SignumInfirma
SOCIAL WEAK SIGNAL RESEACH

Highlights "Proto Signals"

Beau Hasham 2024-09-09

Interoceptive Errors To Predict The Present (an Active Inference account)

Introduction

In today's world, strategic agility and anticipative capabilities are more important than ever. Across various levels and disciplines, we aim to detect threats sooner than we currently do and ahead of our opponents. Therefore, from a management perspective, weak signals are receiving increasing attention in various fields including economics, politics, security, and safety. These signals serve as early warnings of significant future events but identifying them is challenging. Weak signals are ambiguous: they are selected from the environment, but their existence as distinct entities depend on how they are interpreted. There is an *external* perspective as well as an *internal* one, and the gap, an *outside-inside dilemma*, is not well understood and often taken for granted. This gap often unwittingly leads to misinterpretation and misuse of weak signals. To address this gap, the book "Proto Signals" delves into fundamental questions such as: What are weak signals? How do they emerge, and where do they originate? Additionally, the book examines how weak signals are processed, exploring factors like memory storage, communication, schemas, and perception. Surprisingly, it reveals that popular assumptions about these processes are inaccurate. This document presents the highlights of the book.

Weak signals (M)

First a brief explanation of how the conventional weak signal (M) is typically understood.
Various definitions of weak signals challenge to speak of a "conventional" weak signal. A weak signal is often seen as a probability, symptom, indicator, warning, or even vibration. These phenomena are in the background or obscured by noise (Korsten, 2009). Some view weak signals as "unconnected bits of information, environmental data or stealthy data" (Lesca & Lesca, 2011). Weak signals are usually treated as separate small low-impact incidents that suggest a change that cannot be immediately identified. Therefore, signals need to be interpreted in a coherent whole, and multiple events are often required to recognise a pattern. It is thought that weak signals grow or become stronger over time through successive signals until an unavoidable disaster occurs (Ansoff, 1975; Coffman, 1997; Turner, 1997).

Despite being incomplete, limited, unclear, and ambiguous, weak signals possess a warning capability since even the smallest change can have significant consequences. Weak signals originate from outside and within an organisation and may stem from a transmitter or source (Luyk, 2011). They are received, encoded, and stored in information systems and collective mental maps in human brains (Korsten & Leers, 2005). Weak signals can also be decoded, distributed, and sent to others. After assessment, the status of a weak signal may be transformed into an 'early warning' (Lesca & Lesca, 2011). To put an end to the excess of definitions, Van Veen & Ortt have proposed a new definition:

> Weak signal is the perception of strategic phenomena detected in the environment or created during interpretation that are distant from the perceiver's frame of reference. (Van Veen & Ortt, 2021)

However, this definition does not solve the problem of ambiguity. I present an alternative perspective on the concept of weak signals in management. One of the fundamental issues I address is how state changes in the environment are perceived from an individual perspective. Because there is an *observer* and *perception* I am exploring the role of memory storage, schemas, communication, and perception in understanding weak signals.

Memory storage and schemas

In business and education, human memory is considered a tool for storing knowledge in the form of mental maps and schemas in the brain. While studying memory and storage, I came across the concept of memory networks, engrams, and engram cells (Josselyn & Tonegawa, 2020; Tonegawa, Liu, Ramirez, & Redondo, 2015). Engram cells are activated during learning, undergo physical or chemical changes, and can be reactivated when stimuli from the learning experience are presented. This process contributes to the (re)construction of memories. Engram cells come together to form engram-cell-ensembles, neural correlates, which are widely distributed across various brain regions. Contrary to common belief multiple ensembles can be associated with a single memory. While distinct types of memories may be localised in specific brain areas, they are not necessarily confined to fixed locations. This challenges the common belief that brains *store* knowledge or meaning, as well as the idea that business information systems do the same.

