

# The behavioral decision-making architecture

Markus Domeier\* & Pierre Sachse\*

\* Institute of Psychology, Leopold-Franzens-University Innsbruck

## ABSTRACT

Decision-makers in real life often have to deal with different situational influences while making a decision. They don't know the odds of the outcome of different options and thus make their decisions under uncertainty. Moreover, most real-life situations are fast changing and dynamic, and the decision-maker doesn't always know the exact cause of a given circumstance. This intransparency and interdependency of the decision's different elements can lead to a high complexity of the situation (Schroda, 2000) and thus to a difficult decision. Potential consequences are, besides errors, cognitive biases in the decision-making process, which can lead to erroneous decisions. But why do these systematic unconscious effects occur so frequently and what makes them so robust? This paper investigates the mechanisms and processes which lead to biased decisions. Therefore, a Behavioral Decision-Making Architecture model is presented. It takes a closer look onto the interaction between the characteristics of complex situations (Schroda, 2000), the computational architecture of psychological processes (PSI theory, Dörner & Güss, 2013), and the occurrence of cognitive biases (Carter, Kaufmann & Michel, 2007) as well as their behavioral consequences in the decision-making process. The model depicts these processes and provides an approach to explain the unconscious upside (positive influence on motivational needs) of cognitive biases.

## Keywords

Behavioral Decision-Making Architecture – PSI theory – Cognitive Biases – Erroneous Decisions – Real-life Decisions

## 1 Introduction

In everyday life, we come across a lot of decisions, many small ones and some bigger ones. Usually, one would assume that when you do something on a daily basis, you become better at it over time. Consequently, over the years, we should master the art of decision-making, which allows us to make good decisions, especially when they are important. A group of people who should be very experienced in decision-making are managers. A manager's job is, in fact, to take decisions on a frequent basis, so that this amount of practice should enable them to make good decisions without any problems. But reality looks different as the following example shows.

January 19, 2012 marked the temporary end of a 120-year success story. With the filing for insolvency (in accordance with Chapter 11 of the Bankruptcy Code), Eastman Kodak applied for creditor protection. Until the 1990s, Kodak was one of the five most valuable brands in the world. The company, which was founded in 1892 by George Eastman, had a fabulous rise behind

and quickly became an entrepreneurial success story. With the introduction of the „Kodak Brownie“ in 1900, every photographer could afford a camera for the price of \$ 1. The related sale of films secured the company a highly profitable business for a long time. Thus, for the following decades, Kodak was omnipresent in the US and European markets. In 1988, the photo empire had over 145,000 employees and only three years later their sales rose to nearly \$ 20 billion (The Economist, 2012).

However, in 2012, the former world market leader was no longer able to pay its suppliers, employees, and partners. What had happened? How could a company, that dominated the photo market with its numerous inventions for over a century, go bankrupt?

In the case of Kodak, a decisive point was the advent of digital photography, which took away a large part of the market share for analog photography. Ignoring this new technology was afterwards called Kodak's „cardinal error of the management board“ (Lehky, 2012, p.1). Ironically, Kodak engineer Steven Sasson invented the first digital camera in-house in the 1970s.

When Sasson presented his first functional prototype of a digital camera to the management, they replied: „That’s cute – but do not tell anyone about it“ (Deutsch, 2008, p.1) – as he later reported to the New York Times. Despite the fact that with a weight of 4 kg and a low resolution, the camera was still far away from mass production, its potential was already emerging. The managers of the Eastman Kodak Company, however, completely underestimated this new business field (dpa, 2012). For this reason, very little had been invested in the digital solution. With a price of \$ 20,000, Kodak’s first digital cameras were far too expensive for the consumer. Regarding this, a former Kodak manager told the *WirtschaftsWoche* (Eckl-Dorna, 2010, p.2), „This was further developed, but not further promoted“.

Although the company had been facing the digitalization back then, Kodak entered the digital market only in 2004. However, at this time, digital cameras had replaced traditional analog cameras to a large extent and digital cameras themselves were already being threatened by the increasing popularity of mobile phone cameras. In addition, the competitors among them Sony, Fuji, Canon, and Olympus already had a huge share in the market of digital photography. For Kodak, this competitive struggle ended with the filing of the bankruptcy petition (Gödecke, 2011).

Christensen (2015) has raised the question addressing the underlying reasons of such phenomena: Why do market leaders lose their market share in such a significant way? Have they simply been mismanaged for many years? Christensen himself contradicts this assumption: „an alternative explanation, however, is that these failed firms were as well-run as one could expect a firm managed by mortals to be – but that there is something about the way decisions are made in successful organizations that sows the seed of eventual failure“ (p. 6). Also, Campbell, Whitehead and Finkelstein (2009), according to the analysis of management decisions, state „the daunting reality is that enormously important decisions made by intelligent, responsible people with the best information and intentions are sometimes hopelessly flawed“ (p.2).

How is it possible that experienced and well-trained managers and motivated founders make decisions for which the outcome is sometimes far away from the actual needs? The decline of the Eastman Kodak Company is certainly an extreme case, but it serves as a good example for the impact of wrong decisions. Inevitably, companies all over the world repeatedly make decisions that lead to suboptimal results. The problem is that unforeseeable factors come into play, which influence the results afterwards and couldn’t have been prevented (Edwards, 1984). However, in the analysis of wrong decisions there are also cases in which people could have decided in another, perhaps

better way. These cases have striking patterns which show up again and again.

