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„Confronting Epistemic Semi-Determinism: How To
Change Knowledge and Perception Structures from a
Radical Constructivist Perspective“

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"[T]here is only one principle that can be
defended under all circumstances,
and in all stages of human development.
It is the principle: *anything goes*."

Paul K. Feyerabend (1992, p. 19).

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1 Introduction

1.1 Motivation and Outline

Buzzwords such as *creativity* and *innovation* illustrate that we are currently facing an increasing demand for the creation of new knowledge. This can be seen in various fields and areas; from economics (cf. Freemann & Soete 1997) to medicine and health care (cf. Paulus, Davis & Steele 2008), education (cf. Blouin et al. 2009), technology and science (cf. Fountain 1998), and it is associated with various beneficial effects, such as optimizing services, products or processes or finding solutions to emerging problems (cf. e.g. Hippel 2007; Rosenbusch, Brinckmann & Bausch 2010).

In order to facilitate and enable the creation of new knowledge, a vast body of literature has emerged providing tools and techniques to produce solutions for problems and challenges (cf. e.g. Fountain 1998; Hippel 2001; Mesquita, A. 2013; Pisanu & Menapace 2014).

However, what if our capacity to create new knowledge would not simply respond to existing problems and challenges? What if we questioned our very basic *understanding* of the world to subsequently create new knowledge? Examples from various fields do not only illustrate that we determine how we perceive the world, but more crucially that we can even change our reality to subsequently create new knowledge.

For example, *cognitive reframing* is a technique used in psychiatry and psychotherapy. It shifts a patient's perception of a problem, by re-describing and finding alternative interpretations for it (cf. Barnett et al. 2014; Retzer 2008, p. 837). A patient may complain about her mother butting into her affairs. In a cognitive re-framing process, the therapist could offer the interpretation that the mother is not butting into affairs but that she is merely over-protective; subsequently, the patient may even come to appreciate the mother's behaviour. With this simple shift, the perception of the problem has been changed without actually manipulating the conditions in the outside world; simply the way the patient *sees* the problem has changed (modified from Millner & Rollnick 2002).

Another example for the subjective interpretation of reality comes from the philosophy of sciences. The concept of *theory-ladenness* describes that how we observe the world is influenced by what we know about it (cf. Peschl 2001, p. 127).

For example, the motion of a simple pendulum has been described by Aristotele as a body falling with difficulty, whereas Galileo observed and described it as a body repeating (almost) the same motion over and over again (cf. Kuhn 1970). In both cases, the two men looked at the same phenomenon, but interestingly, they *saw* it differently.

In the same vein, philosopher Thomas Kuhn has investigated what is happening when the perception of the world is changing in the realm of science. In his famous book *The Structure of Scientific Revolutions* he introduces the concept of paradigm shifts (Kuhn 1970). Kuhn argues that a scientist's view on the world is in line with one or more *paradigms* which consist of theories, assumptions and beliefs about the world. When these assumptions are refuted and a phenomenon is re-interpreted, a paradigm shift occurs and scientists begin to understand the world in a new way. An example is the shift from the geocentric to the heliocentric world-view. It had been assumed that the world formed the centre of the universe and this premise formed the starting point for all calculations and models. However, when this basic assumption was disproven, scientists started to look at the world from a different perspective; suddenly, the earth was *perceived* as circling around the sun, and in turn, all subsequent research developed in a different, more fruitful way.

Cognitive reframing, theory-ladenness and the concept of paradigm shifts highlight that it is possible to change the way we *see* the world. Living in an *age of innovation* (cf. Prahalad & Krishnan 2008), the possibility of altering our understanding of the world appears intriguing as it may yield more potential to create new knowledge. The question is; how can we deliberately induce such a reinterpretation of the world?

1.2 Radical Constructivism and the Construction of Reality

We might assume intuitively that the world is just there, objective and independent of our minds. For the past 2000 years, this idea has been dominant in philosophy, formulated and developed by *realists*. Following their idea, the world itself provides meaning which is passively mapped to our minds giving rise to an objective representation of reality (cf. Glasersfeld 1974; Glasersfeld 1992; Maxwell 2012). Considering that the preceding examples give reasons to doubt the idea of

an objective reality, they may better understood from another, counter-wise approach to the topic.

Radical constructivism is a position in philosophy that is concerned with the question of what and how we get to know about the world. In its essence, radical constructivism forms a counter-position to realism as it claims that the world itself does not yield any objective meaning; rather, a meaningful world only exists *inside* subjects' heads. Central to this position is the idea that all knowledge is actively constructed; it is brought forth by an individual to correlate meaningless experiences from the outside world in order create a meaningful reality.

Thus, when facing the question of how we can alter our understanding of the world, the approach of radical constructivism appears to be relevant in two regards.

First, radical constructivists leave behind the idea of an objective reality that is shared by all subjects- on the contrary, anyone has their own subjective reality based on individual constructions and interpretations (cf. Oxford 1997, p. 36).

Second, since the outside world does not provide any meaning, radical constructivists give up the notion of truth; one's internal constructions about the world cannot be *true* or *wrong* as they do not mirror the outside world. Rather, they must be *viable*, i.e. they must *fit* to the structures of the world and make us interact with it successfully (cf. Glasersfeld 1984; Riegler 2012).

In light of these claims, the preceding examples do not seem wondrous. In all these cases, the world itself did not change; what changed was the way it was internally constructed. The behaviour of the patient's mother did not change but the patient's interpretation. A pendulum's motion remained the same but it was seen differently. Also, before and after a paradigm shift the world provides the same information but is interpreted in a different manner.

1.3 Problem Definition: Epistemic Semi-Determinism

The preceding examples highlight that knowledge and perception are closely related; what we know about the world determines how we perceive it and what we perceive determines what we know. For example, scientists had based all their research in the constructed knowledge that the earth was the centre of the universe since the perceived it that way.

From a radical constructivist point of view, the relationship between knowledge and perception leads to a form of epistemic determinism since one determines the other.

In this thesis I will refer to this relationship as *epistemic semi-determinism*. The prefix *semi* serves two purposes.

It distinguishes it off from the concept of *epistemic determinism*. Epistemic determinism is based on the assumption that all events follow universal laws and are strictly pre-determined (cf. Hoefer 2010). Accordingly, epistemic determinism assumes that knowing these laws we can predict all future events (cf. Backmann 2013). In contrast, *epistemic semi-determinism* claims that our perception results from our internal models but does not specify any predetermined progression of events.

In light of the examples of cognitive re-framing, theory-ladenness and the concept of paradigm shifts, the prefix *semi* points to the possibility of reinterpreting the world; since we are the constructors of our experiential reality, we are free to alter our understanding of the world (cf. Watzlawick, recited in: Wuettrich, Osmetz & Kaduk 2006).

However, the question of how we can alter the way we interpret the world is not easily answered. We cannot simply step out of our internal constructions and perceive the world in a new way. From a radical constructivist point of view, we cannot act as if we are not there because we, as subjects, construct the objects.

In order to acquire a new understanding of the world we have to *confront* epistemic semi-determinism. How can we achieve this?

1.4 Research Question & Goal

Epistemic semi-determinism results from the determining interaction between knowledge and perception; what we know about the world determines how we perceive the world and how we perceive the world determines the construction of knowledge. Therefore, in order to construct new knowledge about the world we must confront epistemic semi-determinism. It is argued that we can do so by changing either knowledge or perception structures. Changing knowledge structures will lead to the creation of alternative conceptions of the world which we may subsequently perceive; changing perception structures will result in the

integration of new sensory experience which, in turn, may lead to the construction of new knowledge.

Accordingly, the thesis pursues the following research question:

How is it possible to change knowledge and perception structures from a radical constructivist perspective in order to confront epistemic semi-determinism and by that, facilitate the creation of new, viable knowledge about the world?

The goal is to find relevant strategies to change knowledge and perception structures and develop a toolkit which can be used in order to confront epistemic semi-determinism and which has the potential to facilitate the creation of new viable knowledge about the world in various fields and areas.

1.5 Structure of the Thesis

The structure of the thesis is divided into three main parts.

1.5.1 Theoretical Foundations: Radical Constructivism

Section 2 introduces the theoretical foundations of radical constructivism.

Findings from biology, psychology, neuroscience and cognitive science will provide an interdisciplinary approach to the basic assumptions of radical constructivism in order to highlight that a cognitive system is organizationally closed, self-explicative and self-referential (section 2.2.).

These assumptions will lead to the epistemological claims of radical constructivism (section 2.3); reality is subjective as it results from internal knowledge constructions; all knowledge serves the function of being viable, i.e. being *useful* for an individual to interact with the world. Furthermore, perception will be defined as an active process of organizing the outside world according to one's knowledge structures.

1.5.2 Epistemic Semi-Determinism

Chapter 3 will elaborate on the notion of epistemic semi-determinism. It will be argued that radical constructivism suggests a determining relationship between knowledge and perception structures.

Furthermore, it will be argued that we should confront epistemic semi-determinism (cf. section 3.1). Changing knowledge and perception structures may lead to the creation of new knowledge about and a new understanding of the world. The model of single- double- and triple-loop learning illustrates that in order to confront epistemic semi-determinism, we have to change underlying assumptions and beliefs about the world (cf. section 3.2). This does not only require cognitive effort but also a distinct mind-set; accordingly, there will be a brief excursus on attitudes required for confronting epistemic semi-determinism.

1.5.3 Confronting Epistemic Semi-Determinism: A Toolkit

Chapter 4 pursues the question of how we can confront epistemic semi-determinism. A set of strategies will be introduced that is derived from the theoretical considerations in the first part. Furthermore, a framework depicting all tools assigned to the particular strategies will be introduced.

Chapter 5 elaborates in detail how we can change our perception structures. A variety of tools allow changing perception structures. It is argued that this facilitates a reorganization of knowledge structures.

Chapter 6 provides a detailed overview of the tools that allow for changing knowledge structures. Manipulating what we know opens the possibility for new interactions and perceptions to emerge.

2 Theoretical Foundations: Radical Constructivism

2.1 The Context of Radical Constructivism

Radical Constructivism is an epistemological position in philosophy. It claims that we do not passively acquire a "picture of the 'real' world" (Glaserfeld 1992, p. 91), but that all knowledge results from our constructions.

While traditional positions investigated *what* we can get to know about the world, this approach shifts its focus on the question *how* we get to know the world (cf. Glaserfeld 1984). This makes it a "theory of cognition" (Schmidt 1987, p. 13, translated by the author) that aims to understand the processes by which "people construct their own understanding of reality" (Oxford 1997, p. 36).

The following will provide a brief overview of the context of radical constructivism and the contributing research fields.

2.1.1 Radical Constructivism as a Major Shift in Epistemology

The question of what we know and how beliefs about the world are being formed is one of the most controversial topics in philosophy; it is summarized as *epistemology* (cf. Brugger & Schoendorf 2010, p. 115).

Realism has been the most dominant position in epistemology for the past 2000 years (cf. Glaserfeld 1974). Realists start from the premise that "entities exist independently of being perceived, or independently of our theories about them" (Phillips 1987, recited in: Maxwell 2012; p. 3). Knowledge is thought to represent a possibly accurate picture of a world which is mapped to our internal representations. One crucial epistemological assumption is that knowledge can be *true*, if it mirrors an objective world (cf. Glaserfeld 1992).

Radical constructivism constitutes a major shift in Western epistemology. It suggests a rejection of realist ideas by calling off the search for an objective world (cf. Glaserfeld 1984). Radical constructivists shift their focus to the operations that knowledge is brought forth by and diverges from realism in that it claims that knowledge is always the result of subject's cognitive operations and does not mirror the world in a picture-like manner (cf. Glaserfeld 1984; 1995a). Knowledge is not objective and cannot even be proven to be, since "a conceptual (intellectual) copy of reality [...] [cannot be compared] with the original reality" (Bettoni 2007, p. 21).

The emergence of radical constructivism cannot only be understood as a reaction to dissatisfaction with realist ideas. By focusing on internal mental processes, radical constructivism emerged as a counter-movement to behaviourist psychology, which has been the dominant approach to psychology in the middle of the 20th century, focusing solely on the subject's measurable behavioural responses and rejecting the necessity for the investigation of internal, unobservable cognitive processes (cf. Anderson, Reder and Simon 1998, p. 228; Riegler 2007, p. 91).

Since the emergence of radical constructivism, the idea of reality being based on subjective constructions influenced various other fields, such as international relations and law (cf. Hopf 1998), communication sciences, mathematics and sociology (cf. Rusch 1987), psychotherapy and counselling (cf. Mahoney and Granvold 2005), philosophy of science (cf. Riegler 2001a), literary sciences, media sciences and design (cf. Mueller 2010).

2.1.2 Three Pillars of Radical Constructivism

Radical constructivism is an interdisciplinary research endeavour, which has its roots in biology, cybernetics and psychology (cf. Mueller 2010; Rustemeyer 2013; Schmidt 1987). In the following, the individual contributions are briefly outlined.

Biology

Biologists Maturana and Varela had an influence on the emergence of radical constructivism in claiming that any organism needs cognition in order to survive in the environment (cf. Maturana & Varela 1980; Rustemeyer 2013, p. 126). Central to their theory is the idea that living systems possess an autopoietic organization maintaining the organism's life. Autopoietic organizations -as opposed to allopoietic or non-living objects- are organizationally closed, self-referential and are acting in a circular manner so that any of the organism's properties are brought forth by the existing properties (cf. Maturana & Varela 1980).

Maturana and Varela claim that living organisms are autonomous; how they behave is not determined by stimuli from the external world but by the structural organization of their internal configuration (cf. Rustemeyer 2013, p. 126).

Cybernetics

Radical constructivism is influenced by the work of Heinz von Foerster who investigated the internal processes and operations taking place inside a cognizing organism (cf. v. Foerster 1987; Schmidt 1987). He introduced the principle of undifferentiated coding, which claims that any sensory experience is transmitted by neural signals; any qualitative feature must be brought forth inside the cognitive system.

Furthermore, the findings from cybernetics suggest that organisms interact with the environment in a reciprocal manner, where interactions provide feedback to the cognizing organism (cf. e.g. Power's Feedback Model, in: Powers, Clark and McFarland 1960).

Psychology

The work of Swiss psychologist Jean Piaget added a psychological dimension to radical constructivism. Piaget found that children *develop* cognitive structures in order to organize their experiences (cf. Glasersfeld 1982; Piaget & Inhelder 1971). By performing sensorimotor interactions with the external world, children actively construct knowledge about the world. He found two principles guiding the cognitive development of children. *Assimilation* refers to organizing the environment as being suitable with their existing knowledge; *accommodation* is a process of re-organizing knowledge so that it is consistent with the outside world. (cf. Glasersfeld 1995b; Piaget & Inhelder 1971).

To sum up, radical constructivism is a position in epistemology that describes knowledge as being the result of an individual's subjective construction. It is based on an interdisciplinary research endeavour, which incorporates findings from biology, cybernetics and psychology. The respective contributions will be considered over the course of this thesis.

The following section reviews the basic assumptions of how a cognitive system works.

2.2 Basic Assumptions of Radical Constructivism

Radical Constructivism addresses the questions of how humans think and how they get to know (cf. Glasersfeld 1984). It rests on basic assumptions about the processes taking place in our "cognitive apparatus" (Glasersfeld recited in: Saalman 2007, p. 2), which are outlined in the following.

The first assumption is that the brain is *organizationally closed*; any information that enters the nervous system is of quantitative nature but does not yield any qualitative features (cf. v. Foerster 1984, p. 138; Maturana 1999, p. 154; Saalman 2007, p. 2; Schmidt 1987, p. 15). Organizational closedness leads to two further implications: a cognitive system is *self-explicative* and *self-referential* (cf. Reese-Schaefer 2014, p. 227; Saalman 2007, p. 2; Schmidt 1987, p. 15; Tschimmel 2011, p. 224). Self-explanation describes that any features about the world have to be constructed internally (cf. Schmidt 1987). Self-reference claims that the internal construction processes refer to each other in a recursive manner (cf. Goolishian 1988, p. 132; Saalman 2007; Schmidt 1987, p. 15; Tschimmel 2006, p. 223).