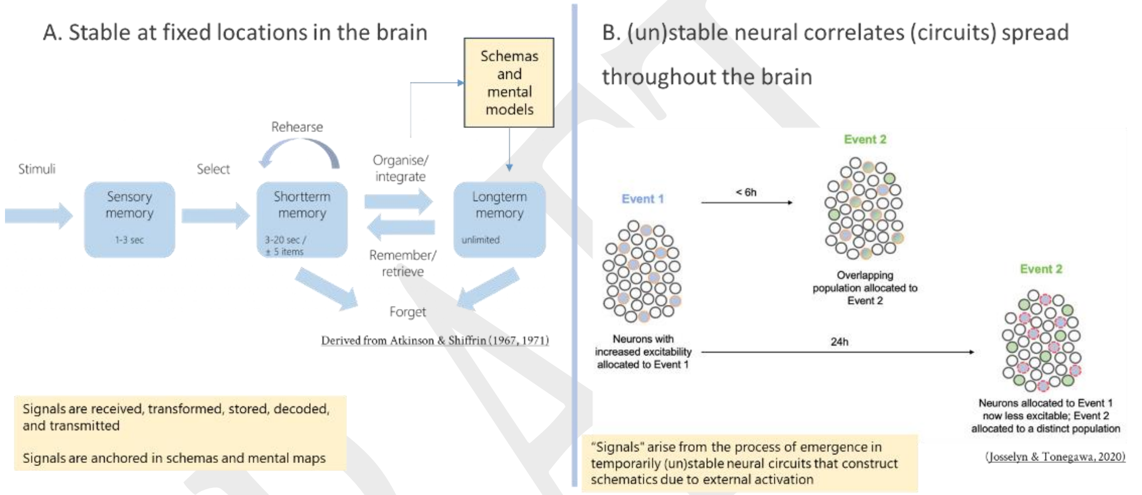

Figure 1: Memory: a shift from fixed locations to (un)stable neural correlates.

Contrary to common belief memories are not stored as a page in a "soldier's handbook": new experiences (re)form neural correlates, which together construct memories, schemas, and representations when those correlates are activated.

An aspect of emotion memory is its ability to function independently from event memory (Guzmán-Vélez, Feinstein, & Tranel, 2014). This means we can remember the emotion associated with an event without recalling the causal event. This phenomenon explains why we may recognise a particular sensory cue, like a smell, which triggers an emotion without the ability to pinpoint the exact reason behind it. Research also suggests that in addition to distinct signal-processing systems, there are separate short-term and long-term memory systems for storing events (Kitamura et al., 2017). Consequently, events are assumed to be simultaneously stored in short-term and long-term correlates (Zhao et al., 2019).

Communication

The classic *sender-receiver model* developed by Shannon & Weaver (1948) forms the basis of many communication models still taught in Dutch schools today. Originally a mathematical model designed to address a telephony issue, it depicts how information from Person A is transmitted as a signal and received by Person B. Both individuals encode and store these signals in their short-term memories. Over time, the signals become part of their long-term memories, forming various mental schemas.

However, we have moved beyond this memory model, as discussed in the previous section. The concept of sending and receiving in interpersonal communication operates differently than previously believed. Processes such as social synchronisation, resonance, and cohesion are underestimated. Yet, these are the very processes by which people connect and remain connected.

Social synchronisation

When people meet, they tend to imitate each other, or rather, *synchronise* with each other (McLelland, 1985). Synchronisation is the alignment of rhythms and behaviours between individuals, which provides the opportunity for effective communication and cooperation. This synchronisation occurs during face-to-face interaction and is crucial for establishing a natural connection. It involves mutual pacing and leading in various aspects such as behaviour, gestures, heart rate, breathing, hormonal release, and even brain waves (Feldman, 2016).

Moreover, there is the phenomenon known as brain-to-brain entrainment (Dikker et al., 2017) where listeners' neural activity synchronises with the rhythm of the speaker's speech. This is the speaker's 'neural' pulling along (Pérez, Carreiras, & Duñabeitia, 2017).

Emotional contagion refers to evoking the same neural representation of an affective state in the observer as that of the person expressing the feelings, along with related autonomic and bodily responses (Prochazkova & Kret, 2017). This implies the "neural entrainment of the brain" of the other person, rather than simply the mere sending and receiving of emotions. Synchronisation, imitation, and contagion are all aspects of the same process and can lead to social resonance.

Social resonance

Mead (1934) argued that animals not only rely on competition to survive but also need to cooperate. For cooperation to occur, social behaviour is necessary for communication between animals. Mead argued that a gesture from one animal elicits a response from the other, meaning emerges through this reciprocal exchange. To explain this process, I use the concept of "sense-and-respond" from Biology, highlighting that humans also engage in sense-and-respond behaviours. This process involves social reciprocal interaction from which knowledge or meaning emerges, which cannot be stored.