Based on the example of the Eastman Kodak Company, the question arises how such decisions can be explained. Let us assume that the managers were well educated, intelligent and wanted the best for the company, how can such decisions happen? Why did they only react when it was already far too late? An explanation along the lines that the managers acted in an irrational way, is too simple and not satisfying. The question is: what are the underlying psychological mechanisms behind this seemingly irrational behavior?

## 2 Theoretical Background

The reason for such devastating decisions is often based on automatic cognitive processes of the individual decision-maker (Dörner & Güss, 2013; Carter, Kaufmann & Michel, 2007). These unconscious systematically recurring processes are called cognitive biases. This explains why, as Campbell, Whitehead and Finkelstein (2009) notice, experience, intelligence, and good intentions may not necessarily avoid such biases and the associated sub-optimal decisions. Fiske and Taylor (2015) provide a key reason for the occurrence of these biases. They claim that people are cognitive misers. Many decisions, especially in everyday life, happen intuitively (Kahneman, 2003) or through heuristics (Gigerenzer & Gaissmaier, 2011). These time- and effort-reducing decision-making strategies are mostly easy and quick solutions, but can lead to fatal errors if, for example, the surrounding situation has changed. We want to take a closer look at this – as Dörner (2005) calls it – logic behind failures. Therefore, in the following, the important aspects of decision-making in real-life are highlighted.

### 2.1 *Erroneous Decisions*

There is a broad interest in the research question why decisions fail. Nutt (2002) states: „Debacles highlight blunders. They offer insights into how a decision can go wrong, why it went wrong, and what changes in decision-making practices could improve the chance of success“ (p.8). Thus, failed decisions offer the possibility to deduce the mechanisms of decision-making.

Not every failed decision has the same impact. Therefore, Spychiger’s (2008) classification of errors can be applied to the results of failed decisions. On two dimensions, consequence and reversibility, the decisions can be described. The four kinds of errors are clustered as big and bad errors (high consequences and low reversibility), smaller errors, annoyances (low consequences and low reversibility), smaller errors,

bagatelles (low consequences and high reversibility), and noticeable but not tragic errors (high consequences and high reversibility).

When can we say that a decision has failed? Yates, Veinott and Patalano (2003) defined 5 criteria for good decision-making. Due to their theory, an erroneous decision doesn't fulfill one or more of these criteria. The 5 different factors are the aim criterion (the decision is congruent with the former objective of the decision), the need criterion (the decision fulfills the needs of the decision-maker), the aggregated outcomes criterion (the chosen option is the best one in the set of all possible options) and the process cost criterion (the decision needed in a minimal amount of resources).

Real-life decisions are affected by chance or environmental influences and mostly made under uncertainty. So when looking at erroneous decisions, a precondition is, that the circumstances, which lead to the error, could have been influenced, avoided, or predicted by the decision-maker (Zapf, Frese & Brodbeck, 1999). Having enough degrees of freedom to make the decision in another or even better way is another important precondition to classify a decision as erroneous.

Moreover, the needed information must have been potentially available for the decision-maker. Hacker and Sachse (2014) classify erroneous actions due to lack of information, which may be caused by objectively missing information or deficiencies in the usage of available information. An example for deficiencies may be the failure to use available information (overlooking, forgetting, skipping, subjective information reduction and mental capacity limits) or the incorrect usage (at the point of orientation, the design of programs, the fit in actions and the decision-making).

But only looking at the results can be distorting. Good decisions may have a bad outcome and bad decisions may turn out to have good results. Focusing on the outcome doesn't seem to be a mutually exclusive way to separate good from bad decision-making (Brown, Kahr & Peterson, 1974; Edwards, 1984). As the outcome doesn't perfectly indicate whether a decision is good or bad, the focus lies on the decision process when it comes to assessing decisions. A good decision process increases the chance of getting good results. Error or biases in the process may result in suboptimal output.

## 2.2 Decision Process

Decision-making can be seen as a process with sequential steps. There are different approaches about how the exact sequence is shaped and which parts are included. Most of the decision process models show the three main phases „Situational Awareness“, „Situation Analysis“ and „Action“ as described in Jost

(2001). At first a decision-maker has to be aware that there is a problem and that a decision has to be made. Second, the situation is analyzed with the aim to gain further information. In the third phase, a decision is taken on the basis of the found and weighted information and the result is implemented. Several decision process models follow roughly this structure (e.g., Bazerman & Moore, 2013). The ProACT (acronym for the core-steps) approach of Hammond, Keeney and Raiffa (1998) has eight elements. The core-steps, suggested by the authors, encompass: problem, objectives, alternatives, consequences, and tradeoffs. Additionally, the last three steps address the role of uncertainty, risk tolerance, and the consideration of linked decisions.

Dörner (2012) describes five steps of a decision-making process (finding objectives, situation analysis, forecast, planning and deciding, action, and self-reflection). Especially forecast is an interesting addition to the aforementioned sequence. It means the anticipation of upcoming events or developments which might be important for the selection of the right alternative. In their seven steps decision process model, Grünig and Kühn (2013) also include the step „Determining environmental scenarios“, which has the same purpose.