In the following, these assumptions are reviewed in more detail.

2.2.1 Organizational Closedness

Organizational closedness means that a cognitive system is not directly connected with the world but that it is a "closed system" (Maturana & Varela 1980, p. vi), which is encapsulated by neural sensors "through which the organism interacts" (p. 20). Any information that enters into the cognitive domain of an organism has to pass these sensory boundaries. This phenomenon is described as *undifferentiated coding* (v. Foerster 1987); it leads to the assumption that the world itself does not transmit any meaningful information (cf. Schmidt 1987, p. 16).

Principle of Undifferentiated Coding

The principle of *undifferentiated coding* specifies that any information entering the nervous system is transformed into *neutral* neuronal code, which does not yield any qualitative information about a stimulus but only quantifies its intensity (cf. Segal 2001, p. 17; v. Foerster 1993, p. 25). The more persistent the stimulus from the environment is, the more frequent the signal (v. Foerster 1993, p. 25). Therefore, the "language of the neurons" (v. Foerster 1993, p. 25; Segal 2001, p.

70) only consists of electric pulses that change "with the intensity of the perturbation" (Segal 2001, p. 70.). It never encodes "the cause of the activity", which makes the neuron fire (v. Foerster 1987, p. 139, translated by the author); thus, it does not transmit any specific information about the environment but it only entails "how much and where [the activity] comes from." (ibid.)

Von Foerster (1987) emphasizes that this is the case for any neuron in the nervous system; "it is astonishing that any rod cell in the retina, any cell of the ear's membrane, any cell transmitting pain or pressure, hotness or coldness do all speak the same language" (v. Foerster 1987, p. 138, translated by the author).

The Internal Organization of the Outside World

The principle of undifferentiated coding contradicts the realist assumption of sensory organs depicting "the world as good as they can" (Roth 1987, p. 231, translated by the author); neurons do not transmit any qualitative features of any experiences, but they only yield quantitative information (cf. Saalman 2007, p. 2). Schmidt (1987) claims that a realist stance towards the world was based on the premise that our sensory organs were "directly connected with the world" (p. 13, translated by the author). However, following the principle of organizational closedness, the outside world cannot be directly mirrored internally. Roth emphasizes, "we do not see with the eyes but with, or rather in, the visual centres of the brain" (recited in: Schmidt 1987, p. 14)

Perspective from Neuroscience: Research on Visual Cognition

The traditional realist conception of vision has been a "snapshot", which provides a "picture-like experience of the world" (Noe 2002, p. 2). However, contemporary neuroscience shifted its attention to the processes inside the brain *after* the eyes transmit neural signals. *Visual consciousness* is defined as the experience of perception (cf. Noe 2002) and is located in the posterior cortex. Recent neuroimaging methods, such as fMRI revealed various areas in this cerebral field involved in the process of allocating meaning to neural activity (cf. Bear, Connors & Paradiso 2007, p. 333; Daw 2012, p. 108; Kashou 2012; Poldrack 2008, p. 224). Thus, perception is not merely a mapping of an outside world but is internally organized.

An example from research on visual illusions serves to illustrate this point.

External World versus Internal Reality: The Investigation of Visual Illusions

Visual illusions suggest that our perception does not correspond to what is offered by the outside world (cf. Sternberg & Sternberg 2012, p. 92) and therefore are useful for understanding how the brain constructs visual consciousness.

In the given context, research on multistable illusions is particularly interesting. Multi-stable illusions offer two (or more) images (Fig. 1) and are ambiguous in that "they can flip back and forth between different perceptions" (Eagleman 2001, p. 922). The actual stimulus does not change and therefore, "[t]he perceptual reversal indicates that cortical processing is an active process that tries to make sense of incoming information." (ibid).



Fig. 1: 'Rubin's Vase' is an example of a Multi-stable Illusion; it depicts both a vase and two faces. (from: Andrews et al. 2002)

Findings suggest that the respective perception of the illusion depends on which specific cortical area is active (cf. Kleinschmidt et al. 2012, p. 988). For instance, studies using fMRI have found that the perception of faces in Rubin's Vase is driven by activity in the visual area V5 -or fusiform gyrus- within the temporal ventral lobe (cf. Andrews et al. 2002; Sterzer, Kleinschmidt & Rees 2009), which is associated with the perception of faces (cf. Andrews et al. 2002; Bar et al. 2006; Grill-Spector, Knouf & Kanwisher 2004), whereas the perception of the vase is correlated by areas within the parahippocampal gyrus and the lateral occipital lobe (cf. Andrews et al. 2002; Sterzer, Kleinschmidt & Rees 2009). Thus, our perceptual experience results from distinct areas *inside* the cognitive system. This is in line with the radical constructivist claim that the brain is organizationally closed and our eyes are not directly depicting the outside world.

In short, a central assumption of radical constructivism is that a cognitive system is organizationally closed. Its boundaries are created by neural sensors, which convert any sensory experience into electrical signals that only yield quantitative information but not any qualitative features.

2.2.2 Self-explication

A compelling consequence of the cognitive system being organizationally closed is that the system itself must bring forth any components; this makes the brain self-explicative (Schmidt 1987, p. 15; Tschimmel 2011, p. 223). Since any information entering the nervous system is encoded in qualitatively neutral signals, the meaning of these signals has to be constructed internally; any "phenomenological characteristics[...] are based on our own computations based on co-occurring patterns of signals that differ only with regards to their point of origin in the living system's network" (Glaserfeld 2005, p. 319). The neural codes are equipped with qualitative features inside the cognitive system (cf. Schmidt 1987, p. 14).

The brain is not capable of depicting reality itself since "there is no proto-representation" (Schmidt 1987, p. 15, translated by the author). Inside the nervous system "[r]elative activity leads to relative activity" and "activity results from and leads to further activity in a closed cycle" (Mingers 1991, p. 323); the brain is self-explicative as it constructs criteria to judge and evaluate information from the environment (cf. Schmidt 1987, p. 15).

Jean Piaget's Research on Cognitive Development

The assumption of a cognitive system being self-explicative has been supported by the research of Swiss psychologist Jean Piaget. He observed that children construct their knowledge about the world, which becomes more and more explicit over the course of their being. According to Piaget, children bring forth an internal world in four main steps (cf. Glaserfeld 1982; Riegler 2012).

First, through repetitions of sensorimotor actions, connections are established and are later turned into operational schemes. They tie together perception and action and aim to produce the expected results, e.g. by grasping an object (cf. Glaserfeld 1982).

Second, complex perceptual compounds are constructed through various sensory experiences; they become multi-modally externalised objects and more real as

they are seen and touched (cf. Glasersefeld 1982), e.g. by grasping an object and recognizing that it is hot.

During the third stage children use previously constructed schemes to develop other schemes; this is what Piaget calls the *operational dimension* (cf. *ibid.*), which is reached through reflective abstraction allowing for relating patterns to one and another and to predict as well as explain; for example, the hot object is identified as belonging to a group of objects that are hot.

Finally, through communicating with others, children validate their constructed knowledge by seeking agreement (cf. *ibid.*). Schmidt (1987) emphasizes that this fourth step is crucial in that it yields the construction of "socially accepted truths" (p. 34, translated by the author) according to which subjects adjust their experiences of the world (cf. Schmidt 1987, p. 35). Following the example, children may learn that this group of hot objects are oven plates.

Central to these steps is that no knowledge or feature about the world is just given. It must be brought forth in a self-explicative process.

Perspective from Cognitive Science: The Enactive Mind

The idea that cognitive systems bring forth their own internal world had a strong impact on the cognitive sciences. While the initial preserving paradigm had been the notion of mind as an information-processing device similar to a computer (cf. Thagard 2005, p. 12), researchers started to shift their attention to how the reciprocal interaction with the environment brings forth knowledge (cf. Wilson & Foglia 2011). Thus, the *enactive mind paradigm* (cf. Varela, Thompson & Rosch 1991) constitutes a counter-movement to the idea of computer-like information processing of symbolic representations; it emphasizes that cognitive agents do not process symbolic representations but that they "bring forth a world by means of the activity of their situated living bodies" (Wilson & Foglia 2011). Central to this paradigm is that knowledge comes from interactions with the environment; accordingly anatomical features of a cognizing system already determine what knowledge can be constructed.

The enactive mind paradigm implies that a cognizing organism actively constructs knowledge in order to ensure survival and successful interaction; as biologists Maturana Varela claim, "to live is to know" (Maturana & Varela 1987, p. 174)

In short, any knowledge about the world must be brought forth inside the boundaries of the nervous system. Therefore, a cognizing system is a self-explicative system constructing a meaningful world based on its internal operations.

The research of Jean Piaget highlights that children are not simply mapping the outside world into internal cognitive representations but that they *learn* to see the world through continuous interactions which are evaluated with regards to their experienced outcome.

2.2.3 Self-Reference

Self-reference specifies that any component is constructed with reference to existing components. It claims that knowledge is always defined by existing knowledge (cf. Maturana & Varela 1980, p. 27).

Organizational closedness leads to a dynamic where one state leads to the next in a continual process- the functional organization is to maintain and restore internal correlations of neurons (Mingers 1991, p. 320). Therefore, the system refers to its previous states recursively "since it would otherwise lose its firmness" (Rustemeyer 2013, p. 137, translated by the author).

Meaning is provided with regards to "previous internal experiences" (cf. Schmidt 1987, p. 15). Thus, "it can only be perceived by what has already been constructed and shaped" (cf. Schmidt 1987, p. 15, translated by the author).

The nervous system repeats, "that which works" (Maturana & Varela 1980, p. 27.). The reproduction of successful behaviour on the basis of self-reference implies that any cognizing organism functions in an inductive manner (cf. Maturana & Varela 1980, p. 27; Schmidt 1987, p. 25), as its future behaviour results from predictions based on the experiences of previous behaviour. The organization of any living system is conservative as the "mode of conduct or mode of behaviour is always specified and determined in the past" (Maturana & Varela 1980, p. 27). In a similar vein, the *predictive mind-theory* forms a recent approach in the cognitive sciences postulating that the brain is a "hypothesis testing mechanism" which aims to predict the sensory experience of the environment based on experiences it has previously made (Hohwy 2013, p. 1)

Self-reference leads to two consequences; first, it makes an organism structure-determined and second, any mutual exchange with the environment or another organism is based on structural coupling (cf. Maturana 2002, p. 5; Mingers 1991, p. 320; Schmidt 1987, p. 24).

Structure-Determinism

The assumption of cognitive behaviour as being self-referential suggests that any cognitive system differs in its individual cognitive states; the respective interactions as well as experiences lead to a distinct cognitive structure upon which an organism acts in a self-referential way. According to Maturana (2002), an organism is structure-determined as the behaviour of an organism depends on what has been brought forth and evaluated successfully in the past; he defines a structure-determined system "as a system in which all that happens with it and to it is determined at every instant by the way it is made [...] at that instant" (p. 5).

It is not possible to access the structure of the organism from the outside as the organism is organizationally closed and thus, one cannot predict how an organism will react to a stimulus from the environment. Due to the structure-determining nature of an organism, it is misleading to state that an input would determine a state in the organization of the organism, but that it can only "trigger or select a change of state" within the organism (Mingers 1991, p. 320; cf. Roth 1987, p. 241). The relationship between input and output is not linear and when assessing the response of an organism, it cannot be distinguished "between internally and externally generated states of nervous activity" (Maturana & Varela 1980, p. 22).

Structural Coupling

Structural coupling refers to the process that establishes an *interlocked* -i.e. balanced- state between an organism and the sensory information from the environment or between two (or more) organisms (cf. Schmidt 1987, p. 24). Each organism exhibits an individual history of interactions and a resulting structure and the process defines how an organism's internal structures adapt to the environment or another organism by recurrent interactions that result in "coherent structural dynamics" (Maturana 2002, p. 17), by "co-drifting and setting up the mutual conditions for effective action" (Castello & Botella 2007, p. 264).

Structural coupling with the environment enables the organism to become adapted to the outside world in that "the changing structure of the organism follows the changing structure of the environment" (Maturana & Varela 1980, p. xxi). The goal is to establish a state of equilibrium between the organism's internal dynamics and the stimuli from the environment which makes an organism interact successfully. From a radical constructivist point of view, an organism lives *with* the world rather than *in* the world (cf. Schmidt 1987, p. 42).

Structural coupling between two or more organisms leads to a mutual recursive change of states so that their respective structures become adjusted to each other (cf. Schmidt 1987, p. 25). This establishes a *consensual domain* between organisms, which is a "domain of interlocked (intercalated and mutually triggering) sequences of states, established and determined through interactions between structurally determined systems" (Maturana 1999, p. 152). A consensual domain forms a space "where the interactors' mutual expectations are more or less regularly realized" (Glaserfeld 1993, p. 28). This forms the basis for communication; since information cannot be simply *exchanged* between two organizationally closed systems, two (or more) organisms have to orient each other in their respective cognitive domains in order to communicate (cf. Maturana & Varela 1980, p. 27; Mingers 1991, p. 325).

Perspective from Cognitive Science: Situated Cognition and Extended Cognition

The concept of structural coupling shifted the focus of research on how a living body is situated in its environment and how it integrates "information about the environment, [...] to support contextually specific behaviours" (Sirois et al. 2008, p. 324). It gave rise to further paradigms, such as *situated cognition* and *extended cognition* (cf. Wilson & Foglia, 2011), essentially claiming that our experiential world is tightly connected with our environment in a recursively coupled manner (cf. Roth & Jornet 2013, p. 468).

Situated cognition ascribes a special meaning to the learning process and the context in which it takes place. It is claimed that knowing and doing cannot be separated as they are both intertwined. When a learner is situated in a meaningful (often real-life) context, knowledge comes as a by-product of the coupling between the organism and the environment (cf. Choi & Hannafin, p. 53). Furthermore, knowledge is not seen as *static substance* (cf. Brown, Collins & Duguid 1989, p. 31)

but it "continually evolve[s] with each new occasion of use" (Brown, Collins & Duguid 1989, p. 33).

The idea of situated cognition has proven influential for educational sciences. The prevailing idea of learning has been that the learner receives knowledge from the teacher and is further capable of deploying it in any given situation (cf. Anderson, Reder & Simon 1996, p. 6). Accordingly, the focus has been on mere knowledge storage and retrieval in artificial, context-unrelated settings (cf. Choi & Hannafin, p. 53). In contrast, situated cognition suggests that learning must take place in a specific context (cf. Anderson, Reder & Simon 1996, p. 6). Accordingly, there is a focus on the design of learning environments and how to create appropriate contexts where knowledge is created (cf. Choi & Hannafin, p. 53).

By enhancing the idea of structural coupling, *extended cognition* raises the question of where the mind stops and the rest of the world begins (cf. Clark & Chalmers 1998, p. 7). The theory claims that by structurally coupling with any means of operators (such as a computer), they become embedded in the cognitive operations of the organism and thus, the external entity "can be seen as a cognitive system in its own right" (Clark & Chalmers 1998, p. 8). By establishing a cognitive process through an interactive link (cf. Menary 2010, p. 2), an external device is part of one's own cognitive structures and thought processes.

To summarize, the assumption of self-reference is that all constructions are based on existing constructions that have proven successful in the past. Therefore, it is structure-determined in the sense that any response to the environment depends on what the organism has experienced so far and what it will be doing based on its inductive predictions.

Summary: Basic Assumptions of Radical Constructivism

Radical Constructivism rests on the assumption that the brain is organizationally closed, self-explicative and self-referential. It follows that no qualitative feature of the world enters the cognitive system but it is constructed internally. This construction process takes place in a self-referential manner, i.e. any construction exists with regards to previous constructions that have been successful.

These assumptions lead to the *anti-realist* stance of radical constructivism (cf. Boden 2010, p. 84; Olssen 1996); since each cognitive agent follows an individual construction progress, there is no sense in investigating a "teleological process towards a final state" (Riegler 2012, p. 236) but the focus should rather be shifted on the "developmental path *from* some initial state" (ibid, italics added.).

Building upon these basic assumptions, the following section elaborates on the epistemology of radical constructivism.

2.3 Epistemology of Radical Constructivism

This section introduces the epistemology of radical constructivism and it will investigate how we come to experience the outside world.