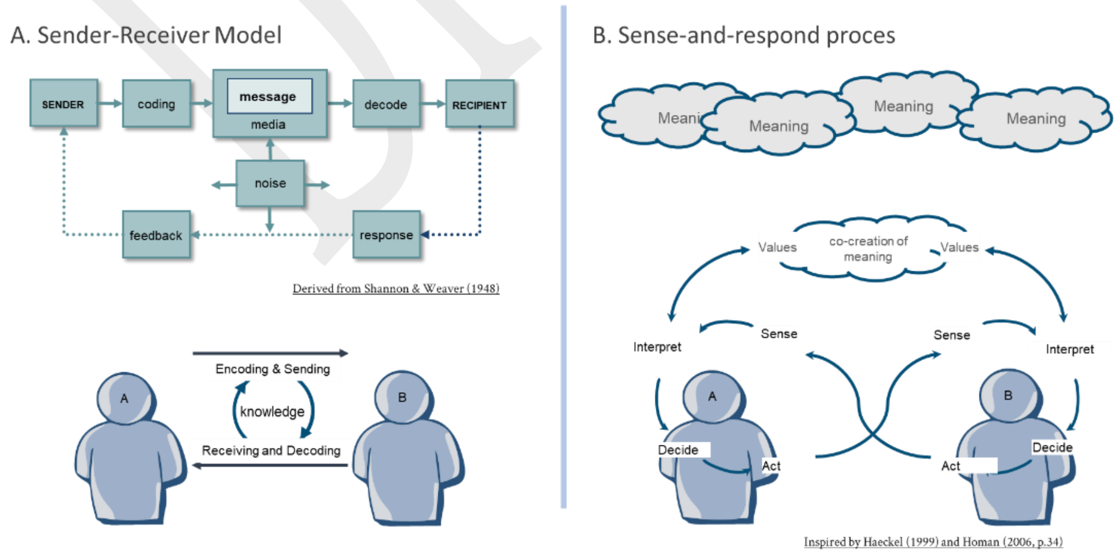

Figure 2: A shift from send-and-receive to sense-and-respond.

The sense-and-respond process in social interaction is the continuous reciprocal alignment of gestures, language, and rhythms from which meaning emerges. Moreover, Mead (1934) hypothesised that the *central nervous system* enables an implicit response to be evoked in the "gesturer" when an explicit response is evoked in the person to whom the gesture is made. When this process has a mutual effect, resonance can occur. Resonance is an aspect of the same process in which meaning or knowledge, emerges from the concert of mutual gestures and language. The sense-and-respond process is a reciprocal response-evocation process, nothing is encoded, stored, shared, or transmitted.

As mentioned, resonance is an emerging phenomenon resulting from the interaction between individuals as they pursue their livelihoods. It is essential for social cohesion, uniting people and transforming a group into a team or even a social movement by connecting individuals through shared values and beliefs. The concept of local self-organising patterns of resonance reflects varying degrees of strength, indicating that groups and social movements are not homogeneous, if they can be considered a "whole" at all. Resonance also influences the processes of inclusion and exclusion. Difficulty in synchronising challenges to find a place within the group as a lack of synchronisation may equate to a lack of resonance. Changes in group composition or diminishing commonalities often alter the "frequency" between members, causing individuals to no longer be on the same wavelength (literally).

Individuals do not necessarily have to achieve resonance in their attempts to synchronise. The synchronisation process continues even in dissonance, although conversations may become more awkward. Resonance involves mutual pacing and leading, influencing and being influenced, forming and being formed, even though the initiative sometimes lies more with one than with the other.

Social cohesion and emergence

Because resonance is an emergent property of social interaction, resonance cannot be reduced nor traced to the inner states of a single individual. The same is also true for the transition from resonance to emerging glocal social cohesion and coherence. Under the condition of resonance, self-organising forms of cooperation can spontaneously arise that were not there before, even, or especially in the absence of formal leadership. This phenomenon is called social emergence. In the book I cover, among other topics, *social movements* and *emergent organisations*. Social synchronisation, resonance, and cohesion are not only processes by which people connect and remain connected, but they are also ingrained in our information-processing, perception, and belief systems.

Perception

Imagine being a huge fan of cognac and being handed a glass of liquid that looks just like it. You're all set to savour your beloved drink without giving it a second thought because your brain is already wired to recognise the glass and sip the drink. Then, when you take a sip, you realise that it's actually tea in the glass. The mismatch between your expectation of cognac and the taste of tea leads to a comical expression of surprise and disgust on your face – this is your brain's response to a *prediction error*.

A relatively new theory of the brain states that our brain is a prediction machine (Clark, 2013). This means that our brains create models of how the world works and make predictions based on these models. When something unexpected or new happens, the brain compares the predictions with what factually occurs. It then evaluates whether the deviation from the prediction is significant enough to lead to a prediction error (Pe) and, if so, determines the appropriate response: either adjusting the model or adapting to the new information. Essentially, the brain does not react to stimuli, but instead to prediction errors. This is governed by the *free energy principle*, which applies to all processes, including how the brain operates.