## 2.3 Cognitive Biases

As introductory mentioned, the reasons for failed decisions might be errors or biases. The difference is that an error occurs randomly, but a bias in a systematic way and therefore can be prevented. There is a huge amount of literature about cognitive biases (e.g., Kahneman, 2011; Ariely, 2008; Ariely & Jones 2010). Depending on which collection is referred to, there are over 100 types of this „systematic departure from the normative standard of judgment“ (Kerr, MacCoun & Kramer, 1996, p.688). Many researchers tried to find logic categories to deal with the different biases. A clear taxonomy divides the biases into categories which put the similar ones together and is mutual exclusive and exhaustive. These groups should differ from the others and should show a higher consistency. The struggle is that there is a lack of agreement on the definitions of biases and their groupings. Most of the taxonomies in the literature sorted the biases along a literature review. The categories represent the origin of their biases or the aspects they have in common. To name a few, with this method, Bhandari and Hassanein (2012) found three categories (Cognitive biases, Affective biases and Conative biases), Stanovich, Toplak, and West (2008) presented four categories (cognitive miserliness, override failure, mindware gap and contaminated mindware), Arnott (1998) developed six categories (Memory biases, Statistical biases, Confidence biases, Adjustment biases, Presentation biases, and Situation biases) as did McFadden (1999; context,

reference point, availability, superstition, process and projection).

Carter, Kaufmann and Michel (2007) identified 76 biases in their literature review. They created a qualitative cluster analysis and grouped the biases with the Q-sort methodology. Finally, the authors assigned the 76 biases into nine categories (Availability cognition biases, Base rate biases, Commitment biases, Confirmatory biases, Control illusion biases, Output evaluation biases, Persistence biases, Presentation biases, and Reference point biases). The following table 1 is based on their meta-analysis.

#### 2.4 Situation Characteristics

What characterizes real life decisions? In which situation do we have problems or struggle with making

a decision? Dörner (2003) describes four different aspects which characterize a complex situation: complexity, connectedness, intransparency, and dynamics. Moreover, people often lack of knowledge on how to cope with the situation. In this tradition, Schroda (2000) analyzed construction tasks for engineers and identified six aspects which describe the complexity of a task, namely conflicting goals, complexity, transparency, freedom degrees, dynamics, and required knowledge. Depending on these aspects, a problem can be described as more or less complex.

Higher levels in several aspects leads to a higher complexity of the task. Conflicting goals means that a task has several goals, that can be contradicting. Complexity describes if a problem has dependent sub functions and their number and strength of connection among themselves. The objective availability of infor-

Table 1: Description of Cognitive Bias Categories after Carter, Kaufmann and Michel (2007).

Category of Cognitive Bias	Description	Associated Biases
Availability cognition bias	Information is judged as more probable due to their cognitive availability.	Availability; Country of origin; Cultural Familiarity; Home; Imaginability; Recall
Base rate bias	The decision-maker ignores the base rates and gives less relevant data more weigh.	Base rate; Recency effect; Subset
Commitment bias	Due to a commitment in the past (time, money, effort, resources etc.), the decision-maker sticks with the option he invested in, even when it is not the best possible option.	Aversion to regret; Concorde fallacy; Endowment; Escalating commitment; Escalation; Loss aversion; Sunk costs fallacy
Confirmatory bias	To confirm ones own hypotheses or opinion about specific facts, only the information are searched which get along with the prior opinion, others are ignored. Moreover, other information is interpreted in the same manner.	Aversion to ambiguity; Bandwagon effect; Belief; Confirmation; Confirmation evidence; Confirmatory; Desire; Fact-value confusion; Halo effect; Prior hypothesis bias; Selectivity; Self-fulfilling prophecy; Wishful thinking
Control illusion bias	Random events are weighted in favor of the accuracy or certainty of the own judgment. Unrealistic assumptions may be the consequence.	Attenuation; Chance; Completeness; Complexity; Conjunction; Control; Correlation; Disjunction; False consensus; Gambler's fallacy; Hot hand fallacy; Impact; Law of small Numbers; Magical thinking; Overconfidence; Planning fallacy; Sample; Similarity; Test
Output evaluation bias	The extend to which past events could have been predicted is overestimated or reasons are misattributed in retrospective.	Egocentric; Hindsight; Rosy retrospection; Self serving; Success; Testimony
Persistence bias	An option is chosen with a higher probability when it has been chosen before.	Habit; Persistence; Status quo
Presentation bias	The presentation of the stimulus material influences the perception of subsequent information in a systematic way.	Contrast; Framing; Frequency/redundancy Issue valence; Mere exposure effect; Mode; Order; Primacy effect; Scale; Search; Series position effect; Von Restorff Effect
Reference point bias	Judgment and evaluations are influenced by initial positions and thus are not adjusted in a sufficient way.	Anchoring and adjustment; Conservatism; First impression; Non-linear extrapolation; Reference; Regression

mation leads to transparency and vice versa to intransparency if the information is not available or accountable. Degrees of freedom are defined as the amount of different attempts of solutions available to the decision-maker. A dynamic problem is subject to temporal changes of a decision's future impact. However, this impact is predictable only to a limited extent. The required knowledge is divided into knowledge about the conditions and methods of processing a problem (Schroda, 2000).

Most of these aspects can also be found in the features of Naturalistic Decision Making (Klein, 2008). Von der Weth (2001) takes individual differences into account. He proposes a description of complexity on three levels. On the job level, objective sources of complexity are analyzed. The requirement level defines complexity in relation to performance prerequisites. In the experience level, the individual representation of complexity is considered.