First, knowledge will be described as resulting from our own constructions and fulfilling the criterion of being viable, i.e. fitting into the outside world and allowing for successful interaction.

Second, perception will be defined as an activity which seeks to adjust sensory experiences to existing knowledge structures; it will be argued that we do not perceive an objective reality but that we perceive an experiential reality based on our constructions.

2.3.1 Knowledge

The Non-Accessibility of the Outside World

Radical Constructivism rejects the idea pursued by realism that the world has an "inherent meaning", which "remains potentially available to people, awaiting their comprehension or discovery" (McWilliams 2010, p. 80). The outside world does not provide meaningful information but any meaning must be constructed based on the experiences a subject makes.

Slezak (2010) emphasizes that Radical Constructivism does not deny a "mind-independent world" (p. 104), but that there is no point in speaking of any world that is beyond our experience (cf. Glasersfeld 1991c; Riegler 2001a, p.1), since "we do not see what we do not see" (Glasersfeld 1995b, p. 149). Accordingly, the search for an ontological -i.e. objective and true- reality is called off (cf. Glasersfeld 1995b; Riegler 2012, p. 245)

Since the subject constructs the object, a clear-cut distinction between those two is not possible (cf. Glasersfeld 1991b). As Glasersfeld (1995b) puts it, "[o]bjecitivity is a subject's delusion that observing can be done without him" (p. 149). Therefore, central to radical constructivism is the epistemological claim that knowledge is subjectively constructed inside the cognitive system.

The Construction of an Experiential Reality

Due to the assumption of operational closedness, all knowledge must be brought forth *inside* the cognitive system in order to equip raw neural pulses with

attributes, such as "emotional, tacit and categorial"; these processes are "the essence of meaning making" (Mahooney & Granvold 2005, p. 74).

Knowledge serves the organism to bring forth a stable world by organizing the flow of experiences (cf. Glasersfeld 1984; 1990). The reality, which we experience, resembles a "cloud of correlated events" (Scarr 1985, p. 502) so that the outside world appears to be stable and predictable.

In this vein, Bettoni and Eggs (2010) claim that constructed knowledge provides a *logic of experience* (p. 134); this means that we actively organize a meaningful world and impose our knowledge structures to provide a "consistent, coherent [and] valid" experiential reality (ibid.). They illustrate their point with a graph that allows for perceiving multiple depictions (Bettoni & Eggs 2010, p. 133). The following picture shows circles in an arbitrary assembly; "is this 'chaos' or the 'cosmos'?" (ibid.)

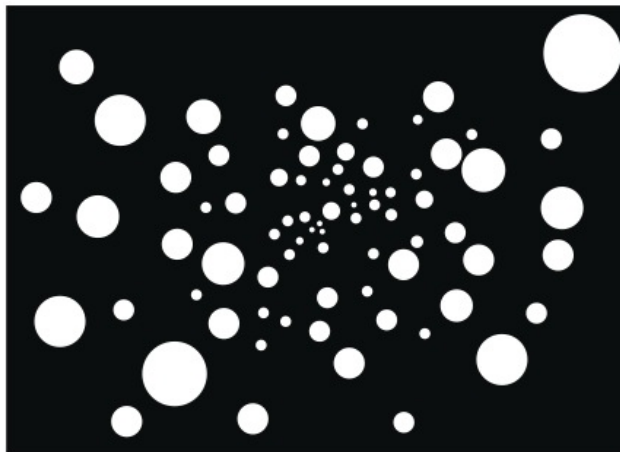


Fig. 2 "The Firmament" (from: Bettoni & Eggs 2010)

The authors claim that what we perceive depends on "how we look at it" (ibid). One and the same assembly can bear different meanings and conceptions. Figure 2 does not provide any meaningful information. However, applying a distinct structure can depict it as a firmament, either in a linear order (Fig. 3) or a circular order (Fig. 4); both strategies seem suitable.

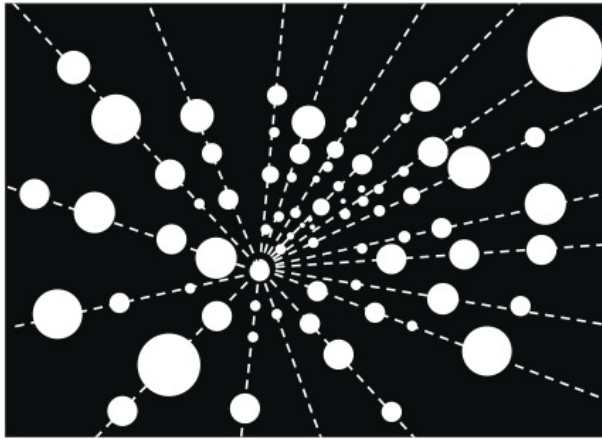


Fig. 3 "Linear order in the firmament" (from: Bettoni & Eggs 2010)

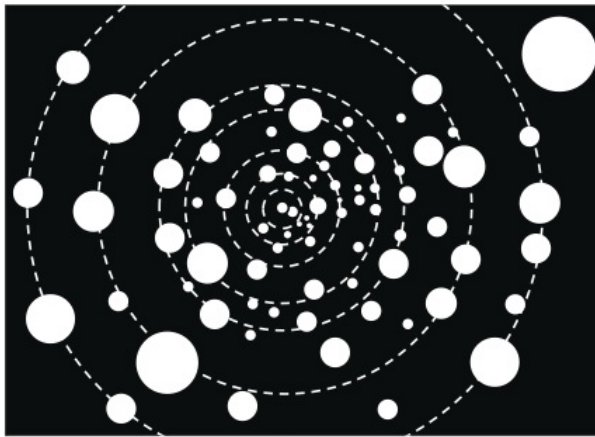


Fig. 4 "Circular order seen in the firmament" (from: Bettoni & Eggs 2010)

The figures illustrate the radical constructivist idea that the way we perceive the world is based on our internal knowledge constructions; since "these multiple perceptions (knowledge) are always the logic of your experience, not [...] of reality", it is "appropriate to understand knowledge as the logic of experience" (Bettoni & Eggs 2010, p. 134). This is in line with the examples brought in the introduction as well as with the multistable illusions described in section 2.2.1. They all illustrate that the way we experience the world (i.e. how we come to perceive it) results from internal constructions that apply meaning to the structures of the outside world.

The Concept of Viability

The internal organization of the outside world -or in the words of Bettoni & Eggs (2010), what an *experiential reality* looks like - is constructed through viable knowledge, i.e. knowledge that fits into the environment.

Knowledge has an adaptive function, i.e. it serves us in interacting successfully with the world (cf. Bettoni & Eggs 2010, p. 133; Glasersfeld 1995a). Biologists Maturana and Varela (1980) highlight that the cognitive operations to bring forth knowledge about the world are essential for the survival of the organism in the environment; "living as a process is a process of cognition" (p. 13). Knowledge serves to provide functional fitness, i.e. it seeks to fit into the environment and facilitate the survival of the organism (cf. Glasersfeld 1984; 1990)

Knowledge structures that fit into the environment and allow for successful interaction are referred to as being *viable* (e.g. cf. Glasersfeld 1984, 1989, 1995b; Rustemeyer 2013; Schmidt 1987). In other words, *viability* implies that knowledge is *useful* for the organism (cf. Rustemeyer 2013, p. 130). Glasersfeld (1984) compares viable knowledge with a "key that unlocks possible paths" (p. 18); the idea of knowledge being viable is "the central feature of [...] Radical Constructivism" (Glasersfeld, recited in: Francois 2004, p. 231).

Viability is a state where the organism is structurally coupled with the environment (cf. section 2.2.3) and the incoming sensory experience does not contradict with existing knowledge (Glasersfeld 1989). Since the outside world is not static but dynamic, viability is an on-going constructive process (ibid.).

The concept of viable knowledge does not allow for an inference of how *true* it is in an objective sense (cf. e.g. Glasersfeld 1984; Joldersma 2011). It is a subjective construction and therefore, it cannot be reasoned if there are other forms of viable knowledge constructions. Viable knowledge only stands for *one* possible way to interact with the world but it does not tell if there are other viable ways (cf. Glasersfeld 1984).

Process of Knowledge Construction

It is crucial to highlight that the cognitive system operates in a self-referential manner (cf. section 2.2.3). Accordingly, knowledge is always constructed with regards to knowledge that has been proven viable in the past (cf. Maturana & Varela 1980, p. 27; Rustemeyer 2013, p. 137; Schmidt 1987, p. 15). Therefore, the construction of new knowledge follows a structure-determined path; i.e. previous knowledge structures determine the construction of future knowledge (cf. Bettoni & Eggs 2010, p. 133).

Riegler (2012) compares the construction of knowledge with a ratchet, where "the constructions run into canalizations [...] or cognitive entrenchments which result from the requirement of assembling and fitting experiences" (p. 247; cf. Riegler 2001). This leads to a "radical reduction of freedom in future developments" (ibid) and prevents "new, innovative ways from being found" (p. 251). Furthermore, if previous knowledge structures entail flaws or are not viable anymore, the hierarchical organization of knowledge implies that the subsequent knowledge constructions keep up these properties.

In short, radical constructivism claims that we actively construct knowledge about the world to internally organize the incoming information of the outside world. Our knowledge structures provide us with an experiential reality, which allows for successful interaction. Knowledge has an adaptive function as it functionally fits into the environment. It is measured in terms of its viability, i.e. how useful it is for our purposes.

2.3.2 Perception

As discussed in section 2.2.1, perception is brought forth inside the organizationally closed system. It is an active process to match sensory input with existing knowledge structures so that we keep seeing the world "as we see it" (Richards & 1987, p. 214, translated by the author). Accordingly, perception is "a process of construction" (ibid.) as it already organizes the sensory information into meaningful structures; thus, "the act of perception equals the act of interpretation" (Richards & Glasersfeld 1987, p. 214). For this reason perception cannot be a passive mapping of an outside world for it does not transmit any *things in themselves* (cf. Glasersfeld 1984).

Knowledge and perception are interrelated as the existing knowledge structures determine how we perceive the world and, in turn, what we perceive is interpreted in regard to what we know.

Furthermore, the *constructivist-anticipatory principle* (cf. Riegler 2007, 2012) emphasizes that perception is subservient to knowledge. He argues that information from the outside world is not constantly assessed but the cognitive

system "occasionally uses sensor signals to verify their validity" (Riegler 2012, p. 241).

If sensory experiences are valid, they can be integrated into existing knowledge structures; however, if they do not fit, the existing knowledge must be re-constructed. Both situations are discussed in the following.

Integration of Sensory Experience

Swiss Psychologist Jean Piaget investigated how children construct a meaningful world out of sensory experiences (cf. section 2.2.2). He distinguished between two central processes. Sensory experience can be integrated into existing knowledge structures; this is referred to as *assimilation*. Otherwise, knowledge must be re-constructed so that the new experiences fit; this is referred to as *accommodation*.

Assimilation

When sensory experience matches with existing knowledge structures, it is being assimilated. Accordingly, assimilation is the construction of similarity, the primary strategy and self-assertive tendency to act on the environment in accordance with "already constructed structures" (Piaget & Inhelder 1976, p. 17). It is a process that refers to the integration of sensory experience without *altering* existing knowledge structures (cf. Anderson 2009, p. 5).

Glaserfeld (1995b) defines assimilation as "treating material as an instance of something known" (p. 62). He highlights that assimilation is already a constructive process; it seeks to maintain or improve viability by actively "reducing new experiences to already existing sensorimotor or conceptual structures"; it is the "modification of what is perceived in order to fit into the organism's conceptual structures" (p. 63).

Accommodation

When new experiences are incompatible with existing schemes, the organism encounters a *perturbation*, i.e. an interference (cf. Glaserfeld 1995b, p. 65), due to experiences which are not corresponding to the organism's expectation. If the primary strategy of looking for similarities fail (i.e. the process of assimilating), contradictions may arise that require a reorganization of knowledge structures so that new experiences can be integrated.

Accommodation describes a process in which knowledge structures are re-organized in order to fit with the sensory experience from the environment, i.e. the overall goal of accommodation is to "establish a new equilibrium" (Glaserfeld 1989, p. 128). The result of an accommodation is a re-organized coherent structure whereby the experienced perturbation has been integrated; i.e. a new equilibrium has been established (cf. Glaserfeld 1989, p. 128; cf. section 2.2.3)

In short, perception is not a passive mapping of the outside world but it is an active process to impose one's knowledge structures on the outside world.

Perception can either lead to an assimilation of sensory experience upon existing knowledge structures, or it can lead to accommodation. Accommodation refers to a re-organization of knowledge and is induced when sensory experience stands in contradiction with existing knowledge structures.

Summary: Epistemology of Radical Constructivism

Radical Constructivism claims that we construct any knowledge about the world *inside* our heads. Knowledge gives rise to an experiential reality, which does not hold the criteria of being true in an objective sense but it seeks to be viable, i.e. useful for us. Viability refers to *one* possible way to interact with the world but there can be other viable ways as well.

Since the organization of the cognitive world is self-referential and structurally-determined, the construction of new viable knowledge is always constructed with reference to the existing one. This reduces our freedom to construct new knowledge.

Perception is not the mere transmission of the outer world. Rather, perception is an active undertaking and seeks to integrate sensory information into existing knowledge structures. If the primary strategy succeeds to match sensory experience with existing knowledge, the sensory experience is assimilated. If it does not fit, the knowledge structures must be re-organized to be coherent and viable.

3 Epistemic Semi-Determinism

From a radical constructivist point of view, the interplay between knowledge and perception constitutes a form of determinism; what we know about the world determines how we come to perceive it, and what we perceive corresponds to what we know.

In the following, this determining relationship will be discussed.

First, it will be argued that it differs from the traditional determinism in philosophy; subsequently, it will be referred to as *epistemic semi-determinism*.

Second, it will be highlighted that we have to confront epistemic semi-determinism in order to construct a new understanding of the world.

3.1 Introducing Epistemic Semi-Determinism

3.1.1 The Determining Relationship between Knowledge and Perception

The knowledge we have constructed about the world makes us organize the incoming sensory experience with regards to what we already know; what is known determines what we perceive and, in turn, what we perceive is matched to what we know.

This arrangement is depicted in Fig. 5.

From a radical constructivist point of view, the interplay of knowledge and perception constitutes a form of epistemic determinism, as knowledge determines perception, and vice versa. However, the term epistemic determinism is misleading as this notion is sometimes used to express the epistemology of classical determinism (cf. e.g. Backmann 2013).

In the following, it will be clarified that the traditional philosophical idea of determinism differs from the determining relationship between knowledge and perception which results from radical constructivism.