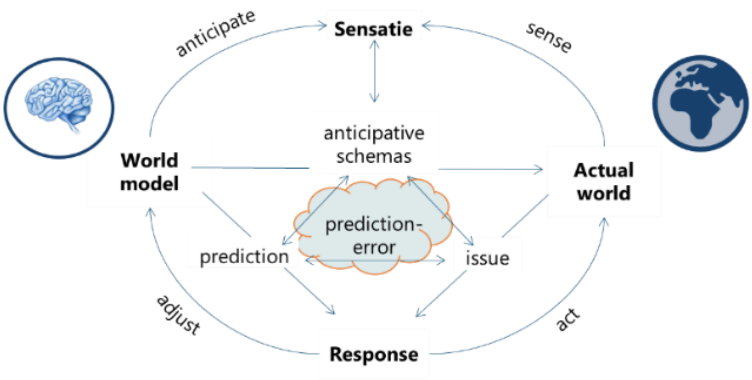

Figure 3: Anticipate-and-adjust.
(Derived from Friston (2010, S45), The Markov blanket and active inference)

Predictions and free energy in a social context

This concept of predictive perception is relatively new to the general public. Dr K. Friston is one of the founders of this theory called "Active Inference," which includes *Predictive Processing, the Bayesian brain hypothesis*, and *the free-energy principle* (Friston, 2010). The energy-free principle states that living systems, such as the human brain, are constantly trying to minimise the uncertainty of their internal states (free energy) and the external environment. This is achieved through a process of perception, action, and learning (active inference), in which the brain makes predictions about sensory input and adjusts them based on the actual input (I refer the technicians to the reference list).

Social synchronisation, resonance, and cohesion are also based on the free-energy principle: synchronisation relates to sense-and-respond processes between people based on mutual alignment and is aimed at minimising energy waste, resonance relates to the co-construction of meaning based on mutual understanding and is aimed at minimising (social) fear, (structural) cohesion relates to prediction complexes based on mutual expectations and is aimed at preventing social exclusion, among other things. These processes all aim to reduce free energy by minimising prediction errors.

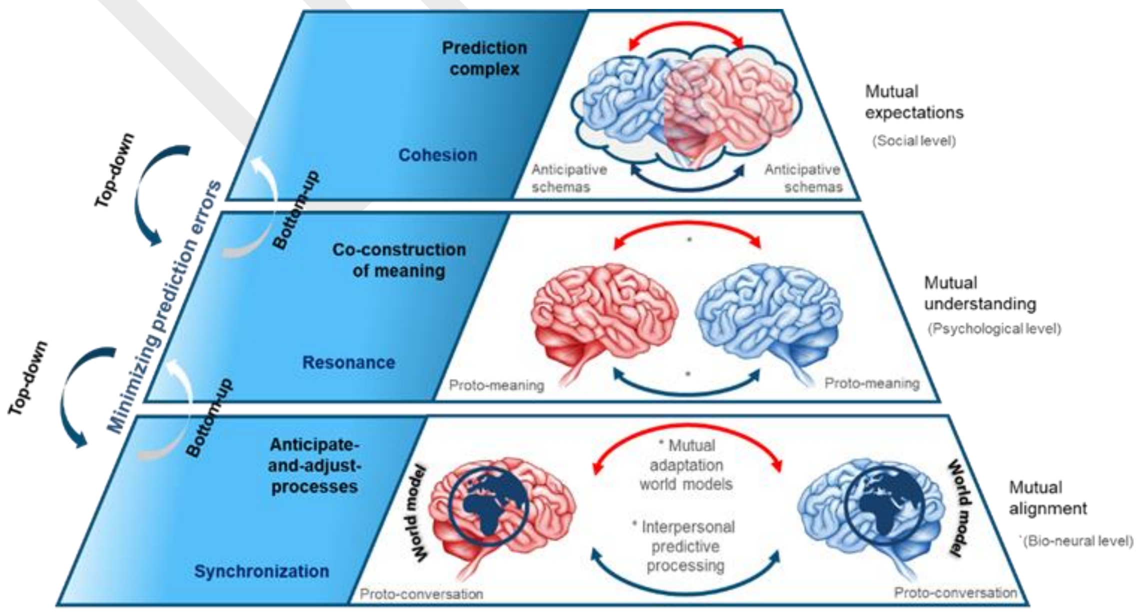

Figure 4: Interpersonal communication (Inspired by Jiang, Zheng, & Lu (2020, p. 247)).

