Futures 119 (2020) 102543

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

Contextualising weak signals: Towards a relational theory of futures knowledge

Toni Ahlqvist[a,b,*], Tuomo Uotila[c,d]

[a] Finland Futures Research Centre, University of Turku, Finland
[b] Turku School of Economics, Rehtorinpellonkatu 3, 20500, Turku, Finland
[c] School of Engineering Science, Lappeenranta-Lahti University of Technology, Finland
[d] Lahti Campus, Mukkulankatu 19, 15210, Lahti, Finland

ARTICLE INFO

Keywords:
Weak signal
Emergence
Relational theory
Context
Perspective
Futures knowledge

ABSTRACT

In this paper we propose a framework to re-think and widen the theoretical assumptions behind so-called weak signal theory in futures studies. This paper suggests that the present understanding of weak signals views the topic as a question of linear emergence, that is, a sequence of development that perceives the topic evolving from an embryo towards a full-blown future issue or trend. However, this viewpoint does not take into account the context and perspective – or positionality – of the perceiver. This issue has, we argue, wide-ranging effects on the identification and interpretation of weak signals. Thus, as a response to this gap, we outline a relational theory of futures knowledge that aims to consider this missing theoretical baseline and widen the understanding of the nature and formation of weak signals. The theory builds on selected tenets of behavioural economics, psychology, human geography and anthropology. This paper outlines the principles of current weak signal theory and depicts the relational theory. It also provides selected empirical examples to emphasise the points made.

1. Introduction

When soldiers in the Finnish army are taught to keep watch when light is poor in field conditions, they are told “not to look, but to see”. In other words, they are advised to move their eyes slowly across the area they are guarding without fixing their gaze on any particular object. If they do not follow this instruction, they will lose their ability to survey their environment objectively. Instead, they are instructed to observe the relationships between objects. If these relationships have changed, then something has moved in the foreground. There is, however, one exception to this rule: when an object is moving straight towards them. In this case, a second lookout is required to spot the change in relationship from a different perspective or angle.

Shifting this sentinel metaphor into the context of futures research and weak signals, one could translate it to the following hypotheses: If the observed phenomenon is two dimensional (a surface), one needs to observe it from two different perspectives (triangulation) in order to maximise the impact of observation. If the phenomenon is three dimensional (spatial), three different lookout points are needed. The more complex (n-dimensional) the phenomenon is, the more (n different) lookout points are needed to make sure that it is accurately observed and acknowledged.

The basic premise of this sentinel metaphor applies more generically in scientific reasoning, since visual observation has been, and still is, an important way to turn data into evidence and evidence into scientific results (see Amann & Knorr Cetina, 1988). It is also

* Corresponding author at: Finland Futures Research Centre, Turku School of Economics, University of Turku, Finland.
E-mail addresses: toni.ahlqvist@utu.fi (T. Ahlqvist), tuomo.uotila@lut.fi (T. Uotila).

https://doi.org/10.1016/j.futures.2020.102543
Received 8 October 2019; Received in revised form 26 February 2020; Accepted 12 March 2020
Available online 16 March 2020
0016-3287/

common in futures studies and strategic thinking to rely on visual metaphors and verbs. Several methods and studies deploy verbs, such as visioning, monitoring or scoping. It is also common to scan the horizon, assess the trend landscape, or view an organisation's strategic radar. However, it is not as common to problematise what happens and what is at stake when one uses these kinds of visual verbs and metaphors. Which types of ontological and epistemological prioritisations and selections are made, either explicitly or implicitly, when these visual practices are engaged? Here we suggest that these verbs and metaphors lead to a positional and relational approach. In other words, they emphasise that all knowledge statements, be they about past, present or future, are made from a specific position, or context, that is in relation to multiple other positions and contexts. What does this argument mean if one takes this suggestion seriously? How does the position affect one's vision of the futures?

In this paper, we contemplate the above questions in the context of weak signals. We apply a positional approach to the recognition of weak signals in order to emphasise the roles of object relations, contexts and perspectives. Weak signals are among the cornerstones of futures studies and related planning practices. Typically, weak signals are represented as emerging phenomena that are the first potential signs of a major change in the future. Thus, in the archetypical exercise it is presumed that the viewer of weak signals can identify seeds of change, and probably also classify them in some fashion. The "standard" theoretical baseline is the Ansoffian perspective, which presumes that the viewer of weak signals identifies issues that are linearly progressing in their early form. In formulating the premise of weak signals theory, the "standard" version of this theory presupposes an emerging issue that is perceived in its rudimentary form. The argument states that by engaging in weak signal detection, organisations, nations or individuals could gain first-mover advantage compared to those who have not yet identified the signals.

Thus, the three basic assumptions of weak signal theory are: 1) weak signals are emerging issues; 2) the emergence is linear, that is, moving linearly from a rudimentary stage towards a more advanced or progressed stage; and 3) issues have universal feature that make them identifiable as weak signals. Complementing, and occasionally challenging, this common baseline, we argue that, in many cases, weak signals are information "read" from a different perspective, position and context, compared to what generic weak signal theory asserts, that is, weak signals are linearly emerging issues. We propose that weak signals are often not just about the identification of linear emergence, but also about the shifting positions and contexts of observers. It means that in the practice of weak signal identification there are also other important elements to consider in addition to the "linear emergence" of an issue. These other issues include the bounded perspective and context of an observer and the context of an observed object. Our proposition opens a pathway to understanding how the relations between and the contexts of observers and objects affect futures thinking, and the identification of weak signals in particular. When re-thought in this way, the identification of weak signals – in their standard meaning – becomes more complex and societally contingent issue linked with positional social power.

We argue that linear weak signal theory should be complemented with something that we call a relational theory of futures knowledge. Relational theory is based on several theoretical lines of social and behavioural sciences. We also suggest, although we are not able to develop this argument at length in this paper, that the relational theory of futures knowledge could be of use in understanding other types of futures knowledge that are gained, for example, through scenario or Delphi exercises. By developing this theory, we aim to deepen the socio-theoretical basis of futures studies and assist it in resonating more closely with discussions relevant to social theory (Ahlqvist & Rhisiart, 2015).

The paper is structured as follows: In Section 2, we provide reflections on the theoretical traditions of weak signals. In the third section, we highlight a perspective on the theoretical lineages of relational theory. This perspective emphasises classic psychological and sociological theories and selected theories of behavioural economics. In the fourth section, we present an outline of the relational theory of futures knowledge and show how it is connected to weak signals. This is supported by Section 5, in which we examine three empirical cases that reveal different aspects of contextualisation. In the concluding section, we discuss the ramifications of our proposals, and provide signposts for further research.

2. Weak signal theories: reflecting on the stylised theoretical constructs

In this section, we provide a stylised outlook on theories scrutinising the emergence, observation and use of weak signals in futures studies and management research. For the sake of brevity, we call these constructs weak signal theories. These theories combine the work of multiple theorists (see the following paragraphs for examples). Our aim is not to cover all facets of weak signal theorisation, but to discuss the main outlines and caveats of the theories and, on this basis, construct pathways for complementing and re-thinking them.