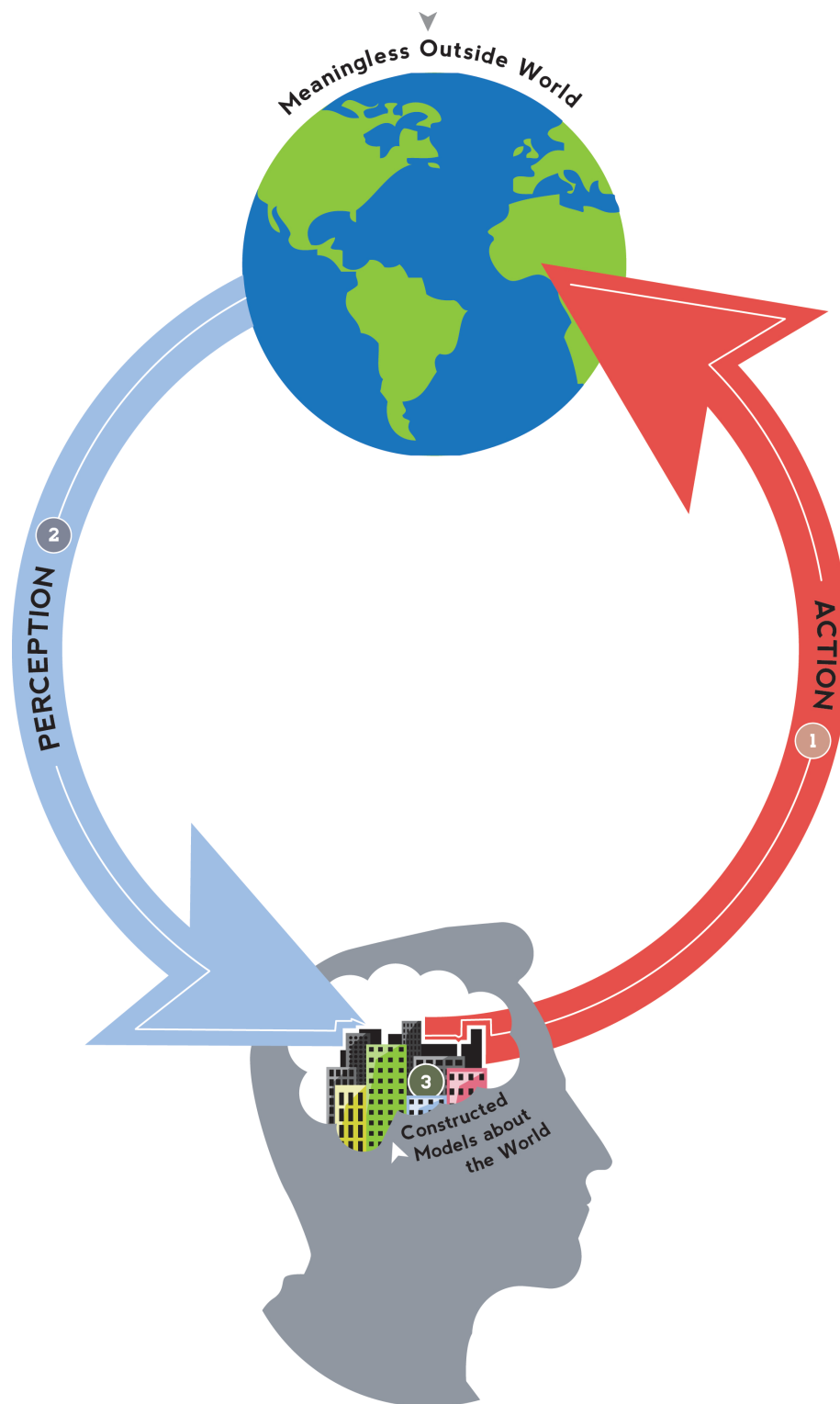


Fig. 5: Epistemic Semi-Determinism. (1) We construct knowledge to interact with the world (red arrow). (2) Our perceptions organize the sensory experience from the outside world according to our internal models (blue arrow). (3) These models remain stable and the world predictable; they serve for subsequent interactions.

3.1.2 Classical Determinism in Philosophy

Determinism refers to the philosophical idea that any event is governed by a preceding event as well as by natural laws (cf. Hoefer 2010; Schoendorf 2010, p. 79). Determinism assumes that "*given* the way things have gone in the past, all future events [...] are *already destined* to occur." (Hoefer 2010). Past events are not to be treated as "done, over, fixed" but -according to this idea- they "determine everything we do in our lives" (Hoefer 2010).

The epistemology of determinism circles around the question if we could know how any future state will be (Carl 2010). It is argued that provided with relevant knowledge about any event along with the "universal laws of nature" (ibid), we could know the subsequent progression of events. The notion of *epistemic determinism* describes that if one knows all relevant states of a system at a given time t_1 , it is possible to predict all future events at a later point in time t^* since all states in t_1 determine subsequent states at t^* (cf. Backmann 2013, p. 16; Hunt 1987, p. 132; Sartenaer 2015 p. 68).

3.1.3 Epistemic Semi-Determinism

Similar to the idea of determinism, radical constructivism suggests that our mode of conduct or behaviour is "specified and determined in the past" (Maturana & Varela 1980 p. 27) as it repeats "only that which works". This is due to the self-referential organization of the cognizing system, which leads to structural-determinism, as discussed in section 2.2.3.

However, the resulting kind of determinism differs from the traditional idea of determinism. Determinism claims that any given state of a system is precisely preceded by another state, thus the line of events is exactly determined. Radical constructivism, on the other hand, suggests that we have made constructions about the world which determine how preceding experiences are categorized and subsequent constructions will look like (cf. section 2.3.1; Riegler 2001; 2012). Knowledge and perception structures determine each other but they are not deterministic in the sense that they strictly predetermine the progression of future events. Furthermore, since we ourselves are the creators of our knowledge structures, we are free to influence them and thus, change the way we perceive the

world (cf. Watzlawick, recited in: Wuettrich, Osmetz & Kaduk 2006; Krippendorff 2009, p. 19).

Thus, in order to clearly differentiate it from the epistemic consequences of determinism, the interplay of knowledge and perception structures resulting from radical constructivism will be referred to as *epistemic semi-determinism*.

3.2 Confronting Epistemic Semi-Determinism

In the following, it will be argued that from a radical constructivist perspective, it is worthwhile to confront epistemic semi-determinism in order to construct new, viable knowledge about the world.

The model of single-, double- and triple-loop learning will illustrate the level on which our knowledge and perception structures must be changed in order to create new knowledge about the world.

Finally, there will be a brief excursus on the attitudes required for confronting epistemic semi-determinism.

3.2.1 Constructing New Knowledge About the World

According to radical constructivism, knowledge cannot be assessed for its correctness in an objective sense. As discussed in section 2.3.1, the idea of searching for an ontological reality is left behind since we cannot observe the outside world without the knowledge that we have already constructed about the world; observation requires someone who observes (cf. Glasersfeld 1995b, p. 149; Maturana 2002, p. 9).

Instead, knowledge is assessed for its viability; it has to functionally fit into the environment so that the organism can interact with it appropriately. When knowledge is viable, it serves our purpose, i.e. it enables us to reach our goals. Given the contrary, when knowledge is not viable, it is unreliable and useless (cf. Glasersfeld 1984).

As discussed in section 2.3.1, viability only stands for one possibility, which tells us nothing about any other possibilities (cf. Glasersfeld 1984). Furthermore, a crucial assumption of radical constructivism is that all cognitive operations are self-referential; this means that any knowledge construction rests on previous knowledge structures, and, in turn, may serve as a basis for subsequent

knowledge; therefore, the progress of construction is entrenched and our freedom for future development is restrained (cf. Riegler 2001; 2012).

Therefore, from a radical constructivist point of view, we can question our subjective reality since we cannot be sure that it is the most viable one.

Considering an example from the introduction, Thomas Kuhn's concept of paradigm shifts in science illustrates this point. Kuhn claims that scientists use paradigms to see a scientific problem within a well-defined frame. A paradigm, however, does not stand for absolute truth but is an accumulation of theories and laws that are applied in a specific domain along with the application to solve important problems (cf. Kuhn 1970; Bird 2013). When the preceding constructions and basic assumptions are no longer viable, a paradigm shift completely reframes the scientific perspective. It is the result of this reconstruction that causes scientists to see the outside world through new eyes. The world itself does not change due to a paradigm shift but the way it is *perceived* (cf. Kuhn 1970). Paradigm shifts highlight that the world does not wait for being discovered by us in a realist sense; instead we *invent* it, as our view on the world results from our own constructions (cf. Glasersfeld 2001).

Thus, we may confront *epistemic semi-determinism* and change our knowledge and perception structures, to subsequently construct more viable knowledge about the world.

In the following, it shall be clarified what impact the tools have on one's knowledge constructions. In other words, how *deep* could the change of one's understanding of the world be when making use of the tools?

By definition, a change in behaviour or thinking is referred to as *learning* (cf. e.g. Entwistle & Peterson 2004, p. 407). Since the aim of confronting epistemic semi-determinism is to construct a new understanding of the world, a kind of learning takes place. In the following, it will be shed light on what type of learning takes place.

3.2.2 Perspective from Learning Theory: Single, Double & Triple Loop Learning

Single-, double- and triple-loop learning is a framework that classifies the degree of change that is induced by a learning process (e.g. Georges, Romme & Witteloostuijn 1999; Peschl 2007). It will serve to classify the impact the tools must have in order to confront epistemic semi-determinism.

The model differentiates three types of learning.

Single-loop learning constitutes the most basic form of learning; it describes that behaviour and knowledge are changed as a consequence of perturbations from the environment. From a radical constructivist point of view, this type of learning is a process to maintain functional fitness (cf. Peschl 2007, p. 137; section 2.3.1). It is a reaction to what is happening in the outside world and does not come with a profound change of knowledge structures or understanding of the world. (cf. Georges, Romme & Witteloostuijn 1999, p. 440).

Double-loop learning also results from detecting mismatching experience but is characterized by a more profound change. It can be described as a *transformation process* over which goals and mental maps are changed (cf. Georges, Romme & Witteloostuijn 1999, p. 440). It is an additional loop to the single-loop learning and it takes into consideration that our understanding of the world is based on "assumptions, premises or a paradigm" (Peschl 2007, p. 137); by questioning them, double-loop learning is characterized by "stepping out of one's normal way of thinking" (ibid.). Therefore, this type of learning comes with a profound re-construction of one's knowledge structures and hence, experiential reality.

Triple-loop learning may be best described as a situation where subjects leave the boundaries of their own cognitive system and start to enter into a state of deep mindfulness (cf. Georges, Romme & Witteloostuijn 1999, p. 441). It constitutes a deep form of learning where a variety of issues and dilemmas are faced and linked together "in one overall learning infrastructure" (ibid.). Triple-loop learning induces a change on a fundamental, existential level which leads to different attitudes, values and habitus (cf. Peschl 2007, p. 139).

Single-, double- and triple-loop learning are depicted in the following graph.

Double Loop Learning as the Required Impact of Change

Following the framework of single-, double- and triple-loop learning, double-loop learning describes what the goal of confronting epistemic determinism is. As it has been argued in the introduction (cf. section 1), it is sought to construct new, viable knowledge about the world in the form that underlying assumptions and constructions are changed; in order to *see* the world in a new manner, one has to step out of one's knowledge structures about the world (cf. section 1.3; section 3.2). While single-loop learning is a mere reaction to perturbations, double-loop

learning is a more profound reflection and questioning of constructions and assumptions. Triple-Loop Learning as a profound existential change going beyond the re-organization of one's understanding of the world is too leftfield from the research question; ways to induce triple-loop learning are an endeavour in their own right and can be found in Peschl (2007).

To sum up, all tools should yield the potential to induce a process of double-loop learning in order question as well as change premises, assumptions and beliefs that underlie our understanding of the world.

3.2.3 Excursus: Tuning Into an Appropriate Attitude

The toolkit aims at confronting epistemic semi-determinism, i.e. it aims to induce a change in knowledge and perception structures. In order to successfully apply the tools, one has to tune into appropriate attitudes. In the following, the needed mind-set when questioning and changing one's understanding of the world will be elaborated.

The first essential attitude is *responsibility*, as people have to understand that they are responsible of changing their experiential reality (cf. Krippendorff 2009, p. 19; Watzlawick, recited in: Wuettrich, Osmetz & Kaduk 2006). Second, changing knowledge and perception structures require *openness* to unfamiliar experiences and unknown outcomes. Since the tools do not instantaneously lead to more viable knowledge, the third essential attitude is *patience and will*.

Responsibility

Von (1995b) emphasizes, "invoking objectivity is abrogating responsibility" (p. 149). This is a central departure from realism, according to which we passively mirror the outside world and by that, "reduce ourselves to response mechanisms" (Krippendorff 2009, p. 22). Radical constructivism however claims that we are free to act and thus, we are free to construct (cf. Heinz von Foerster's *aesthetical imperative*, v. Foerster 2003, p. 227; Krippendorff 2009, p. 19 - 22)

Acknowledging that radical constructivism dissociates from the idea that knowledge holds an ontological claim provides the basis for confronting epistemic semi-determinism; facing the fact that any knowledge constructions rest on one's individual interactions, experiences and inferences creates the opportunity to change them.

Accordingly, psychologist Paul Watzlawick points out that understanding the implications of radical constructivism leads to freedom as it makes one capable of changing their experiential reality at will (cf. Wuettrich, Osmetz & Kaduk 2006, p. 167).

In conclusion, acknowledging that one's understanding of the world results from subjective constructions provides an individual with the opportunity to impinge upon these constructions; however, one must first take responsibility for their own constructions, to then change their understanding of the world.

Openness

The second crucial attitude refers to us being open to the process, and more crucially, to the respective outcomes.

Following the radical constructivist argumentation, we construct knowledge to interact with the environment successfully. When confronted with a potential change, individuals may assume that their knowledge structures and their familiar behaviour are threatened (cf. Scheer et al. 2012, p. 10). They may exhibit resistance in order to protect their familiar meaning making and reject to dwell in this process (cf. McWilliams 2010, p. 82). Baker (1989) highlights that this is due to a fear of the unknown which is a "rational [...] response to change" (p. 53), and it is "inevitable" (p. 54). Therefore, a way to respond to this fear must be found in order to remain open for the change process. In this context, Karagiorgi and Symeou (2005) point out that cognitive restructuring may be facilitated in an environment that enables "reflective thinking, multiple perspectives, modelling [...] in a context domain" (p.19) In a similar vein, the research on *enabling spaces* investigates how an environment can be designed to facilitate such cognitive processes (cf. Peschl & Fundneider 2012; 2014).

Besides the fear and scepticism towards the process there are more mechanisms to be addressed; even when new knowledge has been constructed, new knowledge is not automatically integrated into one's understanding of the world. A subject may "ignore or hardly note any knowledge that is contradictory to existing structures (Perkins 1991, p. 19).

In short, questioning one's assumptions may result in resistance. Therefore, subjects should get into a mindset where they are open for the change process as well as what will result from it.

Patience and Will

Thomas Edison, inventor of the light bulb said he had never failed but had found "10.000 ways that don't work" (recited in: Kirby 2015, p. 125). This quote illustrates that constructing new knowledge does not automatically lead to *viable* knowledge. Thus, being *patient* until a viable outcome has been found is essential when confronting epistemic semi-determinism.

Furthermore, the quote suggests that a construction process may require a lot of effort; inventing a number of ways that are not appropriate or convenient requires commitment and determination. Perkins (1991) points out that any construction process requires a "high cognitive demand" (p. 19). Thus, the *will* to successfully apply the tools is essential.

In essence, patience and will are crucial attitudes to ensure a persistent change process.

Summary: Epistemic Semi-Determinism

The interplay of knowledge and perception leads to an *epistemic semi-determinism*. Knowledge determines perception, and perception determines the construction of knowledge; however, we can challenge the organization and facilitate the construction of new knowledge.

In light of the fact that knowledge stands for one viable construction, this endeavour seems worthwhile. By gaining a new understanding of the world, we may be able to see it in a different, more viable manner. In order to do so, we must challenge the underlying assumptions, beliefs and theories. This undertaking is best described by the concept of double-loop learning.

Furthermore, in order to confront epistemic semi-determinism, specific attitudes are needed; one must take responsibility for one's own knowledge constructions, be open for the change process as well as the results and remain patient until viable knowledge is constructed.

In the following chapter, it will be described how we can change knowledge and perception structures in order to confront epistemic semi-determinism.

4 Confronting Epistemic Semi-Determinism: Strategies & Framework

This chapter discusses how we can confront epistemic semi-determinism. It serves as an introduction to the toolkit.

First, it will be elaborated on how one can change knowledge and perception structures from a radical constructivist perspective. Strategies to target this endeavour will be introduced.

Second, a framework will be introduced in which these strategies are enlisted along with specific tools and techniques. This will serve as an overview of the toolkit, depicting how and when each tool can be used.

Third, it will be described how the toolkit is to be used.

4.1 Strategies to Confront Epistemic Semi-Determinism

We have to change our knowledge and perception structures in order to construct new knowledge about the world. *Changing* means that existing and habitual ways of conceptualizing the world are questioned and overruled; by leaving aside our previously constructed models and conceptions, we may come to construct new interpretations of reality.

As depicted in Fig. 5 (section 3.1.1), both knowledge and perception are reciprocally organized and cannot be strictly separated. Changing knowledge structures leads to new knowledge, which in turn gives rise to new perception structures. On the other hand, changing perception structures intends to perceive unfamiliar aspects of the world which then leads to a re-organization of knowledge structures. Both approaches offer the opportunity to confront epistemic semi-determinism in order to construct new knowledge about the world. They are elaborated in the following.