Consider how we interact. The dynamics of social interactions impact the brain's ability to keep up significantly. Word choice, sentence structure, language patterns, and speech patterns are closely related to the situational context. This is accompanied by various sounds, tones, timbre, volume, and gestures. Smooth turn-taking during a conversation takes about 200 milliseconds (ms), (Stivers et al., 2009) while *word production* takes an average of 400 to 600 ms (Indefrey & Levelt, 2004 in ter Bekke, 2020). The difference needs to be bridged during the conversation. Although many of these processes go unnoticed, the brain is actively engaged in managing them.

The brain copes with this challenge by making predictions before and during the conversation, drawing on past experiences. When articulating sentences, the brain predicts each word and the sentence as a whole, gradually constructing an understanding of the sentence before it is fully spoken. In addition, one needs to respond to an (un)expected reaction, as the other person does the same. Successful interaction with others requires anticipating their thoughts, feelings, and actions. However, the brain does not aim for perfection; it focuses on managing prediction errors (Pe). So, *sense-and-respond processes* are actually *anticipate-and-adjust processes.*

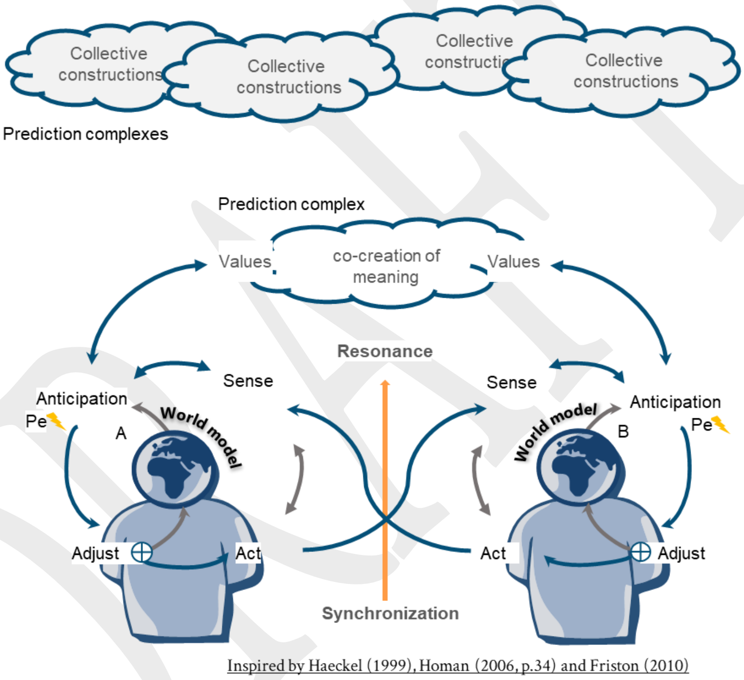

Figure 5: Anticipate-and-adjust in interaction (Pe=prediction error).
(Inspired by Haeckel (1999), Homan (2006) and Friston (2010))

Weak signals (PE)

Figure 5 depicts social interaction as a continuous process of reducing uncertainty by mutually minimising prediction errors (PE). Interlocutors will always have differences in perception that need to be resolved. Co-creation of meaning is a form of mutual minimisation of prediction errors because, knowledge is created between interlocutors that was not there before, which can then lead to adaptation of everyone's model of the world (learning). As stated, the brain does not aim for perfection, but it does alert you to significant surprises in the form of a small surprise: weak signal (PE). This weak signal (PE) is of a completely different order than the conventional weak signal (M).

These weak signals (PE) are markedly different from conventional weak signals (M) in at least four aspects:

1. The start of the perceptual process is a prediction of the brain based on the observer's model of the world and initial external sensory information (onset).
2. When there is an external state change, it must exceed a certain threshold to be noticeable, signalling the next step in the process.
3. This signal is then compared to what the brain expects. If the difference exceeds the threshold, there may be a prediction error, depending on the error's relevance, severity, and precision. When there is minimal but significant information, this discrepancy is a weak signal for the next step in the process, triggering the brain to respond, and resulting in a sensation.
4. Weak signals (PE) are about predicting the present, while conventional weak signals (M) are about the expectations of future events. Weak signals for predicting the present (PE) and expectations of future events can lead to a cascade of predictions influenced by knowledge, experience, and imagination, all aimed at anticipation.

In other words:

> A weak signal (PE) is an elementary perception of a possible near future event in the environment, due to a minimal, but significant difference between the observer's frame of reference and the observed change in state of that environment. A weak signal is technically a prediction error.

