The Hague (2000)
- International Peat Society, Amsterdam (2001)

1998 - 1999 Expo & HOC (merger Holland Organising Centre)
Manager Congresses and Events

Major conferences:

- International Health and Economics Association and Erasmus University, 2nd World Conference, 1999
- UNFPA and Ministry of Foreign Affairs, “The Hague Forum”, 1999

1997 - 1998 Holland Organising Centre BV (100% subsidiary NCC)
Operational Manager

Major conferences:

- OPCW (UN on prohibition of chemical weapons), The Hague (1998)
- International Association of Mathematical Physics and Leiden University, Leiden (1998)
- International Association Geotextiles, The Hague (1998)

1995-1997 Netherlands Congress Center (NCC)
Manager Planning and Reservations
Planning and control of event contracts, yield management, event software development, automation of event related processes

Education

- 1994 Master of Arts, University of Utrecht, International Relations
- Since 1997 Executive education:
    - Situational Management (68 tuition hrs), Nive, 1997
    - Strategic CRM (20 tuition hrs), Focus, 2004
    - Visual Marketing (68 tuition hrs), Artemis Academy, 2008
    - Strategic Marketing (22 tuition hrs), Harvard Business School, 2008
    - Taking Marketing Digital (14 tuition hrs), Harvard Business School, 2009
    - Scenario’s and trends (20 tuition hrs), Focus, 2011
    - B2B Marketing (14 tuition hrs), Harvard Business School, 2012
- Since 2014 Ph.D. candidate TU Delft (part-time)

Languages
Dutch (native), English (fluent)

List of Publications

- van Veen, B. L., Ortt, J. R., & Badke-Schaub, P. G. (2019). Compensating for perceptual filters in weak signal assessments. *Futures*, *108*
- van Veen, B. L., Ortt, J. R., & Badke-Schaub, P. G. (2018). Mental Models Particular to Weak Signal Analysis, presented at 15th Workshop on Corporate Governance, Brussels, Belgium, 2018, EIASM (Best paper award)