Management theorist Ansoff (1984) argues that weak signals are an outcome of an organisation's external or internal issues, which are hard to explain and estimate. Mendonça, e Cunha, Kaivo-Oja, and Ruff (2003, p. 205) define weak signals as "information on potential change of a system toward an unknown direction". They suggest that weak signals are low probability events that cannot be forecasted. As Ilmola & Kuusi (2006, p. 911) suggest, weak signals are "unstructured information" that could be pointing towards a wild card. Mendonça et al. (2003, p. 208) identify an element of cultural context in the identification of a wild card: "The concept of 'wild card' is a culturally embedded one in the sense that we can always note that some things are real surprises to some groups and some individuals". The notions of weak signal, a wild card, as well as the black swan, are connected by a conceptual field. They are concepts that point towards a future potentiality, towards a possibility that something – be it an event, pattern or magnification of stochastic ripples – with wide-ranging and swift socio-economic effects could emerge (Ahlqvist, Uotila, & Hietanen, 2015).

Rossel (2009, 2012) argues that there are two types of weak signal theories. The first is classical Ansoffian theory, which argues that weak signals are fundamentally emergent signs of potential future transformations. The premises of the Ansoffian and neo-Ansoffian weak signal theories can be summarised in three points (Rossel, 2012). First, weak signals are presumed to be phenomena that are in the external environment of the observer. Second, an observer can objectively identify these phenomena as separate and distinct from their surroundings. Third, the observer will identify these phenomena in their early or emergent stage.

Rossel (2009, p. 312) directs several important criticisms towards the Ansoffian tradition. First, he asserts that in this tradition the observers are "contextless", or without frames of meaning. When the above-mentioned points are combined, it follows that the observers are cognitively "flattened": the supposedly objective nature of the phenomena means that practically any observer, armed with the basic weak signal "toolkit", can identify a weak signal if it is detectable in the first place. Second, Rossel states that the process of signal identification is not theorised enough: different mental models, cognitive biases and ideologies that could have relevance in the identification are not reflected upon. Thus, the identification of a signal is based merely on its generic "oddness" (Rossel, 2012, p. 234). This situation leaves signals more on a metaphorical level and disconnects them from actual events or processes (Rossel, 2009, p. 308). Thirdly, the potential causal effects of the signals are not contemplated systematically. The characterisation of causal effects is left to the observer to decipher. At a more general level, Rossel (2009, p. 312–313) argues that there is a "deficit of reflexive precautions" when it comes to weak signals. He argues that most of the identified signals in the studies are only signal "candidates". Thus, weak signal analysis would benefit from a wider assessment of their societal, economic and ethical impacts.

The second weak signal theory suggested by Rossel is constructivist. This tradition is based on the notion that actors are embedded in the production of futures knowledge. Thus, weak signals are perceived more as constructs, or results of an observer's frames and capabilities, instead of "objective observation" by an external observant. Rossel (2012, p. 236) argues that in constructivist perspective, changes are approached as hypotheses that are integrated with other relevant signals and patterns of change. They are then assessed from multiple viewpoints, including potential biases, and monitored from the view of its possible causal effects.

Schoemaker and Day (2009) provide valuable insights into the biases related to weak signal recognition that are of relevance for constructivist theory. They developed a three-step process on how to identify weak signals (Schoemaker & Day, 2009, p. 84–86). The first step is the scanning phase, in which local intelligence should be explored, along with wider networks and search parties. The second step is sensemaking, in which the signals are tested for their diversity and alternative future directions are scanned. The third step is the further probing of the signals by making reality checks, setting constructive conflicts and thinking with "seasoned intuition". Schoemaker and Day's contribution is an apt managerial procedure to identify weak signals. Other methods developed for identifying emerging issues include, for example, early warning system (EWS) (Schwarz, 2005) and war-gaming (Coates, 2016, p. 99). There are also some attempts to develop a quantitative approach of EWS (see Bisson & Yasar Diner, 2017).

Jørgensen (2012) provides a relevant constructivist interpretation of weak signals. He (2012, p. 240) argues that the actors are deeply "entrenched in the constitution of these facts through their anticipation while essentialism stands for the existence of a single true form of reality". Building on Latourian actor network theory and science and technology studies theory, his approach is based on the creation of so-called "design junctions", that is, specific locales of temporary interaction between multiple users around a topic or design. In this setting, weak signals are basically reactions to a design that is set under scrutiny. Design junctions are spaces "for exploration, inspiration, exchange, and idea generation in some chosen field of practice" (2012, p. 243). Design junctions aim at integrating the diversity of actors and, in this sense, they come close to future workshops, a commonly used practice in futures studies (see Dufva & Ahlqvist, 2015a, 2015b). Jørgensen (2012, p. 244) argues that in the context of design junctions, weak signals cannot be understood separately from the context in which they have originated. This means that the design junction limits the possibilities of the weak signals that can be identified. As Jørgensen argues, the basic problem in Ansoffian theory, and the mainstream weak signal theory, is that weak signals are presumed to arise independently from the observer. We aim to further develop the constructivist argument by providing a theory on how to explain the processual nature of weak signals in this framework.

Hiltunen (2008) proposes a sort of mid-range approach between the Ansoffian and constructive theories. Hiltunen suggests a notion of future sign based on the classic semiotic theories by de Saussure and Peirce. Hiltunen (2008, p. 249) defines future sign by using the Peircean concepts of objects, representamen and interpretant. In this case, object is the "emerging issue" to be recognised, representamen is defined as "the concrete form the sign takes", and interpretant is the "sense made of the future potentiality of the sign". Hiltunen (2008, p. 249) notes the context of the interpretant: "Contexts are included in this dimension, because interpreters make their conclusions about the signs in their own context". Hiltunen (2008, p. 254) argues that "weak signals are dependent on the context in which they are interpreted" and "in one context the signal can be weak and strong in another". However, Hiltunen does not fully contemplate what consequences these arguments have, that is, what it means if one asserts that "weak signals are dependent on the context". Thus, the theory of future sign takes for granted the common assumption of weak signals as emerging issues.

Here we argue, building on the previous points, that weak signal theorisation should be taken further by developing novel perspectives. This perspective could be based on so-called relational theory that emphasises the contextual aspects of weak signals in a way that challenges the putative objectivist and linearly emergent baseline of current weak signal theories. In the following section, we present theoretical lineages that endorse a relational futures perspective.

3. Social theoretical lineages of a relational futures perspective

The key argument for a relational perspective is that in the identification of a weak signal the historical and spatial contexts matter fundamentally. The first outline of this argument is the theory of "bounded rationality", as coined by Simon. Simon (2000, p. 25) asserts that bounded rationality "is simply the idea that the choices people make are determined not only by some consistent overall goal and the properties of the external world, but also by the knowledge that decision makers do and don't have of the world". Furthermore, bounded rationality is an outcome of people's "ability or inability to evoke that knowledge when it is relevant", "to conjure up possible courses of action", "to cope with uncertainty" and "to adjudicate among their many competing wants". More recent contributions suggest that bounded rationality may be accelerated by emotional arousal (Kaufman, 1999), and that emotions may cause significant alterations to the rationality presumptions of mainstream economic theory.