In the context of Predictive Processing, a weak signal usually refers to a signal that is less clear or less reliable compared to a strong signal, and it does not necessarily lead to a prediction error on its own. When sensory information is matched, it may not perfectly match the predicted input, but it may still fall within an acceptable deviation range. In such cases, the system may slightly adjust its internal models or forecast to pick up the weak signal without necessarily considering it an error. Weak signals (M) are therefore not analogous to weak signals (PE).

> As Karl Friston explains:
>
> For readers with a technical interest in predictive coding, top-down predictions are compared with incoming sensory information to form a prediction error. This prediction error carries the newsworthy information that the brain cannot predict or explain. This prediction error is then propagated up hierarchies in the brain to update predictions — so that they provide a better account of the sensory input. This leads to a recurrent message passing in the brain with bottom-up, ascending prediction errors providing feedback for top-down, descending predictions.
>
> Prediction errors can come in several flavours. When they are ambiguous or imprecise (i.e., weak) they may have little effect on belief updating. However, this kind of weakness should not be confused with weak signals (M) [Ed.]. Another key distinction is the nature of hierarchical representations that are updated by prediction errors. Effectively, prediction errors can be of two sorts: they can be about the content of sensory streams (e.g., "did she really say that"). Conversely, they can revise beliefs about context (e.g., “she looks as if she's going to explode").
>
> Crucially, the context is future pointing and always lasts longer than the content it entails. It is these contextual signals (and concomitant prediction errors) that can be read as soft signals. Generally, these will be elicited in a social context and are often associated with negative valence and angst. This follows from the fact that contextual prediction errors of this sort (i.e., soft signals) signify uncertainty (i.e., a loss of grip on free energy): in the sense, the contact has suddenly become unpredictable. Theoretical work in neuroscience suggests that this kind of uncertainty is encoded by brain chemicals such as adrenaline. This fits comfortably with our responses to unpredictability; namely, angst, arousal, and various orienting responses that, sometimes, may involve freezing (Friston, 2024).

The notion of the *weak signal* (PE) represents the first step in addressing the outside-inside dilemma. The brain operates not by responding to external signals, but by processing prediction errors in response to external information about state changes. A weak signal (PE) is the result of incoming sensory information compared to previous predictions. Incoming sensory information provides the brain with exteroceptive details, while the body also generates inner signals related to body temperature, heart rate, and emotion, known as interoceptive information.

Interoception refers to an organism's ability to perceive internal signals from its own body, and it plays a crucial role in regulating the body's homeostasis. Physiological sensations are intricately linked to sensation and emotion and are part of the interoceptive system. Exteroception involves perceiving external state changes, such as sight, sound, light, smell, taste, and touch. When an external state change exceeds a certain threshold, it also triggers an internal incentive to respond to those changes in the environment. This type of stimulus is referred to as an exteroceptive signal.

Active Interoceptive-exteroceptive Inference

The idea of *external-information-from-the-outside-the-body* (exteroceptive information) and *internal-information-from-the-inside-body* (interoceptive information) is not new. The brain and body can also link these together. If someone is annoying to you and makes all kinds of hand gestures at you, you get exteroceptive information. If you get irritated by that you get interoceptive information, for example through a noticeably increased heart rate and the irritation itself. Processes such as synchronisation and resonance are intertwined with the processing of interoception and exteroception information. I argue that this partly explains the ambiguous character of weak signals (M), while weak signals (PE) are composite signals, consisting of both exteroceptive and interoceptive prediction errors.

In literature research on *the event* as a concept, I learned that an event is a change of state somewhere in the universe, where *action of the system* is the best response (Chandy, Charpentier, & Capponi, 2007). Events, especially in a social context, are composite events in the sense that events consist of material/technical state changes on the one hand and mental/psychological changes on the other. For example, smelling a certain scent can evoke a mental state change. Material and mental state changes can lead to the aforementioned interoceptive and exteroceptive prediction errors in the observer's brain.

