The Impact of Complexity on Path Dependent Decision Making Processes: An Experimental Study

Abstract

The development of path dependent processes refers basically to positive feedback in terms of increasing returns as the main driving forces of such processes. It is assumed, however, that path dependency could be also affected by contextual factors such as different degrees of complexity. Up to now it is quite open if and how complexity may impact path dependent processes and the probability of lock-in. In this paper we investigate the relationship between complexity and path dependency by means of an experimental study. We introduce a path dependent decision making model and by focusing on the mode of information load and decision quality in chronological sequences, the study explores the impact of complexity on decision making processes. Resulting insights are very helpful for both the development of path dependency theory and for a better understanding of decision making behavior under conditions of positive feedback in different settings of complexity. As previous path research has applied qualitative case study research and (to a minor part) simulations, the paper makes a further contribution by establishing experimental research for path dependency issues.

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Introduction

The hallmark of path dependency theory is its focus on self-reinforcing effects (Arthur, 1983; David, 1993; Arthur, 1994; Bassanini & Dosi, 2000; Ackermann, 2001). These effects are understood as the central triggering elements that drive path dependency (Sydow, Schreyögg, & Koch, 2005). At the same time path dependent processes are embedded in institutional fields and environments which may affect the path process as well (Pierson, 2000). Yet little is known about the particular impact of contextual factors such as ambiguity, power structures, institutional density or complexity on path dependent processes (North, 1990; Greif, 1994; Thelen, 2003; Pierson, 2004).

The assumption that context could matter in path dependent processes is based on the conceptual argument that the complexity of goals, tasks and environments in which decision makers have to operate and the loose and diffuse links between action and outcomes, render

such settings inherently ambiguous and therefore prone to increasing returns (Pierson, 2004: 39 f). By this, contextual factors contribute to imperfect market conditions that are indicated by the existence of transaction costs that make it difficult (if not impossible) to apply rational decision rules in terms of neoclassical theory. However, Pierson's argument that also context matters goes further and refers not only to the constitution of imperfect markets but to the effect that context factors assumingly have a direct impact on the occurrence and intensity of self-reinforcement (Pierson, 2004).

Regarding the different bodies of literature on path dependency in the economic, institutional and political field it is quite unclear if and what kind of impact should be attributed to what kind of contextual factor. In the conceptualization of path dependent processes provided by Arthur self-reinforcing mechanisms are necessary and sufficient preconditions of path dependency. Context is taken for granted or it is assumed as given and is kept constant. This does not mean that context is irrelevant, but it is considered in form of fixed premises (e.g., as a non-sponsoring rule, Arthur, 1989) in order to frame the process. Instead in North's conceptualization of path dependency context is relevant in the sense of a second necessary precondition. Without imperfect markets and thus the occurrence of transaction costs there will be no path dependency at least when path dependency should be considered potentially inefficient. "If institutions existed in the zero transaction cost framework, the history would not matter; a change in relative prices or preferences would induce an immediate restructuring of institutions to adjust efficiently (…)" (North, 1990: 93).

Finally, also in Pierson's consideration self-reinforcing effects are the crucial factors; nevertheless he puts much more attention to the role of contextual influences on path dependency in order to underline his central argument, that politics are prone to path dependency more than economic systems. It is not the place here to discuss these possible differences between political and economic systems. What is of central interest, however, is the basic assumption that also context may affect path dependent processes. Even if this assumption may be intuitively plausible, the argumentation regarding both conceptual and empirical research on the issue is not fully convincing due to at least three different shortcomings.

First, Pierson refers to context in a very broad and unspecified manner, enumerating a lot of possible but nevertheless very different contextual factors such as power structures, uncertainty and unspecified preferences which describe the context of (political) decision making. It is very plausible that these factors may influence political decision making

processes and that they too may lead to inertia and rigidity. In this vein context factors may explain the same results as path dependency, but they also could provide different, alternative explanations in doing so. There may be a correlation between both factors that influence rigidity, but not necessarily a causal link.