An important notion in this context is Polanyi's "tacit foreknowledge" (Polanyi, 2005). Tacit foreknowledge builds on Polanyi's idea of tacit knowledge, which refers to the ability of humans to know much more than they are able to utter, that is, to a kind of systemic interpretative capability that allows humans to identify, for example, social moods by looking at people's faces. Tacit foreknowledge refers to this advanced capability in which humans come to anticipate certain effects based on their experience, without deliberate and focused thought. This kind of foreknowledge has an important role when identifying potentially new and emerging futures elements: the process of identification builds on the experience of the observer that is further based on bounded rationality. This discussion also points out that future-oriented knowledge, particularly in the case of weak signals, is centred on the "knowing self" (see Howells, 2002). This aspect makes future-oriented knowledge sticky and difficult to transfer.

There are also other theoretical lineages that create grounds for a relational futures perspective. For example, sociologist Bourdieu's (1983, 1984a, 1984b) multiple theories on practice, social field and social taste provide a convincing argument that humans, as social beings, are fundamentally tied to a relational web of social meanings. This web channels their perspectives and selections in multiple ways. This channelling is tightly connected to social power. For example, in the field of art production Bourdieu asserts that the perception of arts is a deciphering operation in which the beholder must know the rules of interpretation in order to understand it. In *Distinction* (1984a), Bourdieu offers theory-based evidence that one's socio-cultural position is key to one's socio-cultural preferences and tastes.

In the field of anthropology, the classic writings of Geertz (1973, 2000) call for "thick description," in which socio-cultural phenomena are interpreted through multiple lenses that form a multi-faceted perspective on the research object. Another of Geertz's useful concepts is "local knowledge" (2000). He states that all knowledge is born in and interpreted through a perspective that is inherently tied to particular spatial and temporal contexts. As Geertz (1973, p. 35) asserts: "men unmodified by the customs of particular places do not in fact exist, have never existed, and most important, could not in the very nature of the case exist". In brief, this means that humans are always inherently tied to their contexts, and a perspective without a particular, local context is not possible (see Ahlqvist, 2012, 2018 on the repercussions of this argument). The view is always from somewhere towards something. Human geographers have contributed to this body of theory by asserting that the notions of "region" (e.g. Soja, 1985) and "place" (e.g. Entrikin, 1991) are not only critical contexts for human life but are also themselves contextual. Also, the early work of Knorr (1979) provides insights on how organisations are critical contexts that affect the perceptions and knowledge of humans.

Work in the field of psychology and behavioural economics has made important contributions that reveal the impacts of contexts and biases in human perception. The classic work of Kahneman and Tversky, in particular, has provided important concepts and empirical evidence on these issues. This trajectory is already visible in their paper on the psychology of prediction (Kahneman & Tversky, 1973). Here the authors claim, through an empirical setup, that in the case of numerical data people tend to predict by "selecting the outcome that is most representative in the input" (Kahneman & Tversky, 1973, p. 248–249). This leads to the following interesting outcome: "people erroneously predict rare events and extreme values if these happen to be representative" (Kahneman & Tversky, 1973, p. 237). Thus:

The discrepancies between predictions and outcomes, therefore, are largest at the extremes. … [S]ubjects are most confident in predictions that are most likely to be off the mark. The foregoing analysis shows that the factors which enhance confidence, for example, consistency and extremity, are often negatively correlated with predictive accuracy. (Kahneman & Tversky, 1973, p. 237)

The consistency of the input has a crucial impact on how people view the representativeness of the data and what kinds of intuitive prediction they then make. There are also significant judgment or perceptual biases in human decision-making (Tversky & Kahneman, 1974). With numerical information, the common biases are based on, for example, sample-size insensitivity, misunderstanding the role of chance and validity and the role of regression. Another source of bias is availability, such as the availability of information based on the effectiveness of the search procedure or the combination of different data.

From the perspective of future-orientation, the notion of a "decision frame" that depicts "decision-maker's conception of the acts, outcomes and contingencies associated with a particular choice" (Kahneman & Tversky, 1981, p. 453) is useful. The core issue is that the adopted frame is partly derived from the definition of the problem, and partly from the "norms, characteristics, and personal character" of the decision maker. Furthermore, the authors assert that actors are "not normally aware of the potential effects of different decision frames on their preferences" (Kahneman & Tversky, 1981, p. 457). They further assert that people are usually unaware of different frames and "wish their preferences to be independent of frame" (Kahneman & Tversky, 1981, p. 458). Thus, they emphasise the role of perspective in the psychology of choice. Tversky and Simonson (1993) have also studied the impact of context in choice and decision-making. The notion of "context-dependent preference" (Tversky & Simonson, 1993) is an alternative to the standard value maximisation hypothesis of choice theory. It proposes that choice making is dependent on two contexts – background context and local context.

An interesting issue related to futures knowledge is the role of imagination as an explorative and speculative practice. One could say that issues about the future are utterly unattainable – they are beyond our epistemological reach. However, we can turn the future into an object of our knowledge through the act of speculation. How to identify an issue that is emerging is an intriguing question. We assert that it is not only important to classify different ways of knowing something, but also to think about different ways of not knowing. In a timely paper, geographer Thrift (1983, p. 45) proposed that there are at least five dimensions to how information can be unknown in a specific spatial context. The first is unknown information in the sense that some part of information is totally unknown at a particular moment. The second is information that is not understood because of the societal, regional, local or individual frame of meaning. The third is information that is hidden from people in a spatial setting. The fourth is undiscussed information, that is, information that is taken for granted as being true. The fifth is information distorted by some actors in a spatial setting.

Finally, as we claimed in the introduction, visual metaphors are commonly utilised when searching for weak signals, even though signals might not be "visible" in any concrete way. Neugarten (2006) argues that visual metaphors can be utilised to explain the process of knowledge scanning and cognition. As he (2006, p. 895) suggests: "…rather than 'seeing is believing', it appears that 'believing is seeing'—we see what we expect. The act of classifying inevitably focuses on and privileges certain issues, marginalizing others". He further proposes that a perspective in the visual sense – and through ideas such as attention, noticing, ignorance, selective discarding of information, blind spots, not seeing, inattentional blindness, change blindness, passive/active vision, peripheral vision, foveal or focused vision – can be utilised to explain the ways we seek information. He argues that practices of organisation parallel human visual processes.

All these theoretical lineages depict, from varied angles, the question we are concerned with in this paper: the relationality and positionality of futures knowledge. Obviously, they do not form a solid and unproblematic theoretical baseline, but instead they provide avenues to explore this question further.

4. An outline of relational theory of futures knowledge

After the theoretical discussion, we are able to outline the basic instances of relational theory, and to discuss empirical examples. We aim at providing a framework for understanding the relationality of futures knowledge, and for scrutinising weak signals as context-dependent and perspective-oriented constructs.