### 2.5 PSI Theory

How is the human mind working when solving problems in real-life situations? How does it process information and make decisions? With the PSI theory (named after the 23<sup>rd</sup> letter in the greek alphabet which is associated with psychology), Dörner presents an architecture of the human mind which attempts to explain human behavior with the interaction of cognition, motivation, and emotion (Dörner & Güss, 2013; Dörner, 1999). He compares the model with other cognitive architectures like SOAR (States, Operators and Results; Newell, 1987) and ACT-R (Adaptive Control of Thought – Rational; Anderson, 1990). The PSI theory differs from the before mentioned models as it attempts to integrate cognitive, motivational, and emotional processes as well as their interaction into one architecture. For a detailed explanation of the model, see Dörner and Güss (2015).

Cognition in PSI is described with quads. Quads are defined as one central neuron that is surrounded by and connected to four other neurons. These four neurons are pointing forward, backward, downward, and upward, respectively. When a need triggers a goal that could fulfill the need, a search process is initiated. The upward neuron looks for contexts that may contain a certain goal (e.g., searching for a restaurant when craving a burger). When the context is found, the backward neuron is activated, looking for successful behavior tendencies from the past to reach the goal. If such a behavior tendency is stored in memory, it can be executed, if not, a new behavior sequence has to be created. This is what Dörner and Güss (2015) describe as planning. „One adjusts to the demand of the situation before the situation actually has happened“

(p.306). A more detailed explanation of the quad structure is described in Dörner et al. (2002).

PSI refers to different needs. They can be divided in three categories. Besides physiological needs (need for food, sleep, and sexuality), there are informational needs (need for competence and certainty) and a social need (need for affiliation). Dörner and Güss (2013) postulate that every human motivation can be explained through the aforementioned five needs. In comparison with the findings of Reiss (2004), who identified 16 human motives from a survey with more than 20,000 participants, Dörner and Güss (2013) conclude that these 16 motives can be summarized within their model of five basic needs, namely “existential needs (eating, physical activity, tranquility), sexuality (romance), affiliation (acceptance, honor, social contact, family), certainty (order, savings, curiosity, idealism), and competence (power, status, independence, vengeance)“ (p.302).

In PSI, these needs are symbolized as tanks. These tanks have an in- and an outflow. Related positive signals lead to an inflow and thus to a higher level in the specific tank, related negative information in turn can lead to an outflow. Moreover, there is consumption over time – a positive inflow does not have an everlasting effect – so that there is always a continuous drain. On the one hand, a high level in a tank leads to a pleasure signal. On the other hand, a low level or the anticipation of a further loss leads to a displeasure signal. Low levels in the tanks indicate that one or more needs should be fulfilled. According to the motive strength of every specific need, the one with the highest product is selected and becomes the dominant motive (for the detailed calculation see Dörner & Güss, 2015). When talking about needs, we focus on the informational and social needs, which are explained in more detail hereinafter.

The need for competence is described as the extent to which a person feels capable of solving problems in his or her environment (Dörner, 2012). A high level in the tank for competence means active control of the situation and the ability to cope with it (Dörner, Gerdes & Hagg, 2008). The need for competence can also be described as the need for power, control, or autonomy and is related to self-confidence and self-worth (Dörner & Güss, 2011).

The competence tank is filled by the fulfillment of other needs, when the person experiences success, especially in difficult situations, and in general through the perception of efficacy signals. The tank is emptied by failed attempts to fulfill needs and by failure signals in general.

The need for certainty is described as the need for passive control of the environment. That means knowing or being able to predict what is going to happen in

the future and the meaning for the own needs (Brügge-  
mann, Strohschneider & Rek, 2006). A confirmation of  
ones own knowledge of the future and the elimination  
of uncertainty is targeted. Also, the need for efficacy of  
one's actions is described here. The tank is filled when  
predicted events occur or when an action has expected  
consequences. It is emptied by events which are unex-  
pected or new or where the probability of occurrence  
is unknown (Dörner & Güss, 2013).

The need for affiliation is understood as a need for  
legitimacy signals, which means accordance with the  
norms of a social group. The need gets higher through  
the laps of time. The tank is filled with group conform  
behavior or the feeling of acceptance in the group and  
from positive signals as a consequence of supportive  
and/or helping behavior as in general by signals of leg-  
itimacy. The tank is emptied when people experience  
rejection, exclusion or a lack of recognition.

Emotion plays a special role within the PSI theory.  
It is not seen as a process besides motivation and cog-  
nition, but as a psychological macro. This means an  
overarching model of organization. Dörner and Güss  
(2013) sum up: „As we will see, motivations determine  
what must be done, emotions determine how it is to be  
done“ (p.307).

There is a need to explain behavior with emo-  
tions. Without them, no model can provide any good  
prediction. By looking for a satisfactory definition of  
emotions, Dörner and Güss take a closer look at the  
work of Ekman (1992, 1999) who proposed basic emo-  
tions, and the early work of Wundt (1896), who char-  
acterized emotions as states that are organized along  
three different dimensions (pleasure-displeasure,  
tension-relaxation, and excitement-inhibition/tran-  
quilization). Dörner and Güss (2013) conclude that the  
approach of simply dividing emotions into categories  
(Basic emotions) doesn't provide a sufficient explana-  
tion, as this approach does not clarify what emotions  
really are. In PSI, emotion is seen as a modulation  
of cognitive-motivational processes in combination  
with specific behavior tendencies. To explain human  
behavior, these three entities are inextricably linked.  
This view of emotion is similar to the one's of Scherer  
(2009), who defines emotion as “an emergent, dynam-  
ic process based on an individual's subjective apprais-  
al or significant events” (p.1307).