Second, focusing on context in this very broad sense makes it difficult if not impossible to discern and distinguish the existence of specific causal relations between a concrete contextual factor and a path dependent process. For instance, power structures and complexity are very different but nevertheless potentially interdependent concepts (power structures could be very complex and in turn complexity may foster the emergence of informal power structures). Referring to a broad, multidimensional and not well distinguished understanding of context may entail a lot of unrecognized cross effects and may finally lead to the not falsifiable assumption that context always matters.

Third, given the fact that path dependent processes are evolutionary and contingent, path analysis is often retrograde (especially in political science) and hence it is an ex-post-explanation (see also Mahoney, 2000). This is especially problematic for empirical studies based on single or few cases. Referring to an opaque and highly interdependent context does not provide better insights into the assumed causal relationship due to the threat of ad-hoc-theorizing, because a given result (a path) is referred to an underspecified context which in turn is interpreted as the causal reason for that result. Another result in another case, and another posteriori interpretation of the context as explanation would be the logical consequence of this research approach.

Considering these caveats, it seems more appropriate to opt for a different research strategy by specifying and providing a clear-cut research design, focusing exclusively on very few variables and the direct measurement of their relationship. For that reason, we focus on only one particular context factor: the degree of complexity. We apply an experimental approach to study decision making in order to isolate and control best this factor from possible interferences on both the contextual level and the level of self-reinforcement. Concentrating on complexity as a possible contextual impact factor for path dependency has also the advantage that we can rely on crucial insights from complexity theory and especially from psychological research on decision making heuristics.

First, we give a short introduction into path dependency theory in order to circumscribe and specify our understanding of path dependent processes. Then we specify the context factor complexity by referring to complexity science and psychological research on decision making

heuristics. Building on these insights, we introduce a path dependent decision making model which serves as the basis for our experimental design and for deducing our hypotheses which are presented in the up-following section. Finally, we present and discuss the results of the study.

Path dependency theory

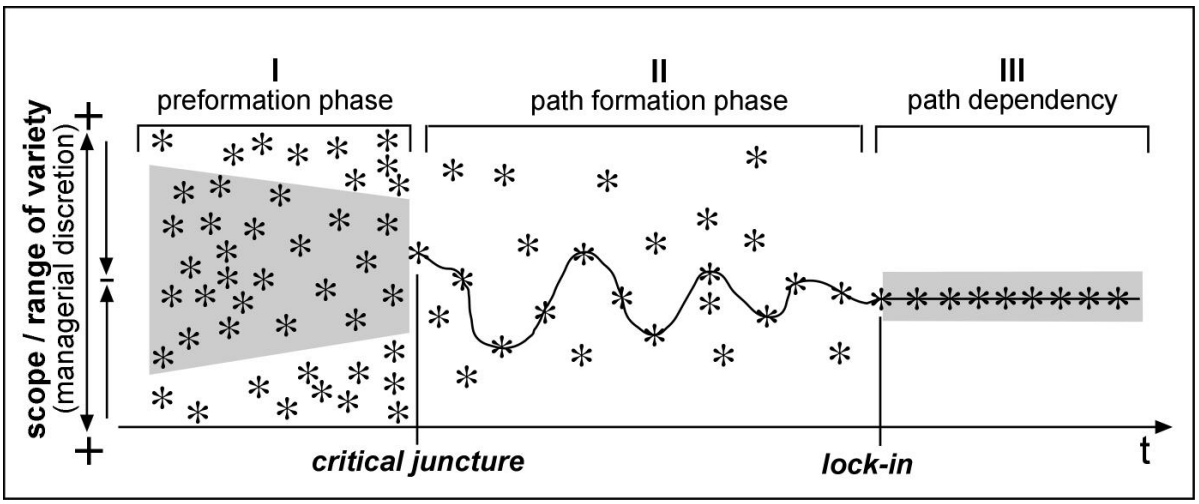
Path dependency is a dynamic theory assuming that initial decisions can increasingly restrain present and future choices. The theory originates in the historical studies of David (1985, 1986) who explored the development of the keyboard technology of QWERTY. He shows how an inferior and inefficient technological standard was established and is still maintained. Brian Arthur (1989, 1994) has formalized and simulated path dependent processes by highlighting the importance of self-reinforcing mechanisms.