4.1. Components of the relational theory

To start with, we emphasise two specific issues. Firstly, the relational theory here refers to a socio-hermeneutic approach that aims at balancing the positionalities of both the observer and the observed object and the social, psychological and material contexts of the observation. We use the notion of relationality in a socio-theoretical, or anthropological, sense in order to decipher the actual practice of weak signal observation. Thus, the notion of relationality refers to the event and the social setting of observation. As such, the notion does not stem from, or adhere to, any specific philosophical styles of thought, such as perspectivism or relativism. Secondly, the relational theory builds on the process of framing, as argued by Rossel (2009, 2010, 2012). Rossel defines framing as follows:

It means a certain way to select features, shape them into a consistent set of references or perspective, supported by more or less explicit boundaries, time considerations or contextual sense-making links and analysing at some point the assumptions underpinning our early detection activity… (Rossel, 2009, p. 315)

Thus, framing is a processual activity in which the interpreter of a weak signal chooses, delimits, assumes and builds meaning (Rossel, 2009, 2010).

There are five basic components in the relational theory of futures knowledge. The first component is the *observer* – the actor who identifies a weak signal (see the next paragraph). The observer can refer to an individual agent, team or collective, or to an organisation or firm.

The *object* is the second component. The object is the signal that is grasped by the observer. It can come in multiple forms: as an observed material object, information pieces, symbols or just noise. An object can be linguistic, visual, symbolic or practice-related. The key idea is that the object is defined in relation to the observer, and vice versa in some cases.

The third component is the *perspective*, that is, the orientation that is fundamentally connected to the sense-making capabilities of the observer. It is critical to understand that the notion of perspective is utilised metaphorically here. In other words, it is not just about visuality. Instead, the perspective refers to an information-scouting practice that is founded on the sense-making capability of the observer. Sense-making capability combines different abilities, such as the ability to spot the linguistic, visual, aural etc. dimensions of phenomena from a complex social environment, and the ability to formulate sensible depictions, hypotheses or speculations based on this information. Thus, the perspective emphasises the viewpoint one has towards a certain issue or phenomenon. The perspective is positional – it is always from somewhere towards something – and it has a particular focal range and limits. The perspective is connected to frames and metaframes, as suggested by Rossel above. The perspective also contains an observer's generic orientation towards his or her way of seizing the world. The perspective also covers the ways in which the observer depicts the signal. It contains, for example, utterings, rhetoric and definitions – different ways of how the signal is interpreted and recorded.

The fourth component is the *context*. The context defines the boundaries of what is possible to know from a certain position consisting of the observer, the object and the perspective. Context can be divided into the spatio-temporal context and the trajectory context of a being. Spatio-temporal context means that every observer has a specific spatial and temporal frame. Trajectory context refers to the history and past lineage of the observer, and to its conditioning effects on the observer. For example, the competence structure of an organisation could have strong conditioning effects and drastic impacts on an organisation's anticipatory culture and systemic capabilities (see Ahlqvist et al., 2012). The trajectory context could be different if the structure is built on a narrow specialist competence, when compared to, for example, more hybrid and generalist structures built on a combination of multiple competences.

Local knowledge is the fifth component of the relational theory. The component emphasises that observers are always embedded in local knowledge, that is, knowledge that is particular, selective, limited and interpreted from a certain perspective (Ahlqvist, 2018). Local knowledge is linked with bounded rationality, as discussed earlier in this paper. Local knowledge and bounded rationality are further connected to social power. While not all perspectives are equal, some perspectives, usually those of particular actors, are more convincing and overpowering than others. The workings of social power can be fostered by futures studies methods. This is because several methods share an orientation towards consensus building. This consensus orientation, as suggested by Ahlqvist and Rhisiart

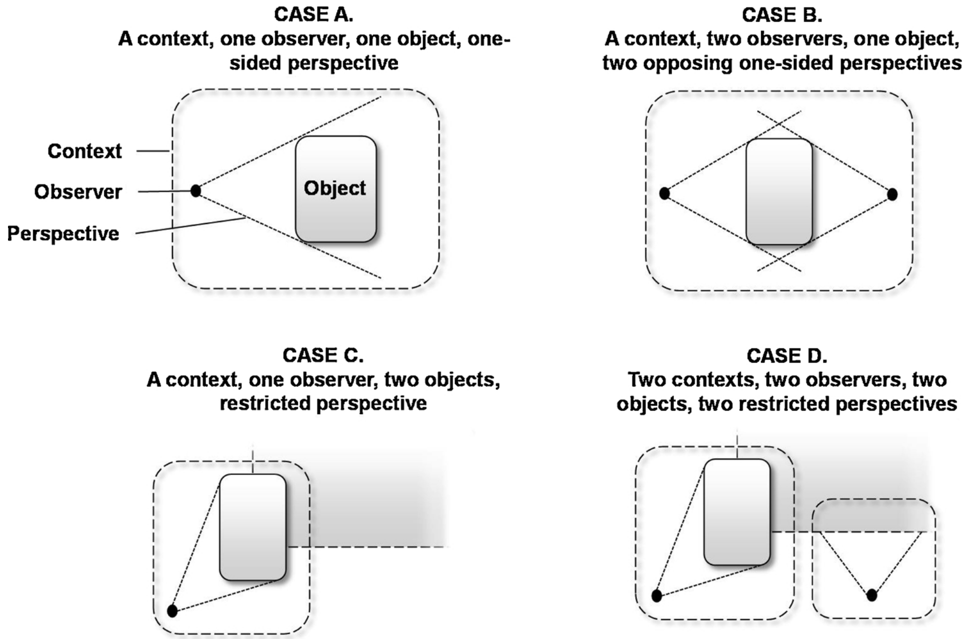

Fig. 1. Examples of the relational theory of futures knowledge: observers, objects, perspectives and contexts embedded in local knowledge.

(2015, p. 102), opens an avenue to use futures methods as tools of governance. This instrumental role of futures could be realised, for example, by constructing a process that endorses a pre-determined perspective of the future. This could be achieved by choosing experts in advance or by "normalising" the process boundaries in such a way that alternatives to the norm are not even discussed. For example, in future-oriented planning processes the result of the work does not often genuinely represent the variegated, often alternative, views of different process participants, but is, instead, a sort of "banal consensus" that reflects the minimum joint worldview of the participants, or, in some cases, the viewpoints of the most socially powerful or outspoken participants.

Fig. 1 presents four schematic cases that are borne out of the interaction of these components. In all cases presented in this paper, the reader should keep in mind that the cases are metaphorical. Thus, while we are using the notion of perspective and playing with the idea of perceiving, this does not mean that we are only talking about visual perception or ocularcentrism, that is, something that is only dependent on the eye (see Gregory, 1994). By using the idea of perspective, linked with the context, we want to highlight the *positionality* of each observation. Weak signals are always observed and grasped from a particular and bounded position, even if the case is about imagining the signals and thus not directly observing them *stricto sensu*. The perspective, as a result, underlines thinking as a prismatic action, in which objects are like holograms – different when you change the angle.

Case A depicts an archetypical situation in which the observer perceives the one-sided outline of an object. In this case, the "other side" – some other dimension of the object – is not perceived and neither understood nor taken into account. Knowledge generation is based on a one-dimensional view. Case B depicts a variation of this similar situation with the exception that there is another observer that is perceiving the object from the opposite side. Knowledge generation is thus based on the combination and interaction between these two observers. Case C presents another variation. In this case, the observer perceives the full outline of an object from a certain position. However, the perceived object blocks a more significant connected object that is not visible to the observer. Again, Case D presents a similar situation, but with two distinctively positioned observers. In this case, two observers perceive the objects from two perspectives. The first perceives the object that blocks the more significant object. The second perceives part of the significant object, but not the connected less significant object.