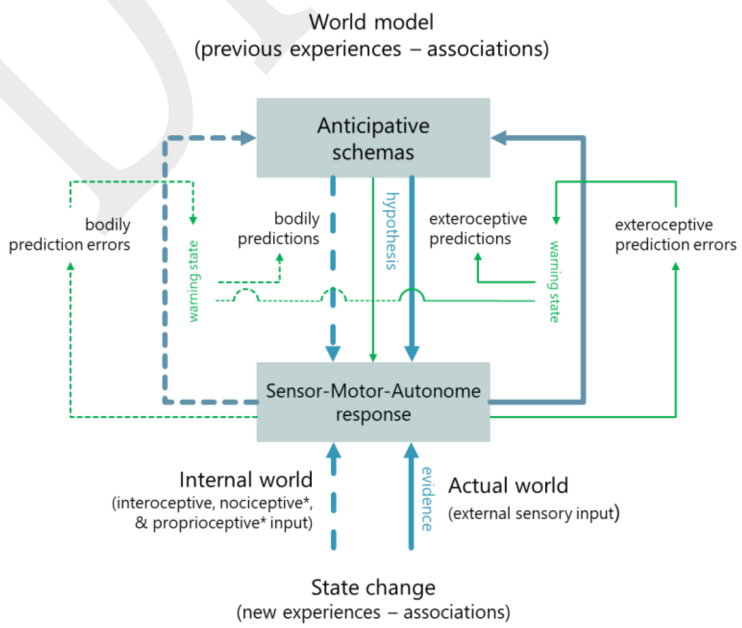

Figure 6: Composite predictions (based on Hung, 2023, p. 782).

So, active inference applies to exteroceptive and interoceptive information (Hung, 2023; Seth, 2013; Seth & Friston, 2016). The figure above (6) suggests that the two streams of information run side by side, in a certain proportion to each other, and ideally in equilibrium. Brains that prefer interoceptive information will react more emotionally than the situation requires e.g. like people with autism (ASD) tend to do, and brains that are exteroceptively focused take less account of other people's world models. Brains that prefer precision/weight of evidence will ask for more details, as do people with autism (ASD). Brains that prefer predictions and less evidence tend to hallucinate more, according to assumptions made by Hung (2023), among others.

In the context of active inference, biases can also be viewed as prediction schemas, but are persistent ones (Hung, 2023). Like all predictions, these have a certain weight, and prediction errors have a degree of precision. If hypotheses (top) from anticipatory schemas do not adapt in the face of unmistakable evidence to the contrary (bottom), then a person is rigid in his opinion and most likely biased.

Weak signal (M) versus Weak signal (PE): Proto signals!

There are examples of weak signals (PE) that are perceived as weak signals (M), but this is not always an issue. The "*Phoenix memo*" is one such example (Williams, 2001):

> On July 10, 2001, an FBI agent from the Phoenix Division sent a memo to FBI headquarters that "an unusually large number of persons of investigative interest" were attending aviation schools in Arizona: "These individuals will be in a position in the future to conduct terror activity against civil aviation targets..." (p.2). There was no indication or anything that referred to a terrorist attack, except for a hunch. You cannot organise an entire operation solely based on feelings(?)

In situations where exteroceptive information lags behind interoceptive information, a prediction error can lead to certain sensations, even if the interoceptive prediction error is minimal, and falls just outside the deviation range. If this sensation leads to heightened vigilance, one enters a *warning state*, where it can be difficult to put this into words. The 'result' of this process often starts another process: the development of proto meaning. This is why the result is called a "proto signal". Then something is not right, or we feel something is amiss. Then there is a weak signal "in the making" so to speak.

> A proto signal is an interoceptive elementary perception of a possible near future event in the environment, due to a minimal, but significant difference between the observer's anticipative schemas and the observed change in the state of that environment, with the sensation of a warning state. Technically, a proto signal is a prediction error for which there is no vocabulary yet.

This *warning state* is essentially a new prediction. Usually, such feelings evaporate due to all kinds of competing issues that also require attention. In addition, people themselves sometimes have difficulty recognising signals from the body (Petersen, von Leupoldt, & Vanden Bergh, 2015). Often it is others who trivialise this feeling, because "you shouldn't exaggerate so much".

Responding to proto signals depends in part on the context and the observer's world model. Caution is advised. For example, if you work in the "security & safety" industry. Prejudice, stereotyping, and bias are also prediction schemas, but partisan and persistent.

There are also differences between outside and inside perspectives. If you feel things are amiss outside the organisation, you show strategic insight, if you feel things are amiss within the organisation, you can be viewed as a whistleblower. Doctors, police officers, teachers etcetera are to a greater or lesser extent dependent on proto signals but are usually unable or not allowed to use them formally. Only Spiderman gets away with it.

A proto signal is a weak signal (PE) under special conditions and can be the impetus for a weak signal (M) as a management tool. Whatever else it is called, the person whose job it is to respond to such a signal has a problem: how do you communicate the seriousness and urgency of a premonition?