The PSI theory was validated by the prediction  
of human behavior, by the construction of artificial  
agents (Dörner, Gerdes & Hagg, 2008), by analyzing  
historical events (Dörner & Güss, 2013), and by experi-  
mental comparisons with human behavior (Dörner et  
al., 2002).

## 2.6 *Synthesis*

The decision cases, to which the following model is  
applied, are erroneous decisions. They are defined as  
decisions which hurt one or more criteria for a good  
decision from Yates, Veinott, and Patalano (2005), could  
have been influenced or prevented (Zapf, Frese &  
Brodbeck, 1999), and where the needed information  
had been potentially available to the decision-maker  
(Hacker & Sachse, 2014). Cases which have high con-  
sequences and aren't reversible are the most interest-  
ing ones (Spychiger, 2008).

We follow the decision process steps of Dörner  
(2012) in a slightly adapted way. To uncover the mech-  
anism behind decisions which went wrong, we take a  
closer look at the systematic occurrence of cognitive  
biases. Therefore, the taxonomy of Carter, Kaufmann  
and Michel (2007) provides a good basis. To detect the  
complexity of situations in real-life and its influence  
on the decision-making process, the characteristics of  
Schroda (2000) are used.

With their holistic approach, which integrates cog-  
nitive, motivational, and emotional aspects as well as  
their interaction in one theory, the PSI theory (Dörner,  
1999; Dörner & Güss, 2013) provides the fundamental  
computational mechanisms.

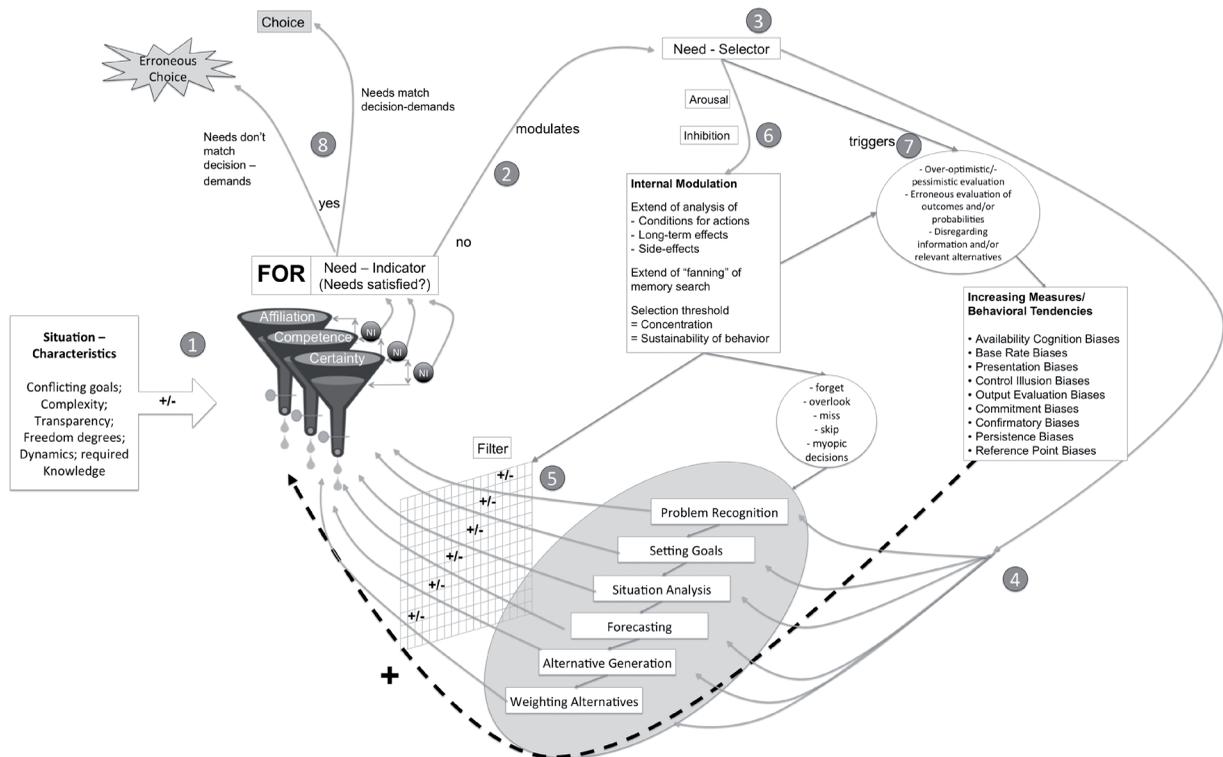
As there is no model, the authors are aware of,  
which covers all of the above-mentioned aspects and  
processes of erroneous real-life decisions, the Behav-  
ioral Decision-Making Architecture was designed. The  
goal is to provide a holistic model that describes and  
explains erroneous real-life decisions. The model inte-  
grates important aspects like the influence of the  
situation on cognitive, motivational, and emotional  
processes, depicts the dynamic of the decision process  
as well as the effects of the cognitive biases. In the fol-  
lowing, the Behavioral Decision-Making Architecture  
is described in more detail.