Fig. 2 presents a more complex situation: a hybrid object, that is, an object constructed of several partially overlapping objects. This kind of situation is more realistic when it comes to the identification of weak signals. Fig. 2 depicts a set of objects perceived by several observers from several contexts. The observers that are in the different positions see the object only from a certain angle.

In Fig. 2, observer I perceives half of object 1, observer II perceives small parts of objects 1, 2 and 5 and so on. Also, observer V is the only one in this group that perceives object 3. Depending on their contexts, every observer perceives only part of the objects and thus has to draw conclusions on a selective basis. The entire hybrid object can only be perceived through combining all the positional perspectives.

4.2. Weak signals and context transformations

An important aspect of relational theory is the role that context plays in the construction of knowledge about the future. Here, we make the argument that in several cases the identification of a weak signal, that is, finding a novel phenomenon or an issue, is more

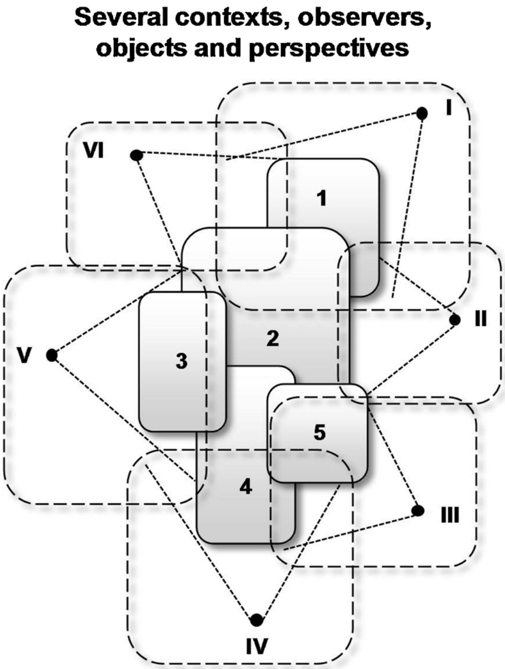

Fig. 2. The case of a hybrid object in the relational theory.

likely to be about context transformation or transition than about the identification of a linearly emerging or evolving issue in a rudimentary state.

Fig. 3 presents four cases on the identification of weak signals when understood in the context of relational theory. Case A depicts a classic case of a transforming object. The object evolves linearly as an emerging weak signal – the object evolves in a context through different phases until at phase III it breaks the recognition threshold. Case B presents the first example of the impact of context transition. It depicts a situation of connected contexts in which the context of the observer is identified, bounded and realised. This information is then utilised in the identification of weak signals. Thus, the objects are searched for from neighbouring, but connected, contexts by using different methods and approaches to interpret and study the objects. Case C depicts a somewhat similar situation to case A, but this time the contexts are disconnected or not directly neighbouring contexts. In this case, one could utilise interpretants or different kinds of knowledge transfer procedures for bridging the context disconnection. Case D depicts a classic case of a boundary object, as defined originally by Star and Griesemer (1989). The object combines at least two contexts and can be interpreted from several contexts.

Fig. 4 presents further examples of the identification of weak signals. The case E shows a polysemic object. Here, polysemic refers to an object that, in order to be understood, should be interpreted from various contexts because none of the singular interpretations fully characterises it. Case F presents a converging object in which parts of the object can be identified in contexts I, II and III, but the entire object comes together only in context IV. Case G depicts a situation of changing contexts. In this case, the object evolves by passing through different contexts, and is interpreted differently in different contexts because it is on a distinct level of development.

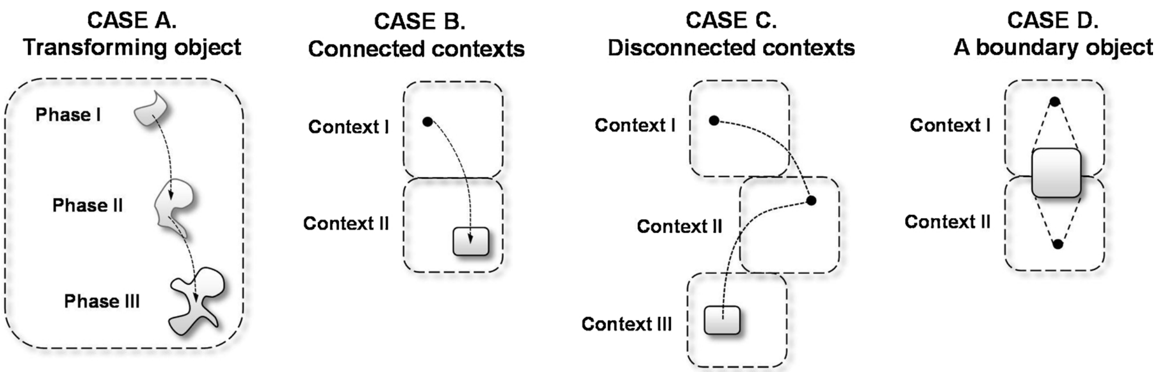

Fig. 3. Identification of weak signals, part one.

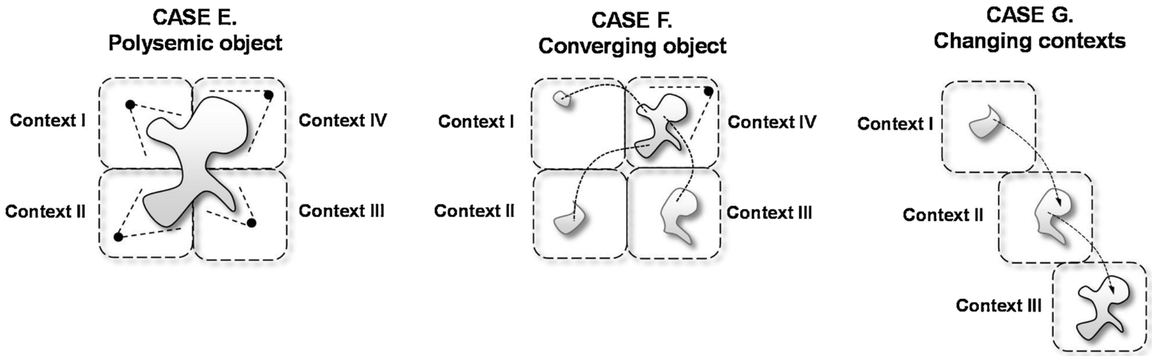

Fig. 4. Identification of weak signals, part two.

5. Contextualising weak signals: empirical examples

In this section, we outline three case examples that exemplify some aspects of the relational theory of futures knowledge. They are from projects that have utilised the notion of weak signal in a specific setting to catalyse the formation of new knowledge in different organisational contexts.

5.1. Case 1: Weak signals in the context of social media

The first case is an example of a hybrid object that is discerned from multiple perspectives. It discusses the results of two experimental weak signal workshops in the field of social media. These workshops were held in 2007 at the VTT Technical Research Centre of Finland in a project called *Social Media in the crossroads of physical, digital and virtual worlds*.