The processing of proto signals

Processes such as social synchronisation, resonance, brain-to-brain entrainment, and interoception/-exteroception in combination with words and gestures, help to infect another person with the warning state. That is to say, where people resonate with supposedly similar values and beliefs, the sensation of the warning state can also arise in others, when similar errors of prediction arise in them. In other words, (un)pleasantly surprising. They can minimise prediction errors by engaging in conversation and learning from each other. Anticipate-and-adjust are processes of co-creation of meaning and knowledge and thus reduce prediction errors, hence reducing uncertainty. Since knowledge and the creation of meaning take place between people, they are not stored in the brain. However, the construction process can affect the brain by forming proto meanings (neural correlates). Proto meaning is what you 'get from' or 'bring to' the conversation. Today's meaning constructs are tomorrow's anticipative schemas.

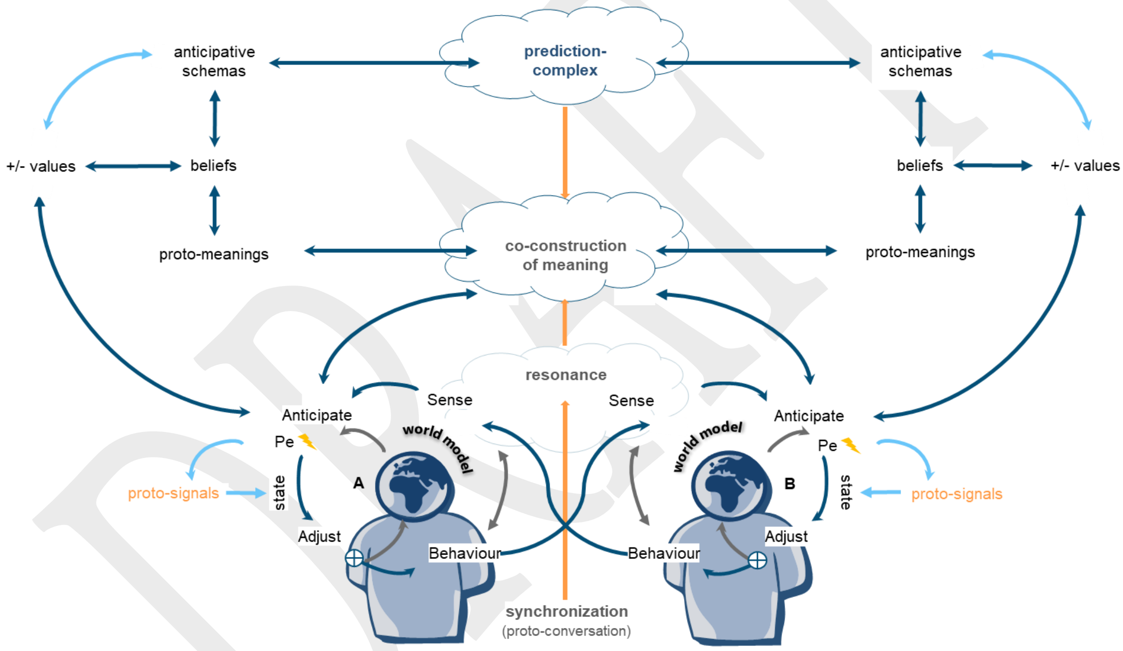

Figure 7: Co-construction of meaning versus co-construction of prediction complexes.

From the perspective of anticipate-and-adjust processes, all patterns of expectation, such as habits, rituals, themes, values, assumptions, prejudices, beliefs, ideologies, (conspiracy) theories, and even entire civilisations, have emerged from the myriad micro-events that anticipate-and-adjust processes are. These are all forms of complex predictions, not just in the minds of individuals, but *between* the minds of people. Along the same lines: during social interactions, people do not have a common prediction system but collectively construct complexes of predictions of various levels of abstraction all the time. Since anticipate-and-adjust processes can lead to resonance patterns, prediction complexes are also diverse, local, and subject to competition and power differences between people. This means that the chance that your proto signals will find their way to those in power is small and unpredictable.

In short: a weak signal is not a signal that is received from the outside world but arises from within the body in response to what is happening outside. If "what happens outside" is different from what is expected "inside" the brain, a prediction error (surprise) occurs. This is what the brain works with. Even a minimal deviation outside the deviation range can lead to a prediction error accompanied by a sensation, such as a hunch or even a warning state. A presentiment is a prediction error based on experience, in which the original causative event does not play a role now: you feel that something is wrong, but you don't know why. Proto signals are interoceptive errors to predict the present, even before the managerial weak signal is acknowledged (M).

I have presented an alternative to the conventional weak signal, which helps bridge the outside-inside dilemma. Additionally, I now understand why I sometimes react late, differently, or not at all to certain signals. Active inference, synchronisation, resonance, and interoception-exteroception work differently in people with ASD and ADD than in neurotypical individuals. I hope others (fellow ASSpies and ADDicts) with similar experiences will benefit from this knowledge.

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