## 3 **The Behavioral Decision-Making Architecture**

The present model (Figure 1) attempts to combine the  
PSI theory and the research on cognitive biases in or-  
der to explain the occurrence of erroneous decisions  
with the interaction of situation, cognition, motivation,  
and emotion. The goal is to provide an architecture  
that explains real-life decisions with a negative out-  
come due to failures – conscious or unconscious – in  
the decision-making process.

These errors occur due to two reasons (Dörner,  
2005; Schaub, 1996). First, there are cognitive rea-  
sons. Humans have a bounded processing and a lim-  
ited memory capacity. This leads them to think eco-  
nomically. The consequence is that complex systems  
are simplified and steps in the decision process are

Figure 1: The Behavioral Decision-Making Architecture.



skipped. Second, there are motivational reasons. Depending on the kind of information flowing in, the motivational processes are influenced. The most important ones, such as the need for competence, the need for certainty, and the need for affiliation are building different motives. These motives can influence our cognition, and therefore our emotions. In the adapted PSI model (Dörner & Güss, 2013), emotions are seen as a modulation of cognitive-motivational processes equipped with specific behavior tendencies. The influence of needs on the cognition may increase the occurrence of cognitive biases (Carter, Kaufmann & Michel, 2007; Dörner, 2003) – confirmatory biases, control illusion biases, commitment biases etc. – in the decision-making process (Dörner, 2012) with the aim to cope with the uncertainty and complexity of the situation. As a consequence, instead of satisfying the decision’s demands, only the fulfillment of personal needs may be addressed by the decision. Biased cognition can be a personal short-term advantage (optimism, protection of competence, keeping up a positive self-perception etc.) – but in the long run, it might lead to suboptimal decisions.

3.1 Description of the Process

The Behavioral Decision-Making Architecture proposes that the process is divided into eight steps (see Figure 1). The following paragraphs explain those steps

in more detail. Plus signs mean positive influence, minus signs mean negative influence (+/-).

1. *Situation-Characteristics.* The characteristics of the situation influence the cognitive needs (+/-), which are represented by the three tanks (Affiliation, Competence, and Certainty). This influence can lead to an inflow (positive information) or to an outflow (negative information). The situation is perceived as more demanding when it contains increasing conflicting goals, connected subfunctions (complexity), intransparency, dynamics, a lot of degrees of freedom and demands of knowledge (Schroda, 2000). According to the levels proposed by von der Weth (2001), the characteristics of the situation are an objective source of complexity.
2. *Need-Indicator.* The context of the situational information gets more important and moreover the meaning for the decision-maker. Due to its complexity, is the situation a threat to the need for competence, as the person is not feeling capable to cope with the situation? In addition to that, is the decision-maker losing passive control and the ability to predict future events? When other people are involved, the complex decision could also be a threat to the need for affiliation as the status in the group might be in danger. The decision-maker’s interpretation of the situation (see

- von der Weth, 2001, requirement and experience level) leads to an in- or outflow and thus to a deviation of the level in the different tanks. If the level falls under a specific set point (negative information or consumption over time), a need is indicated. The kind of need depends on the information flowing in. An unsatisfied need also means a displeasure signal for the decision-maker.
3. *Need-Selector.* To satisfy the needs and to fill up the tanks, an actual need is selected out of the several tanks and their combinations. This need or an amalgam of needs become an action leading motive.
  4. *Decision Process.* The different steps of the decision-making process are used to reduce the deviation in the tanks from its targeted set point. At first the problem of the situation has to be recognized in order to set goals which should be achieved. Followed by the analysis of the situation. The future development of events is forecasted and depending on this, alternatives are generated and weighted. The steps can be taken sequentially, but as the whole cycle has several recurring phases, some steps might also be left out or skipped. Taking steps back is also possible.
  5. *Cognitive filter.* The steps aim at increasing an insufficient present tank level to an aspired higher target level. For example, with more information, uncertainty can be reduced. However, if there is too much information, which the decision-maker can't cope with, uncertainty increases. The cognitive filter can reflect the information from the decision-making process, depending on its resolution level (see step 6). This process of self-reflection can reduce competence and certainty in the short run. However, in the long run, it can increase the level in the tanks as past failures are analyzed and potentially avoided (Dörner & Güss, 2011). Thus, the process itself can lead to in- or outflow in the tanks.
  6. *Internal Modulation.* The assessment of information flowing in and the selected need (and thus the indication of a demand) can lead to a modification of the decision-maker's arousal (Dörner & Güss, 2015). This internal modulation depends on the competence (assessment of ones own abilities to cope with the situation), the importance, and the urgency of the current motive, the menace for the own existence and the relative importance of the current motive (Dörner, Gerdes & Hagg, 2008). Low level in the tanks increase the activation, as the uncomfortable situation should be solved as soon as possible. Thus, a higher arousal increases the readiness to act, but also leads to a higher inhibition and a lower resolution level. The resolution level describes the accuracy during the perception of the situation. When its high, the situation is analyzed and compared very precisely, when its low, the situation is detected more roughly. Inhibition is the counterpart of the resolution level. A high inhibition has several affects on planning, like a narrow memory search, a decrease in the number of alternatives, and no adequate attention to long-term or side effects (Dörner & Güss, 2013). Possible consequences are that important aspects are forgotten, overlooked, missed, or skipped for other reasons, and moreover that myopic decisions occur (Hacker & Sachse, 2014). The selection threshold is positively influenced which means that the current motive stays action leading. Thereby, the system is stabilized, as the different motives are not overlapping each other; however, it gets less sensitive to opportunities and threats.
  7. *Increasing Measures/Behavior Tendencies.* The chosen needs trigger certain behavior tendencies. To reduce the difference in the motivational tanks or prevent the tanks from further drain, these tendencies work unconsciously and can lead to cognitive biases through overly optimistic or pessimistic evaluations, erroneous evaluations of outcomes, and probabilities and the disregard of information or alternatives (Carter, Kaufmann & Michel, 2007; Dörner & Güss, 2011). The subsequent biases take part in the different steps of the decision-making process and can lead to a quick positive inflow (dashed line) in the tanks.
  8. *Choice.* When the need-indicator is satisfied, a choice is made. This point is similar to the effect which Thompson, Turner, and Pennycook (2011) call the „Feeling of Rightness“ (FOR). It is described as a metacognitive experience which signals if additional analysis is needed (p.107). During a constant monitoring of the process, the motivational tanks can be filled up or emptied. The search continues until a set point is reached and the Feeling of Rightness sets in. Moreover, Ackerman (2014) found out that this set point lowers itself over time, (Diminishing Criterion Model) when no satisfying answer could be found yet. When the satisfaction comes from a close research and a good process, in which every important aspect has been analyzed and weighted, the needs meet the decision-demands, and consequently, a „good“ choice – in relation to the decision process – is made. If there is satisfaction, but it is based on biased information the needs don't match the decision-demands (Dörner & Güss, 2015). In this scenario, an erroneous choice can be the consequence.