In the workshop, the following definition of a weak signal was utilised: "weak signals are today's uncommon, new embryonic technological applications or innovations that may turn into significant trends in the future" (Ahlqvist, Halonen & Heinonen, 2007, p. 13). Weak signals were identified via an explorative method called "Futures Window". This is a group work facilitation method, in which a group is presented with "future images" – a type of radical depiction of certain emerging issues. The group then engages in a facilitated discussion and systematic analysis of the ideas that were raised by these images.

Because these workshops were designed for the identification of weak signal type ideas based on visual stimuli, the workshops were systematised around three contexts from which the ideas were interpreted. These were: 1) consumers/producers/prosumers; 2) communities; and 3) recognition and merits. The methodological idea was based on an explicit understanding of the emerging social media applications at the time through these three lenses. First, it was assessed that the actors in social media would be exceedingly hybrid and simultaneously combine the functionalities of consumer and producer as well as transform towards prosumers – in other words, actors that simultaneously consume and produce artefacts, applications and services. Second, communities were evaluated to be the key result that springs from the development of social media. Humans would increasingly be a part of different social media communities that interact in a continual fashion. Third, recognition and merits were assessed to be key motivational factors as to why some people would engage as prosumers in social media communities. The participants in the workshops were given instructions to provide specific information between the interfaces of these contexts, in the form of service or application depictions.

As an example, we present an analysis of the idea of "personalisation and expression of self" that was specifically worked on in the workshop (Ahlqvist Halonen et al., 2007, p. 24–25). This idea emerged from several visual images presented at the workshop, and it reflects a hybrid of different rudimentary ideas. When discussing the role of prosumers, it was outlined that the key actors would be members and users of virtual communities who have developed a high level of trust. The idea of community in this case would be based on the core practices of a social media community, such as publishing, commenting and blogging. Recognition and merits would result from actions. Between these three contexts, several services and applications were developed. This included services for modularisation and collective planning (between prosumers and community), private commenting and feedback services (between prosumers and recognition), and public commenting and feedback services (between community and recognition).

The workshop experiments can be analysed using the relational theory proposed in this paper. The aims of the workshop experiments were to explore the Futures Window method in the identification of weak signals, and to come up with a contextual exercise for channelling the ideas in meaningful directions. Thus, the aim was to create new information on a hybrid object (social media) from multiple perspectives. The experiments were purposely built around three contexts in order to narrow the potentially wide range of outcomes. This worked quite well, because participants were mostly technical and business experts from the VTT Technical Research Centre of Finland, or from stakeholder organisations that shared a somewhat similar organisational mindset and aims. However, it was difficult to apply these contexts in practice, because it required a type of roleplay in which participants set themselves in an imaginary context. Thinking in these new contexts proved difficult in the workshops. Thus, the produced information seemed to be more about fitting the information already known and embodied by the participants into these new contexts (Dufva & Ahlqvist, 2015a). In other words, the participants shifted the already existing information from one context to another, instead of creating new insights (see Fig. 3, case B). As such, this could be a creative endeavour, but it could also signal the stickiness of existing perspectives.

The workshop experiments underline two interpretations. They strengthen the perspective that there is a rather strong context-dependency and path-dependency in the identification of “new” future knowledge. As the saying goes: “If all you have is a hammer, everything looks like a nail”. They also indicate a rather strong interest-based driver – when R&D experts in certain fields collect information about the important issues of the future (those that are likely to be funded), there is a strong incentive to find topics that are quite near the fields in which they specialise. Thus, there is a correlation between the meanings and qualities of produced ideas and the professional interests of the participants.

5.2. Case 2: innovation session method

The second case example is not a single case example but relates more to a method and the experiences gained when using that method. Perhaps this case could be best characterised as representing case E (polysemic object) in the previous theoretical set of cases (Fig. 4). An Innovation Session Method (ISM) was developed as part of a regional innovation policy toolbox in the Lahti region of Finland in 2007, in order to launch and support innovation processes in organisations. Thus, it is an example of a practical policy instrument. During the last 10–15 years, almost 100 innovation sessions have been organised in the Lahti region. Nearly 200 organisations have participated in these sessions, including approximately 125 companies (Melkas, Uotila, & Tura, 2016). Innovation sessions have obtained the status of best practice for Innovating Regions in Europe, and an idea developed in an innovation session won the innovation competition EBN EuroLeaders Award in 2009 (Tura, 2009).

ISM concentrates on facilitating and supporting the so-called fuzzy front end of innovation processes by promoting collaboration, learning, management and the enhancement of new ideas among participants, by developing solutions and skills, and by the creation of resources and capabilities at the early stage of an innovation process (Melkas et al., 2016). Innovation sessions aim to combine expertise and facilitate knowledge creation and transfer between participants from different fields (or contexts) in order to enhance organisations’ innovation activities. The sessions are tailored to the specific needs and aims of the target organisation, although active measures are also taken to introduce new, unorthodox themes into the organisation. The sessions are arranged for a heterogeneous group of people often consisting of representatives from different sectors (public, private and non-governmental) and hierarchical positions within organisations, professions and academia (Melkas et al., 2016).

The aim of an innovation session is to encourage a creative and innovative dialogue between various experts, which leads to concrete development trajectories based on future opportunities. There should be a focus on interpreting the discussion between the experts from different contexts (i.e. different industries, technologies, organisational hierarchies, regions etc.) and backgrounds. During the session, weak signals and their meaning and importance are discussed, especially from the context-specific point of view. The success of a session and the promotion of the visionary capability of the innovating network are closely related to the absorptive capacity of the participants in the session (Harmaakorpi & Uotila, 2006). During this interpretative process, the role of so-called knowledge brokers is of crucial importance (Parjanen, Melkas, & Uotila, 2011). Brokers facilitate discussions and idea generation by furthering the transfer of weak signals and knowledge-end experiences from another context, and by spanning the different roles, experiences and environments of the participants (cf. Parjanen, 2012). Brokers do more than just link together the partners involved in an innovation process. They also assist in the transformation of weak signals and ideas, and the transfer of knowledge from one context to another. At best, they enable the widening of the optimal temporal distance between the partners in an innovation process and enhance their absorptive capacity (Parjanen et al., 2011). These process distances, as presented in Table 1, are key elements affecting the identification of weak signals.

Table 1
Distances in innovation networks (Parjanen, 2012; adapted from Harmaakorpi et al., 2006; temporal distance added).

Distance	Source	Innovation potential
1. Geographic	Physical distance between actors	Geographic proximity does not automatically lead to innovations, but it may facilitate social proximity.
2. Cognitive	Differences in ways of thinking and knowledge bases	A certain degree of cognitive distance enables the creation of new innovations.
3. Communicative	Differences in concepts and professional languages	When making a new idea, understandable concepts from other fields or sciences, for instance, may be utilised.
4. Organisational	Differences in ways of coordinating the knowledge possessed by organisations and individuals	An organisation should have both strong and weak links in its network.
5. Functional	Differences in expertise in different industries/ clusters	It is useful to obtain novel information also from outside of one’s own field of operations. In such cases, the information often needs to be adapted to the field of operations in question.
6. Cultural	Differences in (organisational) cultures, values etc.	The challenge is to get people working in different organisational cultures to collaborate.
7. Social	Social relationships and the amount of trust included in them	Innovations require interaction among different kinds of actors. Trust helps in the creation of radical ideas.
8. Temporal	Differences in ability to imagine possible, potential futures	The challenge is to acquire and assimilate future-oriented knowledge, so that it can be exploited in a proactive manner.