With regard to organizational studies and managerial decision making, path dependency theory constitutes a relatively young and still nascent field of research (Schreyögg, Sydow, & Koch, 2003). A conceptualization of organizational path dependency is rare but the central idea of history dependency fits perfectly into almost all elaborated modern and postmodern organization theories (Child & Kieser, 1981; Kieser, 1994; Clegg, 1990; Reed, 1993; Chia, 2003). Yet, path dependency theory has more to offer than the mere affirmation of the relevance of a historical understanding of organizations and decision making processes. In order to explore this potential, one has to focus on the inner dynamic that drives path dependent processes.

Path dependency can be conceptualized as the possible outcome of a dynamic process that is reigned by one or more self-reinforcing mechanisms leading to a narrowing of the variation and the range of managerial discretion (Sydow, Schreyögg, & Koch, 2005). Path dependency describes a tapering process. Thus, a path constitutes a restriction of choice for a social or psychic decision making system. While choice is not restricted at the beginning, the restriction emerges as a result of an ongoing process of decision making. In this sense the restriction of choice is a collateral effect of an ongoing decision making process.

Consequently, paths can be understood as the emergent outcome of a self-reinforced process resulting in a pattern of action and reflection. The development of such a pattern has to be considered a *non-ergodic process* that becomes more and more inflexible. The concrete pattern is *not predictable* at the beginning and can lead to an *inefficient outcome* in the end (Arthur, 1989, 1994; David, 2001; Pierson, 2004). Sydow et al. (2005) have reconceptualized this process in a 3-stage-model (see Figure 1).

Figure 1: The constitution of an organizational path (Sydow, Schreyögg, & Koch, 2005)



Phase I of the model is built on contingency. The search or decision making behavior is neither undirected nor are choices fully unconstrained. History matters, but in a broader sense of foregoing imprints (Boeker, 1988). These imprints could also carry out a narrowing effect (indicated by the shadow); however, there always remains a considerable scope of choice. Phase I ends with a critical juncture (Collier & Collier, 1991), i.e. a decision and/or event constituting a dynamic regime of self-reinforcement. At that moment, a focal system enters (often unconsciously) into a dynamic narrowing process triggered by positive feedback for a particular option. The system chooses the option by chance (in the sense of a small event) or intentionally (in the sense of a bigger event). The strategic intent, however, does not necessarily reflect the triggering of a self-reinforcing dynamic; this could also be a collateral outcome of strategic action.

Entering into **Phase II,** a new regime takes place favoring a particular type of decisions. This set of decisions is likely to be reproduced over time. The range of options narrows. If the self-reinforcing mechanisms consolidate, a pattern of reflecting and/or acting is likely to build up which reproduces the initial decision or set of decisions, i.e., a dominant solution emerges and the process becomes more stable. Decisions taken in Phase II are nevertheless still contingent, i.e., options for different choices still exist although they are more and more constrained.

The idea of self-reinforcing mechanisms implies a positive feedback and a self-reinforcing mechanism is a necessary precondition for what is defined as a path. That implies that agents act (consciously or unconsciously) upon these mechanisms and by doing so they reinforce the path-building effects. The diminishing variety and the increased limitations of choices are

collateral effects of this process. Agents may "loose sight" of other data and adopt (or apply) particular decision heuristics which could guide them more and more in a focused direction. If this is the case, decision heuristics may eventually lead to inflexibility and lock-in.

With the transition to **Phase III** the path becomes locked-in and the dominant pattern gains a deterministic character. The decision processes are fully bound and a particular choice or decision pattern in the past has become the predominant mode. Any other alternatives are ruled out – even if they are now more efficient. In contrast to technological solutions, decision making patterns do not amount to a concrete technology or technological artifact with a material representation. Therefore, a behavioral pattern of acting and reflecting could be less restrictive (indicated by the shadow in Phase III).