The model describes a big circle with recurring phases. During a decision, this circle can be run through for several times on its different paths until the tanks have reached their specific set point. The motivational tanks constantly monitor every action. These tanks are influenced externally by the characteristics of the situation and internally by the decision process. The steps of the decision process are mostly conscious ones, while the internal modulation and the increasing measures are unconscious at a large scale. The Behavioral Decision-Making Architecture describes the origins of erroneous decisions within the decision process.

### 3.2 *Behavioral Consequences in the Decision Process*

Because of the described reasons for errors when faced with complex situations – bounded capacity of processing and memory, motivational influences – there are behavioral tendencies that can be observed in the decision process (the following examples refer to Dörner, 2003; Detje, 1996; Dörner, 2014).

Frequent errors in the stage of setting goals are the overevaluation of the current motive, encapsulation, repair-service behavior, or the inaccurate or missing setting of objectives. In the first case, a current motive leads to the fulfillment of an unimportant goal, the important one is ignored even when it is relevant. When faced with complex problems, only manageable problems are solved while no attention is paid to the bigger picture. This leads to an encapsulation due to a high level of uncertainty. Another consequence is the repair-service behavior. Only the current problems are solved – more important ones, which aren't urgent yet, are not paid any attention to. An inaccurate or missing setting of objectives and priorities is the reason behind this effect.

A main error is not to build a model of the situation (situation analysis). Thus, the situation and its developments are hard to predict and long-term and side effects are ignored. Simplified models are also problematic when every component of a complex system is reduced to one causing variable. This central reduction leads to an incomplete representation of the problem.

Another main error is the incorrect, simplified or missing representations of the situation. When the complexity is high, a model helps to understand interdependencies between the different parts of the decision and to recognize long-term and side-effects. However, in order to deal with the complex situation, models are often simplified and reduced to one causing variable. This central reduction leads to an incomplete and wrong representation of the problem.

In many cases, the confrontation with the situation is avoided and no model is created. But even when there is a model but it doesn't fit the situation, it is often argued that that one's own model is good but the circumstances aren't. This behavior is described as immunizing marginal conditioning. When building a model, the selection of information that is equitable with one's own information can lead to an incomplete representation of the situation. An incomplete representation of the situation leads to a behavior in which symptoms instead of causes are processed.

Besides a solid representation the development of the situation has to be forecasted in order to adjust the decision (forecasting). Complex decisions are mostly dynamic and fast changing. A good forecast attempts to take these aspects into account. A purely linear continuation of the current situation can lead to errors as temporal change and the development of important variables are ignored. Another source of errors – when faced with complexity – is the orientation towards a known variable, while other (unknown) ones are ignored. At last, inappropriate optimism may result in bad decisions. This behavior, resulting from wishful thinking, ignores given probabilities and draws an overoptimistic course of events.

The phase of planning describes the mental anticipation of action steps to reach a certain goal. Within a cross-linked system an action has one or more consequences. These consequences are decisive when it comes to good decisions. A central error in planning is not considering long-term and side-effects or frictions (occurring obstacles in planning). Thus, no alternatives are generated if an option is omitted. Holding on to known planning strategies can also lead to bad decisions. This methodism takes place when familiar strategies are used unreflected to a new situation with different characteristics. If the decision-maker avoids the confrontation with the complex situation, this can lead to what is called a horizontal or a vertical escape.

The horizontal escape describes a behavior that is characterized by a retreat into a well-known field of planning. Thus, unknown and uncertain aspects are ignored. The vertical escape is planning within one's own worldview. Thereby, the planning seems to fit perfectly to the own and biased picture one wants to draw from reality. Another misleading strategy is the intuition actionism. Solely relying on one's own feeling can be a good strategy in an environment that is predictable and has learning potential (Klein, 2008), but in complex situations which don't show these characteristics, this behavior carries the risk of an insufficient decomposition of the problem.