4.1.1 Changing Perception Structures

As discussed in section 2.3, perception is governed by the knowledge we have about the world; accordingly, perceiving is not a passive mapping of the outside world but it is an active effort to fit incoming information into our understanding of the world (cf. Glasersfeld 1995b, p. 63; Piaget & Inhelder 1971). Perception is not thought to be a constant scanning of the environment; rather it occasionally

checks whether the sensory information fits to the corresponding knowledge structures (cf. Riegler 2012, p. 241).

Based on the findings of the theoretical review in section 2, three strategies can be derived in order to change perception structures.

Strategy 1: Sensing and Cultivating

Directing one's attention to the environment and cultivating *perturbations* (i.e. sensory experience which does not fit into or is even contradictory to existing knowledge structures) may lead to what Piaget describes as an accommodation and enhance a re-organization of the internal constructions (cf. section 2.3.2; Glasersfeld 1989; 1995b; Piaget & Inhelder 1971).

Strategy 2: Changing Perspective

By changing the perspective and attempting to perceive a phenomenon or specific aspect of the world differently, one may come to construct a new understanding of it (cf. Kolko 2010; 2011).

Strategy 3: Seeking Other's Perspectives

By acknowledging that everyone has their own knowledge about the world and perceives the world in a distinct manner (cf. section 2.3), we can confront our perceptions with another individual's perceptions of the world. This may change perception structures as it brings awareness to how the world can be organized in a different manner (cf. Schmidt 1987).

4.1.2 Changing Knowledge Structures

As discussed in section 2.3.1, all knowledge is constructed and serves the purpose of being viable. Due to the self-referential construction process, our knowledge is based on previous constructions (cf. e.g. Maturana & Varela 1980, p. 35; Riegler 2012). Thus, whatever we know *has* a deeper root that has been constructed, and in turn, what we know *will* form the basis for subsequent constructions.

Following the theoretical considerations in section 2, three strategies can be derived in order to change knowledge structures.

Strategy 1: Making Knowledge Explicit

Underlying assumptions and previous knowledge structures can be made explicit. By revealing and them, we may be capable of changing them (cf. Neimeyer 2009; Scheele & Groeben 1988).

Strategy 2: Reflecting on Future Constructions

By reflecting on the process of knowledge construction (cf. section 2.3.1), it may be possible to change knowledge structures with regards to their future development (cf. Umpleby 2014).

Strategy 3: Constructing Viability

Since knowledge must allow for successful interaction, tools are introduced to construct viable knowledge structures (cf. Peschl et al. 2014; Richards 2014).

4.2 Framework

The following framework (Fig. 6) provides an overview of the tools and specifies their respective requirements as well as their possible applications. They are organized according to the strategies in section 4.1.

The toolkit constitutes a synthesis from findings in various areas. Based on the theoretical foundation of radical constructivism, the tools were collected from fields such as Design Thinking, especially by the Institute for Design at Stanford (e.g. *Saturate and Group*, *Interview for Empathy*); creativity research, especially by Edward de Bono (e.g. *Six Thinking Hats-Method*); innovation research (e.g. *Prototyping*); research in psychology and cognitive-science (e.g. *Mindfulness*); organizational management and learning (e.g. *Appreciative Inquiry*, *Interacting with an envisioned future*); and general findings from the realm of radical constructivism (e.g. *Multiple Perspective Environment*).

Riegler (1998) argues that humans stick to the behaviour they acquire habitually and they generally act according to the principle, "if it ain't broken, don't fix it" (p. 41). Thus, realistically speaking, individuals may come to see the necessity of confronting epistemic semi-determinism only when they experience their subjective reality as being no longer viable, i.e. when they face a problematic context and are prevented from successful interaction. However, from a radical constructivist point of view, *all* knowledge adheres to the purpose of being viable

so it may always be worthwhile to apply the toolkit, or at least to question one's constructions about the world in order to see if there are more viable ones. Therefore, some of the tools are applicable to a *specific* problem or context, and others are *general* tools in the way that they are principally applicable. The specific tools will be marked with *[S]* while the general tools will be marked with a *[G]*. Tools that are applicable to a specific context as well as in a general way are marked with *[G] [S]*.

The tools differ with respect to the setting in which they can be applied.

Some of the tools need a *group setting*. They require at least two subjects for successful application.

The tools differ in the complexity of application. Some tools can be easily used, as they do not require extensive preparation in terms of creating an appropriate context or specific supplies; these tools will be marked as *simple*. Other tools require more effort in their preparation and some of them need specific materials; these tools will be labelled as *sophisticated*.

		GENERAL APPLICATION	SPECIFIC CONTEXT	GROUP- SETTING	SIMPLE	SOPHISTICATED
CHANGING PERCEPTION STRUCTURES						
SENSING AND CULTIVATING	Mindfulness	✕			✕	
	Purposefulness	✕			✕	
	Seeking for Flaws	✕			✕	✕
	Six Thinking Hats- Method		✕	✕		✕
	Body Storming		✕	✕	✕	✕
	Seeking New Environment	✕			✕	✕
	Using New Tool	✕	✕		✕	✕
	Breaking Routines	✕	✕	✕		✕
CHANGING PERSPECTIVE	Re-Frame	✕	✕	✕		✕
	Semantic Zoom		✕			✕
SEEKING OTHER'S PERSPECTIVES	Multiple Perspective Environment	✕	✕	✕	✕	✕
	Engaging in Dialogue	✕		✕	✕	
	Appreciative Inquiry		✕	✕		✕
	Interview for Empathy		✕	✕		✕
	Story-Share and Capture		✕	✕		✕
	Observing Others	✕				✕
	Group Brainwriting		✕	✕	✕	✕
	Learning New Language	✕	✕			✕
	Comparing Language	✕	✕		✕	
CHANGING KNOWLEDGE STRUCTURES						
MAKING KNOWLEDGE EXPLICIT	5 Why's	✕	✕		✕	
	Thinking Aloud	✕	✕		✕	
	Saturate and Group		✕			✕
	Half-Standard Interview		✕	✕		✕
	Structure-Formation		✕	✕		✕
	Method					
	Concept Mapping		✕			✕
REFLECTING ON FUTURE CONSTRUCTIONS	Interacting with Envisioned Future	✕	✕			✕
	Reflecting on Future Knowledge	✕			✕	
	Creating Chaos	✕	✕		✕	✕
CONSTRUCTING VIABILITY	Prototyping	✕	✕	✕	✕	✕
	Articulating	✕	✕		✕	

Fig. 6: Framework for changing knowledge and perception structures; strategies and tools.

4.2.1 How To Use the Tools

Before elaborating on the tools and presenting them in more detail in the next two chapters, will be clarified how they are to be used.

The toolkit offers different ways to confront epistemic semi-determinism; the context or problem determines which tool is appropriate.

Everyone has different intentions. Thus, there is no distinct strategy to construct new knowledge (cf. Jonassen 1991, p. 12). The toolkit aims to empower individuals to find whatever is most suitable to them; in the end, "[the individuals] themselves specify the operating mechanisms proper to them" (Goolishian & Winderman 1998, p. 132).

Structure and Outline

The toolkit comprises various tools and methods to affect knowledge and perception structures. They are selected based on their potential from a radical constructivist point of view, and address various aspects and possible contexts.

They are presented in a user-friendly way.

Presentation of the Tools

Each technique is described with respect to two key points;

- *What & Why* describes the basic idea of the tool and shows which processes are induced and what the effects are from a radical constructivist point of view.
- *How* provides an instruction on how the tool is to be used; it specifies the way a tool is applied and what possible contexts are, i.e. what it is suitable for and what setting is needed.

To sum up, there are three strategies for changing perception structures and three strategies for changing knowledge structures. Based on these strategies, a framework has been developed that contains suitable tools and techniques that have been collected from different fields and research areas.

In the following, this toolkit will be presented in more detail; chapter 5 introduces tools to change perception structures and chapter 6 will present tools to change knowledge structures.

5 Changing Perception Structures

5.1 Sensing & Cultivating

The following tools aim to change perception structures by enhancing the awareness for perturbations (i.e. unexpected sensory experience) from the environment. Sensing and cultivating experiences that do not fit or stand in contradiction to one's knowledge structures may lead to a re-organization of knowledge structures.

5.1.1 Mindfulness [G]

What & Why

Mindfulness is a state of heightened awareness of one's internal and outer processes (cf. e.g. Bishop et al. 2010).

While mindfulness has been linked with several enhancing effects, such as reducing of stress, affective responses and emotional well-being (cf. e.g. Bishop et al. 2004; Keng, Smoski & Robis 2011), it is interesting for the research at hand as it provides a "deep, non-conceptual seeing into the [...] world" (Kabat-Zinn 2003).

In its essence, mindfulness is a "consciousness discipline" (ibid) in which one dwells in the very moment and remains in a non-judging posture towards themselves and the world and further creates awareness of any upcoming "sensations, thoughts or feelings" (Keng, Smoski & Robis 2011).

By seizing and focusing on the moment, mindfulness enhances the awareness of sensory experience. Expectations, judgements and predictions result from previous experiences and by not responding to them, we may become aware of sensations that have not been expected. As discussed in section 2.2.3, an increased awareness of sensory experience facilitates the structural coupling between the environment and one's internal cognitive operations. By integrating these unexpected sensory experiences, mindfulness may provide building blocks for a re-organization of internal structures.

How

Mindfulness is often referred to as meditation in a strict sense, i.e. remaining in a distinct position and actively focusing on internal and outer sensations (cf. e.g.

Keng, Smoski & Robis 2011). It is practiced when one focuses their attention towards specific inner or outer events (e.g. one's breathing or odours from the environment). Empirical research suggests that even a short period of practicing (in the range of a few weeks) to not judge or assess upcoming experiences, leads to a significant increase in general awareness and attention (cf. Brown, Ryan & Creswell 2007; Chiesa, Calati & Serretti 2011).

In the context of the research question at hand, however, it must be emphasized that mindfulness in a general sense -i.e. *being aware* of inner and outer sensations- constitutes an efficient strategy to change perception structures from a radical constructivist point of view. It seems beneficial to be *mindful* in day-to-day life, using it as a general attitude.

5.1.2 Purposelessness [G]

What & Why

Purposelessness calls for interacting with the environment without any specific intentions or goals. It is argued that the application of purposelessness suits any context and should therefore be considered a general attitude for interacting with the world.

The way we perceive the world does not only depend on what we know but also on what we want to achieve. In psychological literature, this is referred to as *selective attention* (cf. Sternberg & Sternberg 2012, p. 152), whereby task-relevant stimuli are considered while irrelevant ones are ignored (cf. Gazzaley & Nobre 2012, p. 129).

The disregard of stimuli, which appear to be irrelevant for a specific goal, but nevertheless are salient, is referred to as *inattentional blindness* (cf. e.g. Simons 2000; Simons & Chabris 1999). One extreme form of this phenomenon was demonstrated in a famous experiment by Simons and Chabris (1999); subjects were asked to observe a scene where people stand in a circle and throw around a ball. They are asked to count how often the ball is caught. While they are performing this task, a man in a gorilla costume enters the scene and stands in the midst of the circle for several seconds. However, only half of the subjects notice the gorilla. The authors conclude that "we often fail to perceive unexpected events

[and] we often fail to notice unexpected changes to the [...] details of the environment" (Simons & Chabris 1999, p. 1071).

Therefore, *purposelessness* aims to encourage interaction with the world without pursuing any purpose or goal. This way, attention is not directed towards specific cues which may lead to innovative ways to interact with the world as well as the detection of unexpected stimuli and unfamiliar cues.

How

Purposelessness encourages interaction with the environment without any specific goal, since "goal guides behaviour through attention, and this guidance can occur outside of a person's awareness" (Dijksterhuis & Aarts 2010, p. 468). In a way, not having a purpose is already a purpose, but the point is to not pursue any *specific* goal. While purposelessness is similar to mindfulness in that it seeks to enhance perception to be free and unrestricted to familiar and/or expected stimuli, this tool is an explicit invitation to interact with the outside world without any goal or purpose.

It is crucial that one's attention is free to select targets from the environment which in turn serve for further interaction. While interacting with the environment subjects do not pursue a specific purpose but remain open for what it has to offer and thereby, they allow for interactions and cognitive operations that emerge; thus, they experience the environment in an unexpected way. It is crucial that while applying purposelessness, the subject remains in an unprejudiced state and observe what emerges between them and the outside world.

5.1.3 Seeking for Flaws [G]

What & Why

As discussed in section 2.3.2 we seek to assimilate information; integrating experience into existing schemes and structures is the primary strategy for organizing the environment, as it requires less cognitive demand (cf. Perkins 1991, p. 19). Accordingly, we try to maintain our knowledge structures and even ignore contradicting experience (cf. Fosnot & Stewart 2005). *Seeking for Flaws* calls for questioning the familiar perceptions as well as conceptions about the world. By actively searching for contradictory and non-fitting sensory experience, it

facilitates to induce a process of accommodation. The underlying idea is close to Karl Popper's principle of *falsification*. According to the philosopher, science must always seek to falsify its theories and assumptions; since any theory cannot be conclusively verified, he argues that the only way to come closer to truth is to falsify existing beliefs. (cf. Popper 1963; Thornton 2014).

From a radical constructivist point of view, we aim to establish as well as maintain cognitive equilibrium with the outside world (cf. section 2.2.3). Since any construction comes with a subjective effort, we tend to prefer our old beaten paths (cf. Riegler 1998, p. 41). We do not only not-search for any evidence, which may put our constructions into question; we might even *ignore* such evidence (cf. Perkins 1991, p. 19). Actively searching for flaws or contradicting experiences enables us to change our familiar perception structures and facilitates a re-organization of knowledge structures.

How

In practice, this tool can take on various forms. Seeking for flaws and unexpected or unfamiliar experiences require us to leave the comfort of settled assumptions about the world; for example, by shifting one's attention towards things that *do not* work, concentrating on questions that *cannot* be answered or searching for evidence which *does not* make sense. Sensory experiences that do not seem compatible with existing knowledge structures indicate that the construction is either to be extended or re-organized. Considering this enhances the construction of holistic structures that remain sustainable and more reliable.

5.1.4 The Six Thinking Hats-Method [S]

What & Why

The *Six Thinking Hats-Method* refers to a special technique for viewing the environment in a specific pre-determined way, and to accordingly focus on specific sensory experience. It was introduced by creativity researcher Edward De Bono (cf. De Bono 1995; 1999).

From a radical constructivist point of view, we are used to perceiving the world according to how we understand it. Wearing a distinct hat, taking on a specific role along with specific attitudes towards the world shifts our attention to certain

categories and classes of sensory experience. Accordingly, we narrow our attention and change our perception structures by letting in very specific information that would otherwise remain unconsidered. This technique can be regarded as an opposite to mindfulness or purposelessness, where the goal is to free oneself from any expectations about cues. Instead, wearing a hat encourages the subject to concentrate on specific categories of sensory experience in the environment (De Bono 1995, p. 14). Accordingly, by increasing the attention towards selective aspects of the world, the gathered experience is increased and more extensive impressions can be gathered (cf. Sternberg & Sternberg 2012, p. 152).

How

De Bono suggests taking on six different hats, with each hat providing a distinct mind-set, thereby selecting and elaborating upon specific types of knowledge (for the complete list, see De Bono 1995).

The *White Hat* refers to a strongly analytical stance; attention is to be focused on hard data, such as facts, figures and numbers.

The *Red Hat* focuses on purely affective responses; whatever comes to mind shall be articulated, without any need for logical explanation.

The *Black Hat* calls for a judging stance; attention is shifted towards boundaries and limitations.

The *Green Hat* focuses on existing knowledge, to provoke and to think of alternative conceptions.

The *Blue Hat* asks to oversee the whole subject and decides which hat shall be worn.

De Bono (1995) highlights that the distinct sequence of hats is not determined; depending on the subject matter at hand, one can choose the hat depending on what is needed. For the sake of this thesis, it shall be underlined that -in order to change perception structures- one should focus on the hats which enhance perception that usually remains neglected. By becoming fully immersed in the role given by the hat, one may come to perceive new aspects of the world. This, in turn, may lead to the detection of shortcomings and incongruences in existing models and thereby, it may facilitate an accommodation.