The lock-in situation is associated with the assumption that a path dependent process leads to a stable and thus rigid outcome which is potentially inefficient and could not be overcome by the focal system which is path dependent. Thus, the potential inefficiency refers to a rationality shift indicating a relevant change in the environment and making another choice more attractive and the impossibility for the focal system to reach this other choice due to the lock-in.[1] However, a rationality shift may occur even before a system is really locked-in. In this case we would have to assume that a decision making system will not get locked-in if it is aware of such a change in the environment and hence it will use the remaining range of variety to switch over to the now more attractive solution. Yet there is strong evidence from different bodies of literature that such a change will not occur if the focal decision system perceives itself as still successful. Thus, path dependency has much to do with a potential trade off between the inner rationality of a decision system and a second point of view (an outer or observer perspective) applying another form of rationality. Therefore a rationality shift is defined from the observer's perspective but whether and how it is perceived depends on the inner rationality of the decision system.

Up to now, path dependency research has hallmarked the pivotal elements that drive path emerging processes in phase II of the model which finally lead into a lock-in. According to previous research, we can distinguish between at least six different forms of self-reinforcing mechanisms (Sydow, Schreyögg, & Koch, 2005): (1) economies of scale and scope, (2) direct and indirect network externalities, (3) learning effects, (4) adaptive expectations, (5) coordination effects and (6) complementary effects. On a more abstract level all these effects lead to positive feedback processes, i.e. processes in which at least two different variables are

[1] This argument of potential inefficiency has provoked remarkable defensive routines from neoclassical mainstream (Liebowitz & Margolis, 1990; Liebowitz & Margolis, 1994; Liebowitz & Margolis, 1995; see also Regibeau, 1995), because in the neoclassical world an inefficient but nevertheless rigid solution can not occur and if it occurs it is always remediable.

reciprocally linked in a way that a higher (or lower) level of one variable leads to a higher (or lower) level of the second variable which in turn leads to higher (or lower) level of the first variable and so on. As referred to in the introductory section, it is argued that beyond these mechanisms a particular context may influence path dependent processes as well (Pierson Pierson, 2004; see also Beyer, 2005). We will now focus on complexity as such a potential contextual factor. We further refer to decision making in complex situations and we combine these different theoretical elements in order to provide a conceptual framework of a path dependent decision making process in which complexity and self-reinforcement are built in.

Complexity theory, decision making and path dependency

According to Anderson (1999) complexity can be understood as a structural variable that characterizes both the internal and external environment of an organization or respectively a decision making system. In our study we focus on the external environmental complexity that a decision making system is facing. In this vein "complexity can be equated with the number of different items or elements that must be dealt with simultaneously" (Anderson, 1999).

Thus, complexity is referred to possible relations between elements; an interconnected collection of elements is called complex "when, because of immanent constraints in the elements´ connective capacity, it is no longer possible at any moment to connect every element with every other element" (Luhmann, 1995: 24). Complexity also refers to decision making systems and their ability to cope with situations of incomplete information. "Complexity (…) means being forced to select" (Luhmann, 1995: 25). Therefore dealing with a complex environment requires a reduction of complexity in order to make decisions. "People in organizations reduce a complex description of a system to a simpler one by abstracting out what is unnecessary or minor (…) compressing a longer description into a shorter one that is easier to grasp" (Anderson, 1999).

Complexity impacts decision making behavior in various ways. The first and the most important implication is that complexity leads to a situation in which the application of rational decision making models is no longer possible or does not lead to better decisions: it is not rational to apply them (Simon, 1987, 1990; Weick & Sutcliff, 2001). As it is well known from the bulk of research describing and analyzing how decisions are made in organizations (Allison, 1971; Cohen, March, & Olsen, 1972; Pettigrew, 1973; Mintzberg, Raisinghani, & Théorêt, 1976; Beyer, 1981; Brunsson, 1982; March, 1994; Crozier, 1995; Staw, 1997; Hendry, 2000), rational decision behavior rarely occurs in the mode presumed by rational choice theory: problems are ill-definied, solutions are seeking for problems, evaluations are implicit, etc. For that reason, the linear logic of rational choice theory and the assumption of

rational behavior are problematic premises for both prescribing and describing decision making in the real world.