5.3. Case 3: technology signals in Lahti, Finland

The Lahti technology foresight process is an example of disconnected contexts (Fig. 3, case C). It is also an example of the asymmetries in weak signal observation that are primarily caused by contextual discrepancies. The starting point for the Lahti foresight process was to engage in a "regionally embedded technology foresight" (Ahlqvist, Uotila, & Harmaakorpi, 2007). The first phase in such an endeavour is to identify the regionally specific critical targets at which to focus the foresight process. These include key problems, development needs or some core factor in the operational environment. In the second phase, these targets are detached from their regional setting and oriented towards the future. This could be done through a Delphi-style expert process. In the Lahti regional process, this was realised by collecting data from various sources, but, most importantly, from the signal bank of MIT Technology Review. In the third phase the critical targets are embedded into the regional setting and become a key part of regional strategy practice.

The selection criteria for the primary technology signals were three-fold: First, the signals had to have an explicit or at least a potential connection to the most important clusters in the Lahti region. Second, the signals had to be hybrid by nature, reflecting the prevalent paradigms for technological convergence and fusion. Third, the chosen signals should be concrete enough to be presented in a questionnaire in a thesis-like form in order to characterise the content and the social context of the technology in question. Here are two examples of technology signal theses:

- Integrated technology is applied in built environment and production. Technology does not require a separate terminal and it enables efficient interaction. It responds to speech and motions and is, in principle, ubiquitous (ICT).
- Nanoelectronics or molecular electronics that enable the combination of organic and inorganic parts, so-called "cyborg machines" (emerging technology).

The foresight process was planned to give additional input from "outside" for the strategy creation and related discussions in the Lahti region.

In the exercise, the knowledge creation process was complicated by the contextual distance on three levels: (1) the distance between the signals and their interpretants (Delphi panel), (2) the distance between the signals and the Lahti regional knowledge base; and (3) the asymmetry between the signals and the regional knowledge base. The first contextual distance was caused by the seeming "futurity" of the signals, even though they were based on topics that were, in 2007, already researched. However, the contextual discrepancy between the basic and applied research proved wide. The second distance was caused by the wide distance between basic technological research and regional capabilities for applying the knowledge. Several of the companies in the Lahti region were quite small, and not R&D oriented, and thus the application of knowledge was mainly realised through incremental processes. Technology signals, in this case, would have required quite significant research orientation, which was lacking in most companies. This fact also caused the asymmetry between the signals and the regional knowledge base. Thus, a key lesson in this case is that the technology signals studied in the project were assessed to be too far from the context of the regional actor. In other words, there was a disconnect between the context of the basic research, in this case the information collected by MIT Technology Review, and the regional context that operated in a different way.

6. Conclusions and discussion

In this paper, we propose a relational theory of futures knowledge that emphasises bounded perspectives and contextuality as additional elements of future-orientation. Relational theory complements and sometimes even challenges the perspective of linear emergence that commonly dominates futures methods and approaches. In the common perspective, the future is understood through the continuous emergence of novel issues that are identified by observers, usually through a lens that is thought to be objective. In this vein, weak signal theories start with a supposition that every novel signal that is identified is a new and rising issue that can be grasped by an observer ("a weak signals specialist") in a rudimentary form. The relational theory of futures knowledge aims to complement, and intermittently challenge, this epistemology by a view that emphasises the boundedness of the observer perspective and contexts of both observers and objects. Furthermore, by outlining a relational theory we aim to set futures studies in the context of ongoing ontological and epistemological discussions in the social and behavioural sciences.

Relational theory suggests there are new core elements – position and relations – in futures knowledge. The first issue is that relational theory widens assumptions about the linearity of emerging future signals. When weak signals are understood as contextual phenomena, and when their dynamic aspects are deciphered in full, the assumptions about linear emergence are set in a more robust analytical frame. Following the relational perspective, an analyst can assess how an object (supposed signal) is connected with other objects, how it seems when scrutinised from other contexts, or how partial the interpretation could be. Relational theory highlights the nature of context and knowledge frames in the identification of weak signals: weak signals are not always emerging issues, but often the result of a contextual shift, a widening of the perspective or a change in the observant position.

It is of crucial importance to understand that there are varied dynamics that constitute the futures object. It is hardly ever the case that the object can be defined completely with one definition or depiction. The situation is often quite the opposite – the supposed signal cannot be grasped by singular depiction but requires multiple depictions from different angles and different framings. There are three basic reasons for this. The first is that the object could be only partially "visible" or graspable from a specific perspective. Here, the question is about partial perspective (see Figs. 1 and 2). The second reason is that the object could be a nexus of different processes. In this case there exists, potentially, a multiplicity of processes that should be explained. The third reason is that the object, especially if it is an emerging issue and if it magnifies towards a wider trend-like issue, crystallises varied tendential features that could be contradictory or antagonistic. The societal process of urbanisation could be an example: it is a process that combines at least two opposing processes – centralisation and peripheralisation – along with multiple variants in-between.

A core issue in the relational approach is the positionality of futures knowledge. Through relational theory it is possible to theorise future knowledge as positional knowledge, dependent on the relations between actors, objects and contexts. Through relational theory it is also possible to emphasise the partiality and boundedness of observations. This boundedness is not just the result of bounded rationality, but also about the practical access to futures knowledge – all observers have their own biases, and some might not have the capabilities of identifying every possible signal. Therefore, it is important to assess the context and position of the observation, but also the futures capabilities that an observer has or does not have.

There are, at least, three avenues to advance the relational perspective of futures knowledge. First, this paper raises the need to develop clear analytical steps for relational futures analyses. This could be best realised by making nuanced empirical analyses of varied futures signals. Perhaps increasing application of artificial intelligence, even in the near future, can provide assistance in developing methods capable for these kinds of sophisticated analyses. Second, relational theory should be coupled with a dialectical understanding of futures phenomena (Ahlqvist & Rhisiart, 2015a). This coupling would endorse the understanding of the fundamental multiplicity and process-like nature of futures issues. The analyses should not lock the issues into an "iron cage" of one interpretation but leave open possibilities also for other viewpoints. Third, the social theoretical foundations and arguments of the relational perspective could be developed further. In this paper, we have provided a selective reading of the relevant social theoretical lineages, but there are, obviously, other theoretical frameworks and models that could bring further clarity to the "wicked challenges" of context, position and relations. Indeed, the endeavour to integrate futures studies and social theories would also be beneficial outside this theoretical opening.

References

Ahlqvist, T. (2012). Entering the "Darwinian markets of Europe": Strategic management of space– time in two regional strategy processes in Southern Finland, 1990–94. *Space and Polity, 16*(2), 153–174.