5.1.5 Bodystorming [S]

What & Why

Bodystorming is a tool to create new knowledge by physically experiencing a situation or specific problem. Despite the similar name, Bodystorming differs from Brainstorming in that it does not seek to produce a variety of ideas, "but [it is] the idea of 'being there' and living with data in embodied ways [...] being physically present in the context of interest" (Oulasvirta, Kurvinen & Kankainen 2003, p. 127).

This technique has been developed for user-centered design, where designers and product developers aim to create products and solutions that "fit the goals, tasks and needs of the users" (Endsley 2007, p. 7).

From a radical constructivist perspective, this tool is appealing in two respects.

First, it "enacts experiential awareness" (Schleicher, Jones & Kachur 2010, p. 47); by residing within an environment and exploring what it has to offer, one may come to a new understanding of the outside world.

Second, by interacting with the environment in a way that is relevant to the context of the problem (e.g. re-enacting specific movements that are required to perform an action), we are experiencing relevant aspects of the environment which lead to practical solutions (cf. *ibid*). Taking action is the fundamental precondition for creating new knowledge (cf. v. Foerster 1987; Krippendorff 2009); therefore, bodystorming is particularly interesting for the research at hand.

How

The concrete application leads to a "prototyping of experience" (Bontoft & Pullin 2013, p. 529); it can be applied to any problem that can be broken down to a real-world environment where experiences can be enacted.

Accordingly, when applying the tool, one must first identify the context that is of interest; which aspect of the world should be investigated? Where and when does the problem occur? Who is involved?

In a second step, subjects get physical and are encouraged to "walk through [...] experience" (D.School 2015, p. 31). By simulating the context of interest and observing one's movement and experience, subjects may arrive at new ideas and ways of looking at the problem (cf. *ibid*). This can take on original forms; for

example, the Institute of Design at Stanford, *D.School*, suggests wearing glasses with a layer of Vaseline rubbed onto them when designing a product or service for elderly people so that the world is experienced in a more authentic manner (D.School 2015).

5.1.6 Connecting With New Environment [G]

What & Why

Connecting With a New Environment refers to the change of one's surroundings while performing cognitive operations.

From a radical constructivist point of view, our cognitive operations are structurally coupled with the environment; any perturbations from the outside are integrated into the organizationally closed cognitive system. Accordingly, the concept of extended cognition (cf. section 2.2.3) explains that our cognitive operations are "intrinsically coupled with the environment" (Peschl & Fundneider 2014, p. 351) and therefore, a change in the environment leads to a change in one's internal world; "environmental engineering is also self-engineering" (Clark 2008, recited in: *ibid*).

Therefore, confronting oneself with a new environment leads to new perturbations, which, in turn changes perception structures.

How

Connecting with a new environment is a general tool making use of the fact that our cognitive operations are structurally coupled with the environment. New sensory experience and perturbations from the outside world are beneficial with different regards; connecting with environments can be done in a small-scale setting (e.g. changing the room or the social surroundings) or in a wider-scale setting (changing the culture one is situated in).

5.1.7 Using a New Tool [G] [S]

What & Why

Using a New Tool is a method that contributes to the change of perception structures by extending the cognitive process and therefore, it assists in "acquiring, restructuring and tuning knowledge" (Jonassen 1992, p. 4).

From a radical constructivist point of view, this technique is interesting as it may induce a structural coupling (cf. 2.2.3); it leads to unfamiliar interactions and so it recursively couples our cognitive processes with the outside world.

The technique leads to an organization of thinking skills (cf. Jonassen 1999, p. 226) as a new tool generates thoughts that would not be possible without it. (cf. Jonassen 1992). They enable subjects "to construct their own realities using the constructs and processes in the environment on a new content domain" (Jonassen 1992, p. 4).

How

Which tool is relevant depends on the context. Generally speaking, a tool is any "device, or technique, for focusing the learner's analytical processes" (Mayes 1992, p. 6).

Possible examples are switching from typing on a laptop to writing on a sheet of paper, the use of graphical illustration when information had previously been represented in data and numbers, or the use of a different computer program.

5.1.8 Breaking Routines [G] [S]

What & Why

Breaking Routines encourages identifying one's routines and habitual ways of interacting with the world and subsequently overruling them. The tool is inspired by creativity researcher Edward de Bono. He suggests that one should apply *provocative operations*, which serve to "challenge [...] established patterns" (De Bono 1970, p. 167); he claims that the active pursuit to question our patterns of thought and behaviour leads to the establishment of new connections.

From a radical constructivist perspective, the knowledge we have constructed about the world serves to be viable, i.e. it allows for successful interaction with the world. As discussed in section 2.3.1, the progression of knowledge structures is entrenched so that new constructions emerge with reference to preceding ones. Breaking routines may lead to a revelation of unquestioned habitual interactions which then can be suspended. Subsequently, guiding perception to the results from new ways of interacting with the world may provide new information about the environment, which, in turn, yields potential for new constructions.

How

Breaking routines may be beneficial for any context or problem.

Bringing to awareness the most natural behaviour in a given situation and actively searching and deploying new ways of interaction may provide grounds for constructing new interactions with the world.

As discussed in section 3.2.3, it is crucial to remain patient and committed while guiding perception towards new and unfamiliar experiences until useful routines have been identified.

5.2 Changing Perspective

Our perceptions of the world are guided by previous assumptions and underlying patterns. Accordingly, we automatically put our observation in the context of pre-defined references. For example, the concept of theory-ladenness (cf. section 1.1) demonstrates that our observations are framed within our conceptions of the world. The following tools suggest how the context of a perception can be changed in order to construct different outcomes.

5.2.1 Re-Framing [S]

What & Why

In design literature, *framing* refers to a perspective or context from which a problem is seen (Dorst 2011, p. 525). *Re-Framing* constitutes the active undertaking to change the perspective and find a new interpretation of one and the same observation. This leads to the perception of an aspect of the outside world in a different manner (cf. Kolko 2010).

From a radical constructivist point of view, we organize the world in a way so that it matches the schemes of our existing knowledge structure (cf. section 2.3.2). Accordingly, research on design thinking has labelled these schemes as *frames* through which we look at the world. A frame represents an excerpt of the outside world and it is based on experience and underlying assumptions (cf. Kolko 2010). Reframing is a tool which aims to distort or remove a frame by actively restructuring specific aspects of the frame. Thus, from a radical constructivist point of view, re-framing leads to the construction of new perception structures.

How

The technique of reframing is conducted by "shifting semantic perspective in order to see things in a new way" (Kolko 2010, p. 23). The goal of the found frame is to put a problem or an aspect of the world into a new context, which then allows us to "explore associations and hidden links to and from the centre of focus" (ibid). Based on Kolko (2010), reframing may be best accomplished by following a distinct sequence of steps.

Identifying an initial frame. By deciding what is of interest, one can identify all relevant elements and connections that are involved in the frame. The more concrete the frame, the easier (and more effective) the step.

Changing the frame. Either by using graphical support, taking notes or running through this process in one's mind, it is now crucial to question, remove and change the particular elements and connections and to create a variety of possible alternatives to a frame.

Extrapolate. Analysing and extrapolating the reframed outcome may bring to the surface "existing constraints and implications that may have been otherwise hidden or overlooked" (Kolko 2010, p. 24).

While the technique of reframing is primarily used in the context of innovation and business studies (Kolko 2010; Seelig 2013), it may be used in any given context; by investigating the how we perceive and by re-framing it, we may be able to change our perception structures.

5.2.2 Semantic Zoom [S]

What & Why

Semantic Zoom is a tool that allows for investigating the larger context in which a problem or specific aspect of the world is embedded. It has been developed by design researcher Jon Kolko (cf. Kolko 2011). The underlying idea is to change the perspective and to look at problems or aspects of the world "from a closer perspective, or from further away" (p. 125). Any aspect of the world or problem is part of a network of other constructions. Our underlying assumptions may influence any other observation in the environment. The idea of literally zooming into and out from an aspect is that "[c]hanging the scale of a problem illustrates new problems, issues, and opportunities, and it allows the designer to re-contextualize the problem" (Kolko 2011, p. 125); therefore, it is a technique that enhances a "new thinking about a [...] space" (ibid). Its application may change perception structures by coming to identify aspects that would not be taken into account otherwise. (cf. ibid)

How

Semantic Zoom suggests that any problem can be either zoomed in or zoomed out.

Thereby, one takes the intuitive -i.e. habitual- perspective on a problem; this is labelled *Zoom 0*, and it will be the starting point for the zooming out three times (i.e. creating three subsequent representations of the problem context).

Then, one returns to the level *Zoom 0* and zooms in three consecutive times. Each of these levels will generate new knowledge about the chosen aspect of the world (Kolko 2011, p. 132), and thereby, it will allow us to adopt one or more new perspectives of the problem.

Zooming in reveals details and "new problems and design opportunities in the nuances of a specific area" (Kolko 2011, p. 125); thereby, one can come to identify specific "problem constraints" (p. 126).

Zooming out leads to the identification of "the larger context of a problem" (p. 125)

It is crucial that the technique is applied after an exact aspect of the world or a problem context has been identified. Furthermore, Semantic Zoom may be best used in combination with other tools, such as Concept Mapping (cf. section 6.1.6).

5.3 Seeking Other's Perspectives

Since everyone constructs their own subjective reality, it is worthwhile to seek other's understanding of the world. As discussed in section 2.2.3, structural coupling is an underlying mechanism to re-organize one's cognitive structure by bringing it in line with another's realities. In the following, tools are discussed which enhance structural coupling to change one's understanding of the world.

5.3.1 Multiple Perspective Environment [G] [S]

What & Why

A *Multiple Perspective Environment* is an environment where people with different understandings of the world come together to work on the same task or problem (cf. Peschl et al. 2014; Umpleby, Anbari & Mueller 2007).

From a radical constructivist point of view, each of us holds his/her own experiential reality. Our cognitive operations are structurally-determined, i.e. they develop in such a way that interactions with the world are maintained and continuous. A Multiple Perspective Environment leads to a situation where individuals recursively couple with each other's cognitive structures so that they form a consensual domain (cf. Glasersfeld 1991b; Goolishian & Winderman 1988, p. 133; Maturana 1999, p. 152), which in turn changes the cognitive structure of all participating members. Acknowledging that others have their own viable ways of approaching problems may open opportunities to extend one's own way of thinking and thus, confront a subject with a wider range of viable ways to interact with the world (cf. Schmidt 1987, p. 51).

Thus, a multiple perspective environment changes one's perception structures and contributes to a new understanding of the world.

How

A Multiple Perspective Environment can be beneficial in any given context, e.g. in a working or educational environment.

A crucial requirement is that the members come to interact with each other sufficiently. Structural coupling results from the interaction between subjects and thus, a multiple perspective environment is effective when the participants are

engaged in group activities (cf. Peschl, Zimmermann & Roemmer-Nosseck 2010, p. 152).

Members of such an environment can differ in all sorts of aspects, such as working and research backgrounds (cf. Umpleby, Anbari & Mueller 2007), talents (cf. Lindberg, Noweski & Meinel 2010) or cultural roots (cf. Anbari et al. 2004).

5.3.2 Engaging In a Dialogue [G]

What & Why

Engaging In a Dialogue is a general tool that yields the potential for changing perception structures as it leads to a situation in which individuals exchange their world views (Bohm 1996, p. 2).

From a radical constructivist point of view, we do not simply *exchange* information when we communicate. Since any cognitive system is organizationally closed, communication means to recursively couple with each other's cognitive domains and to mutually present each other's descriptions of the world (cf. Mingers 1991, p. 325). Thus, successful communication means to work on one's own cognitive structures to understand another's cognitive reality (cf. Maturana & Varela 1980). By focusing one's perception on the other's cognitive world, we can facilitate our own cognitive restructuring and expand our own understanding.

How

To change the structure of one's perspective, it may be beneficial to engage in any kind of dialogue which forces one's understanding of reality to be confronted by another's to affect one's "description of the environment" (Mingers 1991, p. 325). Being open while listening to what another individual is saying and pursuing to understand how an individual perceives the world, may lead to a clash with one's own assumptions and constructions about the world.

Dialogue is not synonym to a trivial small talk; participants have to talk about a topic where opinions and understandings diverge and they must aim at understanding each other (Bohm 1996, p. 3; Peschl et al. 2014, p. 427). One basic precondition for successfully engaging in a dialogue is that the respective cognitive domains are at least "widely coincident" (Mingers 1991, p. 27), meaning that the

engaging individuals use more or less common descriptions of the world and talk about a topic which both can relate to.

5.3.3 Appreciative Inquiry [S]

What & Why

Appreciative Inquiry offers a special form of dialogue which focuses on the positive core of a situation, people or organization (cf. Cooperrider & Whitney 2005, p. 8).

While Appreciative Inquiry is a method that evolves over several steps, including the creation of a future scenario, in this context it should be noted that the technique offers two elements that foster engagement in a deep and encouraging dialogue; discovery as close listening to what another member is saying, and the creation of destiny, with the aim "to build hope and sustain momentum for on-going positive change and high performance" (Cooperrider & Whitney 2005, p. 16). Thus, Appreciative Inquiry provides a tool that encourages honest appreciation what the other person is thinking and saying; another's world view is not only acknowledged but the dialog partner aims at understanding and integrating it into their own thinking.

Appreciative Inquiry constitutes a special form of dialogue (cf. section 5.3.2). Individuals are encouraged to discover each other's "strengths and best practices" (Cooperrider & Whitney 2005, p. 16). Thereby, the technique is useful for immersing oneself into another's understanding of the world to change perception structures.

From a radical constructivist viewpoint, the consensual domain resulting from Appreciative Inquiry is based on positive properties and features. Consequently, whoever is coupled to this environment is more prone to enter interactions, which in turn correspond to the shared positive experiential reality. In other words, engaging in Appreciative Inquiry may lead to a positively affected continuance of epistemic semi-determinism, since the constructed perception and knowledge structures rest on a positive core.

How

Appreciative Inquiry provides a dialogue technique that calls for focusing on only those things that are positive. It is crucial that all participating members take an appreciating stance towards whatever emerges; i.e. they are open and non-judging. Depending on the context of the application, the process may be short-term or long-term. It is imperative that members fully immerse themselves into this process and appreciate and elaborate on a positive core (cf. Cooperrider & Whitney 2005, p. 30).

5.3.4 Interviewing for Empathy [S]

What & Why

Interview for Empathy is a technique to get a thorough understanding of another's subjective understanding of the world. It has been developed by the Institute of Design at Stanford, to gain genuine insights into a target group. Since it provides a strong insight into "a person's thoughts, emotions, and motivations" (D.School 2015, p. 10), it is suitable for the research at hand and contributes to change one's perception structures.

This technique offers a process to create a deep understanding of another's experiential reality. *Interview for Empathy* offers concrete instructions on how to immerse into another's experiential reality and to change one's perception structures.

In the pursuit of studying the mind, the approach of creating empathy with other subjects has a strong tradition in the cognitive sciences. It is argued that in order to fully understand consciousness, scientists must link third-person data (e.g. data gathered from behavioural experiments) with first-person data (i.e. experiential data of the subject). (cf. Markic 2012; Van Gulick 2014). In this vein, it is sought to "comprehend another individual's experience [...] to experience the other directly as a person" (Thompson 2005, p. 263-264). However, there is a lack of agreement on how this first-person approach should be implemented (cf. Overgaard, Gallagher & Ramsoy 2008).

How

The goal of Interview for Empathy is to create a deep understanding of another's understanding of the world. According to the Design School of Stanford, this is provided when specific points are being considered (cf. D.School 2015, p. 10). For the research at hand, the following points seem particularly interesting when conducting an Interview for Empathy.