Due to complexity only a bounded form of rationality applies to these situations in which it is impossible for a decision making system to realize and to compute any possible relation between information elements. Thus, complexity and bounded rationality are two sides of the same coin, because the limitations of the human mind and the structure of the environment in which the mind operates, are interlocked (Simon, 1991; Gigerenzer & Todd, 1999). Decision making systems in real world settings have only limited time, knowledge and computational capacities and therefore complexity restrains them to make inferences of the environment in order to reduce complexity.

In real world settings decision makers rely on cognitive heuristics while processing information and making decisions (Goldstein & Gigerenzer, 2002). Heuristics are an appropriate strategy for reducing complexity in decision making processes and the higher the degree of complexity the faster and the more frugal heuristics have to be in order to work under these conditions (Rieskamp & Hoffrage, 1999).

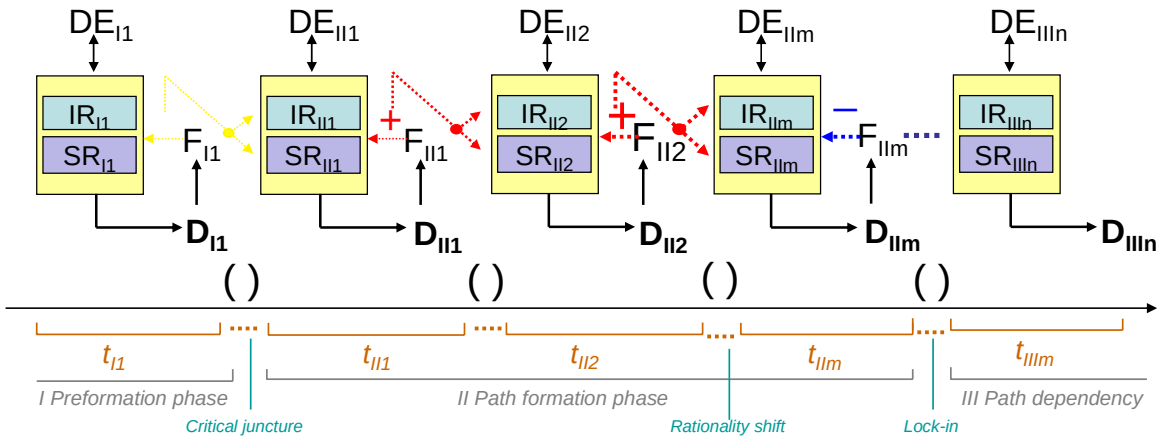
There are many different forms of heuristics (for an overview Gigerenzer, Todd, & ABC_Research_Group, 1999) but there are three principles characterizing any heuristic strategy: search, stopping and decision (Rieskamp & Hoffrage, 1999). Principles of search describe how information is retrieved, principles of stopping define when information retrieval is terminated and principles of decision specify how decisions and what kind of decisions are taken (Gigerenzer & Todd, 1999). Corresponding to these three principles there are three distinctions further characterizing a specific heuristic by concerning (1) how search is guided (e.g., alternative-wise vs. attribute-wise), (2) if and how a stopping rule is applied, and (3) whether decisions are taken on the basis of compensatory (cues are outweighed by other cues) or non-compensatory strategies (a specific cue is not outweighed by any other cue). The three different principles and the characterizing dimensions are not totally independent. The application of an early stopping rule for instance makes a non-compensatory strategy more available due to less information retrieved.