Ahlqvist, T. (2018). Dynamic elements in regional development: An explorative genealogical analysis of the region of Southwest Finland. *European Planning Studies, 26*(12), 2427–2447.

Ahlqvist, T., Halonen, M., Eerola, A., Kivisaari, S., Kohl, J., Koivisto, R., & Wessberg, N. (2012). Systemic transformation, anticipatory culture, and knowledge spaces: constructing organisational capacities in roadmapping projects at VTT Technical Research Centre of Finland. *Technology Analysis and Strategic Management, 24*(8), 821–841. https://doi.org/10.1080/09537325.2012.715490.

Ahlqvist, T., Halonen, M., & Heinonen, S. (2007). *Weak signals in social media: report on two workshop experiments in futures monitoring.*(Research report VTT-R-03466-07). Espoo: VTT Technical Research Centre of Finland1–53.

Ahlqvist, T., Uotila, T., & Harmaakorpi, V. (2007). *Kohti alueellisesti juurrutettua teknologiaennakointia: Päijät-Hämeen klusteristrategiaan sovitettu ennakointiprosessi* (VTT Publications 667). Espoo: VTT Technical Research Centre of Finland1–114.

Ahlqvist, T., & Rhisiart, M. (2015). Emerging pathways for critical futures research: Changing contexts and impacts of social theory. *Futures, 71*, 91–104.

Ahlqvist, T., Uotila, T., & Hietanen, O. (2015). Chasing black swans through science fiction: analysing the dimensions of surprising future events in the materials of a writing competition initiated by the Finnish state. *Journal of Futures Studies, 20*(2), 47–66.

Amann, K., & Knorr Cetina, K. (1988). The fixation of (visual) evidence. *Human Studies, 11*, 133–169.

Ansoff, H. I. (1984). *Implanting strategic management.* Englewood Cliffs, NJ: Prentice/Hall.

Bisson, C., & Yasar Diner, Ö. (2017). Strategic early warning system for the French milk market: A graph theoretical approach to see volatility. *Futures, 87*, 10–23.

Bourdieu, P. (1983). The field of cultural production, or: The economic world reversed. *Poetics, 12*, 311–356.

Bourdieu, P. (1984a). *Distinction. A social critique of the judgment of taste.* Cambridge, MA: Harvard University Press.

Bourdieu, P. (1984b). *The field of cultural production: Essays on art and literature.* New York, NY: Columbia University Press.

Coates, J. F. (2016). Scenario planning. *Technological Forecasting and Social Change, 113*, 99–102.

Dufva, M., & Ahlqvist, T. (2015a). Knowledge creation dynamics in foresight: A knowledge typology and exploratory method to analyse foresight workshops. *Technological Forecasting and Social Change, 94*, 251–268.

Dufva, M., & Ahlqvist, T. (2015b). Elements in the construction of future-orientation: A systems view of foresight. *Futures, 73*, 112–125.

Entrikin, J. N. (1991). *The betweenness of place. Towards a geography of modernity.* Baltimore, MD: The Johns Hopkins University Press.

Geertz, C. (1973). *The interpretation of cultures.* New York, NY: Basic Books.

Geertz, C. (2000). *Local knowledge. Further essays in interpretive anthropology.* New York, NY: Basic Books.

Gregory, D. (1994). *Geographical imaginations.* Cambridge, MA: Blackwell.

Harmaakorpi, V., & Uotila, T. (2006). Building regional visionary capability. Futures research in resource-based regional development. *Technological Forecasting and Social Change, 73*, 778–792.

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

Howells, J. (2002). Tacit knowledge, innovation and economic geography. *Urban Studies, 39*(5–6), 871–884.

Ilmola, L., & Kuusi, O. (2006). Filters of weak signals hinder foresight: Monitoring weak signals efficiently in corporate decision-making. *Futures, 38*(8), 908–924.

Jørgensen, U. (2012). Design junctions: Spaces and situations that frame weak signals – The example of hygiene and hospital planning. *Futures, 44*, 240–247.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review, 80*(4), 237–251.

Kahneman, A., & Tversky, A. (1981). The framing of decisions and the psychology of choice. *Science New Series, 211*(4481), 453–458.

Kaufman, B. E. (1999). Emotional arousal as a source of bounded rationality. *Journal of Economic Behavior & Organization, 38*, 135–144.

Knorr, K. D. (1979). Contextuality and indexicality of organizational action: Toward a transorganizational theory of organizations. *Social Science Information, 18*, 79–101.

Melkas, H., Uotila, T., & Tura, T. (2016). Policies of related variety in practice: The case innovation session method. *European Planning Studies, 24*(3), 489–510. https://doi.org/10.1080/09654313.2015.1088515.

Mendonça, S., e Cunha, M. P., Kaivo-Oja, J., & Ruff, F. (2003). Wild cards, weak signals and organisational improvisation. *Futures, 36*(2), 201–218.

Neugarten, M. L. (2006). Foresight—Are we looking in the right direction? *Futures, 38*, 894–907.

Parjanen, S. (2012). *Creating possibilities for collective creativity. Brokerage functions in practicebased innovation*, *474*Lappeenranta: Acta Universitatis Lappeenrantaensis Diss. Lappeenranta.

Parjanen, S., Melkas, H., & Uotila, T. (2011). Distances, knowledge brokerage and absorptive capacity in enhancing regional innovativeness: A qualitative case study of Lahti region, Finland. *European Planning Studies, 16*(6), 921–948. https://doi.org/10.1080/09654313.2011.568804.

Polanyi, M. (2005). *Tacit dimension.* Chicago, IL: The University of Chicago Press.

Rossel, P. (2009). Weak signals as a flexible framing space for enhanced management and decision-making. *Technology Analysis and Strategic Management, 21*(3),

307–320.
Rossel, P. (2010). Making anticipatory systems more robust. *Foresight, 12*(3), 72–85.
Rossel, P. (2012). Early detection, warnings, weak signals and seeds of change: A turbulent domain of futures studies. *Futures, 44*, 229–239.
Schoemaker, P. J. H., & Day, G. S. (2009). How to make sense of weak signals. *MIT Sloan Management Review, 50*(3), 81–89.
Schwarz, J. O. (2005). Pitfalls in implementing a strategic early warning system. *Foresight, 7*(4), 22–30.
Simon, H. A. (2000). Bounded rationality in social science: Today and tomorrow. *Mind & Society, 1*(1), 25–39.
Soja, E. W. (1985). Regions in context: Spatiality, periodicity, and the historical geography of the regional question. *Environment and Planning D, Society & Space, 3*, 175–190.
Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects. Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Social Studies of Science, 19*, 387–420.
Thrift, N. J. (1983). On the determination of social action in space and time. *Environment and Planning D, Society & Space, 1*, 23–57.
Tura, T. (2009). Innovaatiosessio [innovation session]. *A Presentation (in Finnish). Lahti Science and Business Park/Lappeenranta University of Technology* Unpublished manuscript.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science New Series, 185*(4157), 1124–1131.
Tversky, A., & Simonson, I. (1993). Context-dependent preferences. *Management Science, 39*(10), 1179–1189.