- *Ask Why.* Even when thinking that an answer may be obvious, one should still ask why another acts or thinks in a specific way; we cannot read the minds of others and their answers may surprise us.
- *Pay attention to nonverbal cues.* Body language and emotions are part of another's experiential reality too. They, together with spoken content, indicate how a person thinks or feels about the world.
- *Don't be afraid of silence.* Allowing sequences of silence may provide the interviewee with time and space to reflect on what they have said; this may reveal even deeper assumptions.
- *Don't suggest answers to your questions.* Even when the interviewee pauses, give them time to formulate their *own* answer.
- *Ask neutrally.* Answers should not be formulated in a way that already suggests a specific answer.
- *Ask open questions.* Binary questions in the form of yes/no cannot grant an insight into how another understands the world; they merely mirror whether they agree or disagree with the interviewer's view of the world.

5.3.5 Story Share-and-Capture [S]

What & Why

Developed by the D.School of Stanford, *Story Share-and-Capture* is a method that makes subjects present to each other how they came to experience or perceive an environment or specific situation; if participants are present for the same field observation, "comparing how each experienced it, is valuable" (D.School 2015, p. 13).

From a radical constructivist viewpoint, the technique allows for making use of the fact that everyone has their own perception structures and thus, experiences the world in a different manner. When presenting each other interesting or striking

points that have been noted whilst being in the same environment, one may realise what else is out there. Accordingly, one's perception structures are changed after a phenomenon has been observed; by getting to know what others perceive, one may start to guide attention towards aspects of the world that have not been considered before.

How

After subjects return upon observing a specific situation or environment, they are asked to report what they have experienced and perceived. They should write down bits of information on Post-Its (e.g. headlines, quotes, surprises, impressions).

Then, the information is collected and saturated on a wall or on the floor. Now, each member is being confronted with a variety of environmental aspects that have been perceived and experienced. Furthermore, the information can be grouped to form a holistic image of the problem or environment.

5.3.6 Observing Others [G]

What & Why

Observing Others makes use of the fact that everyone has their own specific ways to interact with the world in any given field (cf. section 2.3.1). In this context, observing as a form of learning (cf. Mbatia 2013, p. 170; Schmidt 2010, p. 123) refers to guiding attention towards how others behave in a given context and approach a specific problem, to extend one's own understanding of the world and provide new, viable ways of interactions.

Guiding perception to how others interact with the world may provide new possibilities for one's own constructions. By observing how others interact with the world we may draw analogies and integrate them into our interactions. A theoretical foundation comes from *case-based reasoning*; when we seek to deal with problems, we automatically check if our memory provides similar cases along with solutions (cf. Jonassen 1999, p. 223). Accordingly, we can simulate case-based reasoning when we integrate someone else's behaviour into our own; this may result in innovative ways of interacting with the world. Jonassen (ibid) points out that case-based reasoning is facilitated with a narrative approach; by creating

analogies and expressing how others solve a problem, we may come to find new viable constructions for our interaction with the world.

How

This technique constitutes a general possibility for changing perception structures. Guiding perception to how others behave in different contexts may provide us with new viable ways to interact with the world. It is crucial that we can draw analogies even in contexts and environments that do not relate to ours; by guiding attention to how someone interacts differently with the world to reach a specific goal, we may be able to find analogies to how these interactions may contribute to our existing understanding of the world.

5.3.7 Group Brainwriting [S]

What & Why

Group Brainwriting is a technique to confront different experiential realities. People write down what they think and exchange these bits of knowledge so that other people can further elaborate on what has been written down (cf. Hogan 2003, p. 272; Van Gundy 1984, p. 67). The idea of collaborative writing has been formulated in different contexts and has come with different instructions (cf. Van Gundy 1984); for example, the 6-3-5 brainwriting is a sophisticated technique that requires a distinct setting and follows a well-defined procedure (cf. e.g. Schenk & Schwabe 2001, p. 7). However, in the context of this thesis, brainwriting will be described as a general application that may change perception structures.

By writing down how a subject understands a specific problem or aspect of the world and by passing these descriptions along, the next participant has to elaborate on the understanding of another participant and thus, perspectives collide and one can extend their knowledge structures by integrating another's. Over the course of this process, reflection occurs in a twofold manner; first, by elaborating on another's understanding of the world and second, by reflecting on what others have made out of one's own thinking, i.e. how one's initial knowledge has been transformed.

How

Group Brainwriting is suitable for contexts where people work together and therefore, it may be viewed as an extension to the multiple perspective environment (cf. section 5.3.1). The procedure is that participants are asked to elaborate on a problem or task and to write down what they think or know. In the next step, the sheets are passed along and the participants are asked to elaborate on what has been formulated before. This can be carried out until either a pre-defined goal has been reached or each sheet has made a distinct number of rounds.

5.3.8 Learning a Language [G] [S]

What & Why

Language enables us to organize and understand the world in a specific way. It determines what we can think, since we "can only think about whatever we can talk about" (cf. Wittgenstein, recited in: Schmidt 1987, p. 31). Empirical evidence comes from research on bilinguals, i.e. subjects who are native in two languages; how they categorize the environment differs with the language they are using (cf. Athanasopoulos 2015; Bylund & Jarvis 2011).

From a radical constructivist point of view, language is not denotative but connotative, i.e. it does not yield absolute or neutral meaning but instead represents an agreement between organisms, to enable mutual interaction (cf. *structural coupling* in section 2.2.3; Schmidt 1987, p. 32). In other words, language is constructed to ascribe meaning to the outside world and it represents how the experiential reality is organized. Language serves to describe the world in a specific way and thus, it is essential for the maintenance of the outside world. (cf. Schmidt 1987, p. 33). Accordingly, *learning a new language* may guide the perception to new and unfamiliar aspects of the environment and thus, lead to confronting oneself with new conceptions and meanings of the world.

How

This method can be applied either in a strict or loose way.

Strictly speaking, learning a new language may offer to see the world through another culture's eye and thereby, it guides our attention to aspects of the world that are essential for the organization of the outside world in a specific part of the

world. Clearly, this takes a lot of time and may not be appropriate in any given context.

In a loose sense, learning a language refers to learning to describe the world from another's point of view. For example, any profession uses distinct words to condense relevant concepts or ideas. Therefore, by focusing on the language that is used, by perceiving what aspects of the world are made explicit, one may come to construct new perception structures.

5.3.9 Comparing Language [G] [S]

What & Why

Language represents mutual agreement between organisms to describe the world in a specific way. Comparing language, i.e. comparing one's own with another's connotations may allow for becoming aware of new and unfamiliar aspects of the outside world.

Radical constructivism postulates that the world does not yield any objective meaning and therefore, language is not just given, it emerges through structural coupling between two organisms and it serves to describe the outside world (cf. section 2.2.3). Accordingly, Maturana (1987) highlights that language evolves from descriptions of internal states. Since every subject has developed in an individual way, a specific word may have a different meaning for each subject.

Words do not yield any normative definition of what it means but everyone has to actively make sense of a word by ascribing meaning to it. Therefore, by comparing the different connotations one may be able to change their perception structures.

How

The tool aims to question and compare what others mean by what they are saying. Comparing language may be applicable to any context or situation where language is used. It can be effective in a situation where a problem between two or more individuals must be resolved and furthermore, when a mutual agreement must be reached.

6 Changing Knowledge Structures

6.1 Making Knowledge Explicit

The following tools aim to make knowledge structures explicit, i.e. to assess how a subject constructs her experiential reality (cf. section 2.3.1). From a radical constructivist point of view, knowledge follows a hierarchical organization and its progression follows an entrenched course (cf. Riegler 1998, 2012). Making underlying assumptions explicit helps to question their viability as well as to re-organize them.

6.1.1 5 Why's [S]

What & Why

5 *Why's* refers to a technique to re-track the assumptions and constructions that have led to a current situation or issue. The underlying assumption is that by asking 5 *Why's* in an iterative fashion the core or root of a problem is made accessible; by using this technique, "it becomes inevitable to ask the essential reason behind your thought or action" (Nonaka & Toyama 2005, p. 426; cf. Chiarini 2013, p. 77).

From a radical constructivist perspective, the 5-*Why's* technique touches two interesting aspects.

First, it allows going back to previous assumptions with regards to a *temporal* dimension; i.e. by asking backwards, one can review preceding assumptions in a chronological manner.

Second, the 5-*Why's* allow assessing assumptions with regards to an *abstract* dimension; underlying constructions in the form of deep beliefs and assumptions can be reconsidered. The hierarchical organization is hereby revealed in terms of what has been decisive to come to a specific construction. In this vein, *laddering* is a process similar to the 5-*Why's*, which is used in constructivist psychotherapy; by starting with a personal problem of the client and questioning it in a backward-iterative fashion. It aims at eliciting "hierarchical features of the individual's personal construct system" and assessing pivotal reasons for the problem (Neimeyer 2009, p. 35).

How

The 5-Why's is a process in which a problem is questioned in an iterative manner; by asking why a problem exists, and by questioning the respective answer another four times in a row, it is thought that one can assess what has led to a problem or issue.

The technique can be used in all contexts and domains. It is a method that delivers quick solutions and does not require any specific setting. Therefore, it can be generally used or for a specific problem. It is suitable for a group as well as a single setting. (cf. Chiarini 2013. p. 77).

6.1.2 Thinking Aloud [G] [S]

What & Why

Thinking Aloud refers to a method of self-ascertaining internal knowledge structures (cf. Scheele & Groeben 1988, p. 32) by providing a "window into the mental activity which is not directly observable" (Seguinot 1996, p. 75). By verbally reporting how and what subjects think while performing a task may make the underlying thought patterns, assumptions and beliefs explicit; an fMRI-study has confirmed that thinking aloud might mirror the common silent thinking process; the neural activity while thinking aloud corresponds to the activity while thinking silently (cf. Durning et al. 2013).

As discussed in section 2.3.1, we organize the world in accordance with our knowledge structures. These structures may not be obvious or accessible all the time; instead they become embedded and silent. While performing a task we may be directed by assumptions we are not fully aware of, or which we do not question those we are aware of. Thinking aloud offers the possibility to make knowledge structures explicit, assess their viability and seek contradictions or gaps (cf. Scheele & Groeben 1988, p. 48).

How

Thinking Aloud is a technique in which a subject verbally expresses their thinking and thus, their knowledge about the world (cf. Scheele & Groeben 1988, p. 32; Boren & Ramey 2000). The technique is applicable in general and specific contexts where subjects work on a task or problem and can express their internal

operations. Thinking aloud can be used either during a task or retrospectively (cf. Durning et al. 2013; Scheele & Groeben 1988, p. 32).

6.1.3 Saturate and Group [S]

What & Why

Saturate and Group is a technique developed by the Design School of Stanford, to make knowledge explicit and re-organize it (cf. D.School Stanford 2015). By making knowledge involved in a problem explicit, one can look for general patterns or underlying assumptions.

From a radical constructivist perspective, the technique is suitable for revealing deep and underlying constructions we have about the world. Since all knowledge rests on previous knowledge constructions in a hierarchical organization, we may come to change knowledge structures by making these previous structures explicit and by re-organizing them. We may come to detach from our previous understanding of the world and perceive it in a different manner.

How

The technique requires a specific problem or aspect of the world, which is of interest.

It consists of two general steps.

The first step consists of *downloading* one's knowledge; whatever comes to mind is written down on sheets of paper. By doing so, various aspects are made explicit. All sheets of paper are then put on a wall.

The second step is *saturation*; the bits of information are clustered according to similarities or possible relations. This step can take up to several days; there is no right or wrong way to cluster all the aspects but the goal is to find all sorts of possible saturations. Over the course of the process, general patterns should emerge and underlying constructions may become obvious.

6.1.4 Semi-Standardized Interview [S]

What & Why

A *Semi-Standardized Interview* is a technique that allows for the explication as well as the precision of underlying and implicit knowledge structures (Christmann, Groeben & Schreier 1999, p. 142).

The idea is to specify a subject's understanding of the world by asking the subject a specific set of questions.

The technique is particularly interesting due to the fact that the knowledge structures are made explicit over the exchange with another person; the interviewer initiates and propagates the process and thus, they are involved in the construction process. By formulating hypothesis regarding subject's conception of the outside world (cf. Christmann, Groeben & Schreier 1999, p. 138) and asking corresponding and contradicting questions, the interviewer participates in and exerts influence on the respective outcome; any reconstruction of knowledge structures "necessarily constitutes a construction, i.e. a modification" (Scheele & Groeben 1988, p. 69). Therefore, from a radical constructivist point of view, the knowledge structures of a subject are made explicit and, at the same time, they are being changed.

How

The technique allows for assessing how a subject thinks about the outside world, i.e. the content of subjective knowledge (Christmann, Groeben & Schreier 1999, p. 141). It is suitable for any application and in any context where it is possible to initiate an interview with a subject on a specific problem. Over the course of the interview, the interviewer employs three classes of questions.

Hypothesis-unspecific questions are open questions to mark off the subject's general beliefs about an aspect of the world (e.g. "What do you think about.... ", "What could be the reason for...", cf. Scheele & Groebe 1988, p. 35). The subject's answers serve to bring her experiential reality to light. At the same time, the interviewer can generate possible hypotheses about her *subjective theory* (i.e. how she understand the world) (cf. *ibid*).

Hypothesis-directed questions confront the subject with possible theories about how their subjective theory looks like and why this might be the case (e.g. "Could it

be that...?", Would you agree that...?", cf. Scheele & Groeben 1988, p. 39). These questions serve to make the subject's knowledge structures more explicit and provide possible ways of organizing these knowledge structures.

Perturbing questions yield contradictions to the subject's knowledge. They constitute alternative hypothesis and by making the subject to compare them with their own subjective theory, they must either modify or precise their view. This leads to a higher degree of explicitness as well as coherence of the knowledge structures. (Scheele & Groeben 1988, p. 38).

Over the course of the interview these questions are alternated, according to how the interviewer progresses. The goal is to provide a thorough understanding of the subject's understanding of the world.

6.1.5 Structure-Formation Method [S]

What & Why

The *Structure Formation Method* (german, "*Strukturlegetechnik*"), as suggested by Scheele and Groeben (1988) serves to make subjective assumptions and beliefs explicit (cf. p. 7). It is a graphical method which applies structure to one's domain specific knowledge (Buch 2012, p. 79). Furthermore, by revealing assumptions and beliefs in a coherent manner, the structure-formation technique supports the elimination of internal contradictions and indicates non-optimal constructions. (Scheele & Groeben p. 72).

The tool enables us to reconstruct internal knowledge structures and reveal one's underlying assumptions and thought patterns about the world (cf. Scheele & Groeben 1988, p. 69). From a radical constructivist point of view, this technique is suitable for identifying deep constructions which form the basis for current behaviour; it is aimed to identify deep and underlying assumptions of the individual cognitive system (p. 70). Accordingly, this technique constitutes a particularly thorough method to break up knowledge structures.

How

After a specific problem or aspect of the world has been selected for investigation, the process consists of two steps (cf. Christmann, Groeben & Schreier 1999, p. 141).

First, the contents of knowledge are made explicit and organized in a way that all relevant information is revealed and connected in a coherent way so that it becomes obvious where assumptions come from and what other assumptions they trigger. This is done with a complex collection of symbols that express intentions, relationships and dependencies between elements, degrees of emphasis, and many more (for a complete listing, cf. Scheele & Groeben 1988, p. 53 - 62).

Second, the subject is confronted with the explicit knowledge structures and is asked to adjust and refine them so that they correspond to internal assumptions and beliefs; in doing so, contradictions and non-optimal constructions are made visible and may then lead to an extension, differentiation or simplification. (Scheele & Groeben 1988, p. 72)

The technique is a complex undertaking, which requires the subject's effort to work its way into the procedure. (Scheele & Groeben 1988, p. 77). It is effective when a researcher familiar with the technique guides the subject through the process. The second step in particular can be enhanced by the application of the semi-standardized interview (cf. section 6.1.4).

6.1.6 Concept Mapping [S]

What & Why

Concept Mapping is a graphical tool that facilitates the organization as well as representation of knowledge structures (cf. Kobo 2011, p. 104); it can be seen as a simpler form of the Structure Formation Method (cf. section 6.1.5). It depicts the associative and hierarchical relation between individual elements that form one's understanding of a specific aspect of the world.

This technique is appealing as the process of creating a concept map is generative and engages the subject in a process of making explicit as well as reflecting on one's internal knowledge structures (cf. Kolbo 2011, p. 106f.) Thereby, underlying patterns and assumptions may become obvious so that the technique "informs and shapes the internal structures" (p. 105). Moreover, this technique allows us to visually organise the elements of a concept according to their relevance.