We combine these insights with the theory of path dependency depicted in Figure 1 and transform them into a path dependent process model of decision making. The following variables are used to define that process in the three different phases (I preformation phase; II phase of positive feedback; III path dependence) and in consecutive sequences over time:

- DE_{pt}: Decision Environment in phase p and period t (for p = I to III and t = 1 to l, m, n)
- IR_{pt}: Information Retrieval in period t (for p = I to III and t = 1 to l, m, n)
- SR_{pt}: Stopping Rule in period t (for p = I to III and t = 1 to l, m, n).
- D_{pt}: Decision taken in period t (for p = I to III and t = 1 to l, m, n)
- F_{pt}: Feedback perceived in period t (for p = I to III and t = 1 to l, m, n)

As argued above the rationality shift (indicating an important change in the decision environment by making another choice more attractive in relation to past decisions) does not necessarily occur only in phase III. In the following model we refer to a rationality shift in phase II which will give decision makers the possibility to anticipate and prevent a lock-in. The process of path dependent decision making is depicted in Figure 2.

Figure 2: The process of path dependent decision making



Hypotheses

The main hypothesis to be tested is whether complexity has an impact on the probability of becoming path dependent. As shown above this hypothesis derives directly from the path dependency literature (Pierson, 2000; 2004). However, this is not a trivial hypothesis regarding the state of research in that field and by considering possible counter effects stemming form the application of heuristics. As it is known, fast and frugal heuristics may result in good and sometimes even better decisions than decisions taken on the basis of more

information (Czerlinski, Gigerenzer, & Goldstein, 1999). Thus, it is reasonable to assume that complexity leads to the application of heuristics, but the application of a specific heuristic may prevent path dependency if it allows making either good decisions on the basis of fewer information. On the other side, a path dependent process comes along with a self-reinforcing dynamic and a rationality shift. For that reason, one can assume that an initially chosen decision strategy (which is reinforced by positive feedback) may not adapt to a changing environment and thus may result in path dependency. Consequently, a faster and more frugal heuristic is more prone to non-adaptation. Hence, a higher level of complexity, which requires a faster and more frugal heuristic, may increase the threat of a lock-in. Therefore we assume:
H1: The higher the level of complexity, the more likely a decision maker becomes path dependent.

Besides testing the hypothesis whether complexity indeed leads to path dependency, we further try to explore the way ***how*** complexity has an impact on path dependency. Referring to our decision making model we distinguish three different levels for possible impacts: (1) the information retrieval (IR), (2) the stopping rule (SR) and (3) the decision (D). All three levels may be affected by complexity and require a different and differentiated operationalization.

(1) Information retrieval

If we consider previous studies on decision making behavior (Anderson, 1999) and basic assumptions of path dependency theory (David, 1985; Arthur, 1994; Schreyögg, Sydow, & Koch, 2003) we can assume that complexity may have an impact on the distribution of retrieved information in a way that information retrieval is more focused on particular information units in high complexity environments. In studies on decision making the distribution of retrieved information is commonly operationalized with regard to the amount of alternatives and cues (i.e. attributes of the alternatives). A lot of studies have shown that a higher amount of alternatives lead to the increase of non-compensatory strategies (Billings & Marcus, 1983; Timmermans, 1993) and that in turn leads to a focus on alternatives (FAl). On the other side, the influence of a higher amount of attributes is less clear with regard to an assumed shift from compensatory to non-compensatory strategies (Payne, 1976). With regard to complexity under the condition of increasing returns a focus on attributes (FAt) seems however possible and plausible, and does not contradict Payne´s (1976) findings, because a focus on attributes can also occur in a compensatory strategy. Thus, we can distinguish

between two content dimensions: different alternatives and different attributes and the two possible effects that decision makers can focus on particular alternatives (FAl) or attributes (FAt).

In path dependent models the distribution of retrieved information has a third dimension: time. The distribution of retrieved information in a time dimension distinguishes between present information vs. future information, i.e., participants can focus on present (FPI) or future information. From the perspective of path dependency theory the investigation of this effect is of importance because path dependency is associated with a lower orientation on future information. Yet, to our knowledge this possible effect is not considered in the research on heuristics and decision making and points also to a research gap in that field. If future information would have a higher degree of uncertainty, then the explanation of this effect would be quite clear, but if we consider the manipulation of complexity the assumption of FPI is more difficult to deduce. What we can assume is twofold: First, in order to make a decision a decision maker has to refer to a specific quantum of information per time period in form of a minimum optimal quantum of information (for example to detect the best alternative a decision maker has to refer to at least one attribute about all alternatives). Second, decisions are made in the present period and therefore present information is the most relevant for present decision. With a higher degree of complexity the optimal quantum of information per period increases (for instance there are more alternatives to be considered) and it becomes more difficult to memorize information on future periods later on when decisions are already made. Therefore, we can also assume that a higher level of complexity increases the focus on present information.