As described in the model, these behavioral consequences and their origins also have positive effects on the self-concept, the feeling of competence and certainty, affiliation to others, the self-protection etc., and

thus serve a reason. This is what makes these effects so robust in decision-making. The problem is when the decision-maker is not aware that these mostly unconscious positive effects take place at the expense of the decision's quality.

#### 4 Limitations

Real-life decisions themselves are complex and have a lot of different influences. Therefore it can be difficult to identify the mechanisms and processes which lead to erroneous decisions. The model does not claim to be a complete representation of the environment and the cognitive architecture. However, it attempts to contain the most important processes in order to depict real-life decisions and the reasons for failure. A retrospective analysis of decisions can be problematic as decision-makers might forget things or reinterpret the situation (Weingardt, 2008). Nonetheless, only afterwards, a behavior can be labeled as erroneous and short- and long-term advantages can be separated. A process of self-reflection can support the insight into the processes leading to a wrong decision (Spychiger, 2008). It will be the focus of another study to reveal the exact relations on how the decision's situation influences the motivational needs. Moreover a deeper look will be taken on the effect of the deviation in the tanks and the occurrence of biases or errors.

#### 5 Conclusion

As described, cognitive biases can influence the motivational tanks and lead to an increased tank level. The question whether cognitive biases are irrational depends on the model they are compared to. In relation to the goal of the decision, cognitive biases in the decision-making process may have the consequence that the goal is not met, even if the decision-maker had the best intentions in mind and wanted to achieve it. According to a rational view of the decision-maker, this seems quite irrational. The cognitive biases, however, fulfill another function. With filling up the tanks of certainty, competence, or affiliation, they keep us in the game in complex and threatening situations. The unconscious usage of biases gives a short cut to the thinking process, is less effortful and fulfills motivational functions associated with the avoidance of uncertainty, keeping up a positive self-image, making a competent impression and thus strengthening the affiliation to others (Dörner, 2005; Dörner & Güss, 2011; Dörner, 2012).

Introductory, we asked for the logic behind the failure of Eastman Kodak's downfall. If we look at this case again from the viewpoint of the Behavioral

Decision-Making Architecture, a deeper insight is provided. Kodak's strategy to stick with the analog photography for too long can be categorized as an erroneous decision with high consequences and without reversibility. According to statements in the Forbes Magazine by the former Kodak manager Vince Barabba, the information on the development of digital photography had been present at that time (Mui, 2012). Back then in 1981 – when there was a chance to change the course – Barabba was the Head of Market Intelligence. After Sony launched the first digital camera on the market, one of Kodak's largest retailers asked if they did not worry about the digital photography. Thereupon Barabba conducted a profound analysis and compared the development of the analog with the digital photography.

„The results of the study produced both 'bad' and 'good' news. The 'bad' news was that digital photography had the potential capability to replace Kodak's established film based business. The 'good' news was that it would take some time for that to occur and that Kodak had roughly ten years to prepare for the transition.“ (Mui, 2012, p.2)

As it turned out, the management did not use this time properly. Almost eight years later, the CEO Kay R. Withmore announced that his company, which is known for its films in the yellow boxes, will continue to focus on its original core business: „We defined our focus too broadly (...). Now we are focusing on the sectors we want to be in. We are defining what we mean when we say imaging, chemicals and health“ (Holusha, 1989, p.2). When he retired, Withmore's successor George MC Fisher still relied on Kodak's established business strategy: „Maybe my real failure is that I haven't communicated how powerful our digitization strategy really is“ (Deutsch, 1999, p.2).

The retrospective analysis of this case shows that the information had been available and the decision could have been made in a better way. But when looking at the statements of the CEOs, the logic behind their behavior emerges. The advent of digital photography meant a huge change for the company (threat for the certainty because they couldn't predict what is going to happen). Kodak was world leading in the field of photography (threat for the competence because the analog photography would be replaced), employed a lot of chemists and developers which were specialized in the analog field (threat for affiliation if they are not needed anymore) and had huge chemical installations for the development of the films. What did this situation provoke?

When looking for an explanation, three cognitive biases offer the most elucidation: Confirmation Bias,

Sunk Cost Effect, and Overconfidence Effect. Kodak's leadership ignored the information about the threat and highlighted the advantages of the analog photography (Confirmation Bias). As the leading company in the analog photography, Kodak had invested a lot of resources in this field and therefore ignored the conflicting digital solution for too long (Sunk Cost Effect). Moreover, there was an overestimation of Kodak's strategy regarding the future challenges (Overconfidence Effect). What was the behavioral consequence? Important aspects had been ignored, there was no sufficient consideration of long-term effects and alternatives to the analog photography had been developed far too late.

This behavior had some short-term advantages. The competence was protected and a positive self-image was kept. However, in the long run, it led to the downfall of the company. A comparison of the „Economist“ (2012) dramatically highlights this decent: „Strange to recall, Kodak was the Google of its day“ (p.1).

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Correspondence to:  
Mag. Markus Domeier  
Institute of Psychology  
University of Innsbruck  
Innrain 52  
A-6020 Innsbruck  
markus.domeier@uibk.ac.at