Knowledge structures are changed since the underlying assumptions and constructions are made explicit and thus, they can be questioned and re-organized.

How

Kolbo (2011) suggests that the process should follow a sequence of steps after a specific aspect of the environment has been identified.

Identify relevant content. Relevant words and terms for a concept should be identified and noted on Post-Its.

Create order. The explicit terms and contents should be organized according to their meaning for the concept; the goal is to present hierarchical relationships amongst the elements.

Form a structure. Beginning with the most salient elements a structure should be drawn, which relates the content and forms relationships. Kolbo (2011) suggests using circles to depict the individual elements (cf. p. 108). Semantic connections between the individual nodes are formed with verbs, indicating how one element influences another.

Complete the map. By adding all content to the map, connections will emerge and patterns will become salient. According to Kolbo (2011), "this will likely take several tries", as the creator will understand which elements have more nodes and how deep connections may be (p. 108).

Create order. By creating order (e.g. using a graphical tool on the computer) and constructing a holistic representation of one's internal structures, one may come to find underlying patterns which then can be changed.

6.2 Affecting Future Structures

The following tools aim to change knowledge and perceptions structures *without* focusing on previous constructions. It is argued that we can confront epistemic semi-determinism by affecting the future progression of our knowledge constructions.

6.2.1 Interacting with an Envisioned Future [G] [S]

What & Why

Interacting With an Envisioned Future is a technique which enhances the formulation as well as the crystallization of ideal scenarios in the future (cf. Kaiser, Fordinal & Kragulj 2014; Kragulj 2014). The interaction with this future scenario may bring to the surface what steps are necessary in order to reach the goal.

The underlying idea is that we are restrained by doubts and concerns that are grounded in experiences from the past and from which we can detach, by envisioning an ideal future scenario without putting it to proof with regards to how possible it is (cf. Kragulj 2014, p. 440). From a radical constructivist perspective, this tool allows for constructing new knowledge which is less affected by previous knowledge; i.e. the tool sets free from the structure-deterministic process of knowledge construction (cf. *process of knowledge construction* in section 2.3.1). Perceptions structures are affected correspondingly; i.e. the perception structures will be in line with the knowledge about the steps to actually reach this scenario. Thus, interacting with the envisioned future enhances the construction of a *desired* deterministic arrangement of knowledge and perception.

How

This technique may be suitable when one wants to set free from the current situation or seeks to acquire a more visionary understanding of the world.

The technique requires a person who guides the subject into an ideal future scenario. It is important to provide individuals with an environment in which they feel safe and can let themselves go (cf. Kaiser, Fordinal & Kragulj 2014; cf. section 3.2.3).

After this future scenario has been created, the subject is asked to construct steps that are needed in order to reach this ideal future scenario. This process is referred

to as *backcasting* and serves to construct interactions the subject can enter from the current perspective. For the research question at hand, this is particularly interesting as old knowledge structures are changed while new ones are created.

6.2.2 Reflecting on Future Consequences [G]

What & Why

As discussed in section 2.3.1, knowledge is constructed in a hierarchical manner, i.e. it is constructed with regards to existing knowledge (cf. Riegler 2001; 2012). Accordingly, any existing knowledge yields the potential to provide the ground for future knowledge structures. Building upon this idea, *Reflecting on Future Consequences* calls for reflecting on how current constructions could affect future ones (cf. Umpleby 2014). The tool creates awareness for the epistemic semi-deterministic path that our constructions will take and allows for confronting it *a-priori*, i.e. *before* they are being constructed. Taking into account which problems or issues could possibly arise from current knowledge constructions may lead to more holistic and viable structures.

How

Reflecting on Future Consequences is a technique that can be applied to all contexts. Like Mindfulness, it constitutes a general strategy that appears useful from a radical constructivist point of view; by reflecting on how our knowledge and perceptions structures may evolve we may remain more open to future developments and at the same time, we may detect future flaws or possible conflicts. By continuously reflecting on future consequences we may gain more control over the epistemic semi-deterministic progression our knowledge constructions will take.

While the specific application depends on the problem or context, it is advised to reflect on the matter at hand by asking various questions that refer to the future progression of knowledge. Such questions could be "What will be the next assumption that follows from the current belief?", "What knowledge could be contradictory to my current beliefs?", "What knowledge will be precluded in future, if I accept this belief?"

6.2.3 Creating Chaos [G] [S]

What & Why

Creating Chaos can be seen as a mild form of the tool *Interacting with an Envisioned Future* (cf. section 6.2.1). The tool aims to formulate a variety of ideas, which seem unrealistic and incompatible. It is argued that by trying to consider how these ideas can be reached, existing knowledge structures are being questioned and broken up.

Our goals correspond to our knowledge structures; they represent possibilities with regards to our current situation. The creation of chaos is a way to challenge this and to break up knowledge structures by exerting an influence on the progress of epistemic semi-determinism. As discussed in section 3.2.1, viability is only a possibility (cf. Glasersfeld 1984)- creating chaos makes use of this fact and projects seemingly unrealistic goals into the future. However, these goals seem unrealistic *because* they are seen with existing construction. Nevertheless, by trying to construct steps or conditions which would make them realistic, we come to break up our knowledge structures.

How

The tool can either be applied in a general, day-to-day way or in specific contexts. Creating chaos is a tool used to change existing knowledge by formulating goals or states that do not correspond with existing knowledge structures. Generally speaking, chaos is created when one dares to dream and think unrealistically.

What-if questions enhance this process as they are the beginning for "what could or might be" (Gurteen 1998, p. 7; cf. Gartner 2007, p. 624). By initiating a thought process, these questions may serve as a starting point for escaping the boundaries of the current understanding of the world, e.g. *What if* this was different to what is now? *What if* this limitation does not hold? *What if* this stupid idea was real? (cf. Gurteen 1998, p. 7).

In a second step, in order to break up knowledge structures, it is crucial to analyse how these seemingly unrealistic goals or states can be reached. New knowledge is constructed by creating viable ways to reach the seemingly implausible settings goals.

6.3 Constructing Viability

Viable knowledge refers to *how-to knowledge* (Glaserfeld 1989), i.e. knowledge that makes us successfully interact with the world. Therefore, in order to change our knowledge structures we have to create new knowledge which is *viable*.

In the following, it is discussed how viable knowledge can be brought forth and/or how knowledge can be refined to become viable.

6.3.1 Prototyping [S]

What & Why

Prototyping is the process of creating new knowledge by bringing it to life (cf. Richards 2014, p. 438). The underlying idea is that new knowledge is enacted with creating artefacts (cf. Peschl et al. 2014, p. 428). Prototyping allows for applying different approaches and turns. Over the course of this process, subjects gain clarity and deep understanding of a matter and thereby, create new knowledge structures.

Viability refers to *how-to knowledge* (cf. Glaserfeld 1989), i.e. viability allows for successful interaction with the environment. Prototyping forms the potential to construct new viable knowledge. By making knowledge explicit and interacting with it, one creates a concrete realization of knowledge.

From a radical constructivist point of view, prototyping can be enhanced when two or more individuals work together on an artefact; this way, people structurally couple to each other in order to find a common viable creation.

How

Prototyping is a technique to elaborate on one, or a very few viable knowledge explications and thus, it is suitable where there is at least a very vague direction of possible or necessary paths for construction. Potential applications of prototyping are settings where individuals are not clear yet about a problem or task, or if they should bring forth new knowledge.

It can be useful for the creation of any kind of knowledge, such as theoretical concepts, social formats, touchable objects or physical models (Peschl et al. 2014). Depending on what the purpose of a concept or artefact is, there are specific forms of prototyping. Design research offers particularly thought-through applications.

For example, *Prototype for Empathy* is a technique to create a product with respect to how a user uses it (cf. D.School 2015, p. 33).

6.3.2 Articulating [G] [S]

What & Why

Articulating one's views and beliefs about a problem or a certain aspect of the world, is a simple form of creating and/or testing the viability of knowledge structures. This tool is inspired by radical constructivist views on education; accordingly, when articulating how they understand or see a matter, students can refine their conceptions (cf. Glasersfeld 1991b).

From a radical constructivist point of view, we construct knowledge to understand the world. Articulating and explaining how one sees a problem makes the speaker reflect about the underlying knowledge structures. Articulating is a simple form of prototyping as subjects may recognize the strengths and weaknesses of their understanding (cf. Bettencourt 1993, p. 44). The knowledge structures are changed over the course of making them explicit and refining them.

How

Articulating is a general tool that can be applied in various contexts. Arguably, it is best applied in a dialogue setting (cf. section 5.3.2) where one is confronted with questions and critical comments that challenge their understanding of the world. By considering these comments and articulating responses, there will be a more thorough reflecting on one's understanding of the world.

7 Conclusion

The thesis at hand departed from the argument that radical constructivism suggests an *epistemic semi-determinism*. Since knowledge is constructed to provide meaning to the world, we perceive the world only insofar as we have constructed it. Then, the research question addressed how this epistemic semi-determinism can be faced, i.e. how our knowledge and perceptions structures can be changed so that new knowledge about the world is constructed.

In order to answer this question, the thesis pursued two main endeavours.

First, the theoretical foundations of radical constructivism were reviewed so that distinct features and characteristics of the framework could be identified. Guiding questions were: what are the underlying assumptions about how we come to know? What does that mean for the conception of knowledge and perception? What are the building blocks of epistemic semi-determinism?

Second, strategies and methods were introduced to face epistemic semi-determinism. Based on the underlying theory, it has been found that knowledge as well as perception structures offer three possibilities of change.

Perception structures can be opened up for perturbations and unexpected sensory experience. They can be changed in the way that we seek to perceive aspects of the world in a different manner. They can be changed with respect to how other subjects perceive the world.

Knowledge structures can be made explicit; by subsequently assessing them, underlying patterns can be identified and re-organized. They can be changed by detaching from previous constructions. Moreover, viability can be constructed.

Based on these considerations, thirty tools have been synthesized. They were selected from various fields and areas, including design thinking and research, psychology and creativity research. They cover a broad range of possible applications and contexts and can either generally enhance the change of knowledge and perception structures or provide a reconstruction in specific problem contexts. As discussed in the introduction, they are generally applicable in the context of innovation.

To summarise, the research question of how knowledge and perception structures can be changed has been answered with different strategies and corresponding

tools, i.e. concrete applications that allow for confronting epistemic semi-determinism.

7.1 Discussion and Further Research

In this thesis, the arrangement of knowledge and perception is labelled as *epistemic semi-determinism*, which provided the focal point motivated the formulation of the research question. To the best of my knowledge, this thesis provides the first attempt to thoroughly define how knowledge and perception structures can be changed from a radical constructivist perspective. Therefore, the innovative aspect of this thesis lies in the identification of possible strategies and corresponding applications.

However, the innovative aspect of this endeavour comes at the cost of the specificity of the selected tools. The focus was laid on the rather general question what strategies and tools can be found in order to change knowledge and perception structures from a radical constructivist perspective. Accordingly, the coherence among the toolkit could be stronger and the selection of the tools could point towards more similar applications and outcomes. Some tools were described to be applicable in problem contexts and to focus on *specific aspects of the world*. It has not been clarified what such an aspect would be (as it would vary from application to application), and thereby the toolkit is held vague. Arguably, defining specific fields or contexts of application might lead to a more accurate selection of tools.

Future research could specify in what area or field these tools can be applied best as to meet well-defined demands. It has been shown that changing knowledge and perception structures constitutes a worthwhile endeavour; the individual tools indicate that there are a variety of possibilities to do so.

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Abstract - English

Inspired by the concepts of theory-ladenness and Thomas Kuhn's paradigm shift, this thesis addresses the question of how we can deliberately change the way we perceive the world to subsequently create new knowledge.

Radical constructivism serves as the theoretical foundation. It is a position in epistemology, claiming that the world itself does not yield objective meaning which is passively mapped to our minds but that we actively construct knowledge to bring forth an experiential reality; a meaningful world only exists inside our heads.

Thus, what we know about the world makes us perceive it, and what we perceive is fitted into existing models and conceptions. This relation is labelled as *epistemic semi-determinism*; the prefix *semi* implies that this determinism is not deterministic in a strict philosophical sense and that we are furthermore free to alter the conceptions we have about the world.

Building on the theoretical foundations of radical constructivism, it will be investigated how we can alter our internal conception of the world and confront epistemic semi-determinism. It will be argued that by changing knowledge and perception structures, we can create a new understanding of the world.

Subsequently, appropriate strategies will be derived to then develop a toolkit which provides tools that allow for changing knowledge and perception structures. Three strategies are developed for changing knowledge structures, and three strategies are developed that allow for changing perception structures. A total number of thirty tools are introduced that allow for confronting epistemic semi-determinism and thereby, facilitate the construction of new knowledge about the world. The tools are synthesized from various research fields, such as Design Thinking, creativity research, and from findings in psychology, neuroscience and organizational science.

The scope of the thesis is to identify general ways to create new knowledge about the world; the developed toolkit is applicable to different contexts and areas. Further research could focus on specific areas of application, in order to concretize how the tools can be used and effectiveness increased.

Abstract - German

Beispiele wie die Theoriebeladenheit oder Thomas Kuhns Paradigmenwechsel zeigen, dass wir einen Einfluss darauf haben, wie wir die Welt wahrnehmen. Die vorliegende Arbeit befasst sich mit der Frage, wie wir auf unser Verständnis der Welt einwirken und in weiterer Folge neues Wissen über die Welt schaffen können.

Als theoretische Grundlage dient der Radikale Konstruktivismus. Er ist eine Position in der epistemologischen Philosophie und behauptet, dass die Welt selbst keine objektive Bedeutung hat, die wir erfahren. Vielmehr konstruieren wir alles Wissen und erschaffen eine subjektive Erfahrungswirklichkeit; eine bedeutungsvolle Welt existiert nur in unseren Köpfen.

Folgt man dieser Vorstellung, ergibt sich eine deterministische Situation; was wir an Wissen konstruiert haben, nehmen wir in der Welt wahr und umgekehrt, die Art und Weise, wie wir die Welt wahrnehmen, steht in Einklang mit unseren Konstruktionen. Im Rahmen dieser Arbeit wird jene Beziehung als *epistemischer Semi-Determinismus* bezeichnet; das Präfix *semi* impliziert, dass sie sich von der herkömmlichen Schule des Determinismus unterscheidet und wir die Möglichkeit haben, unser Verständnis der Welt umzukonstruieren.

Aufbauend auf der Theorie des Radikalen Konstruktivismus wird untersucht, wie wir die Welt konstruieren und sie in weiter Folge verändern können. Es wird argumentiert, dass wir durch die Veränderung von Wissens- und Wahrnehmungsstrukturen dem epistemischen Semi-Determinismus entgegen treten und ein neues Verständnis der Welt schaffen können.

Aus den Erkenntnissen im theoretischen Teil der Arbeit werden entsprechende Strategien abgeleitet; drei Strategien werden zur Veränderung von Wissensstrukturen abgeleitet und drei Strategien zur Änderung von Wahrnehmungsstrukturen.

Basierend auf diesen Strategien wird ein Toolkit vorgestellt, das konkrete Möglichkeiten bietet, dem epistemischen Semi-Determinismus zu begegnen. Insgesamt werden dreißig Techniken und Methoden vorgestellt, die die Konstruktion von neuem Wissen über die Welt ermöglichen. Diese Techniken sind aus unterschiedlichen Bereichen zusammengetragen, wie etwa Design Thinking,

Kreativitätsforschung sowie allgemeinen Erkenntnissen in der Psychologie und Neurowissenschaften.

Innerhalb dieser Arbeit werden allgemeine Möglichkeiten vorgestellt, um ein neues Verständnis über die Welt aus radikal konstruktivistischer Sicht; das entwickelte Toolkit ist in verschiedenen Kontexten und Bereichen anwendbar. Weiterführende Forschung könnte sich auf bestimmte Anwendungsbereiche konzentrieren, um die Relevanz sowie die Wirksamkeit der einzelnen Techniken zu erhöhen.

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Focus on cognitive neuroscience;
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