To sum up, we can deduce the following three hypotheses:

H2a: The higher the level of complexity, the more focused is the information load on specific alternatives FAl (versus equally distributed over all alternatives).

H3a: The higher the level of complexity, the more focused is the information load on specific attributes FAt (versus equally distributed over all attributes).

H4a: The higher the level of complexity, the more focused is the information load on present information FPI (versus future information).

Considering these hypotheses we can also assume that FAl, FAt and FPI lead to path dependency because the more focused information retrieval is on one of the three dimensions (alternatives, attributes, and present time) the more probable a decision system becomes path dependent because the more likely it is that potential relevant information may not be

considered or may be considered too late. Therefore, we can deduce that information load mediates the effect of complexity on path dependency such that complexity impacts information load which impacts path dependency. This reasoning results in the following three corresponding hypotheses:

H2b: The more focused the information load is on specific alternatives FAl (versus equally distributed over all alternatives), the more likely a decision maker becomes path dependent.
H3b: The more focused the information load is on specific attributes FAt (versus equally distributed over all attributes), the more likely a decision maker becomes path dependent.
H4b: The more focused the information load is on present information FPI (versus future information), the more likely a decision maker becomes path dependent.

(2) Stopping rule

The second level regards the quantity of information retrieved which is regulated by a stopping rule (Gigerenzer & Todd, 1999). As we know from complexity and from information processing theory (Anderson, 1999), complexity may influence an individual decision system on the level of the amount of retrieved information. Hence, complexity as such makes it necessary to apply a stopping rule, because it is not possible to retrieve all available information. It is also assumed that a higher level of complexity leads to a more selective search of information (Ford, Schmitt, Schechtman, Hults, & Doherty, 1989). For that reason a higher level of the complexity may lead to an earlier stopping rule, when time resources for making decisions are restricted, because the more complex a situation, the more time has to be spent on structuring the situation (e.g. detecting what could be relevant and what could be irrelevant) and the less time can be used for information retrieval. Thus it is assumed that a higher level of complexity reduces the total amount of information retrieval (total information load (TIL)) and this in turn leads to an increased probability of becoming path dependent since it is more likely that relevant information is not taken into account. This leads to the following hypothesis:
H5a: The higher the level of complexity, the lower the level of total information load (TIL).
H5b: The lower the level of total information load (TIL), the more likely a decision maker becomes path dependent.

(3) Decision

Finally, also the decision level in terms of decision quality may be affected by complexity. We define the degree of decision quality (DC) by the concordance of decisions taken (D) with the number of optimal decisions (OD). Even if very fast and frugal heuristics could lead to equally good decisions in comparison to (ideal), decision makers who can refer to complete information without any computational restrictions and without time limitations (i.e., the hyperrational decision maker can transfer complexity into simplicity), it is also plausible to assume that less information undermine the quality of decisions. Consequently, the worse the decisions the higher the probability for a decision maker to become path dependent. Therefore we assume:

H6a: The higher the level of complexity, the lower the decision quality (DC).

H6b: The lower the decision quality, the more likely a decision maker becomes path dependent.

As mentioned above the three different levels of decision heuristics are not independent. As complexity leads to the application of particular heuristics and at the same time complexity is related to decision quality, the effect may be mediated in a sense that complexity influences heuristics which, in turn, impact decision quality. Therefore, we assume the following mediating effects from complexity to decision quality with information retrieval and total information load as mediators. These effects are basically important with regard to a possible impact on decision quality.

H2c: The more focused the information load is on specific alternatives FAl (versus equally distributed over all alternatives), the lower the decision quality (DC).

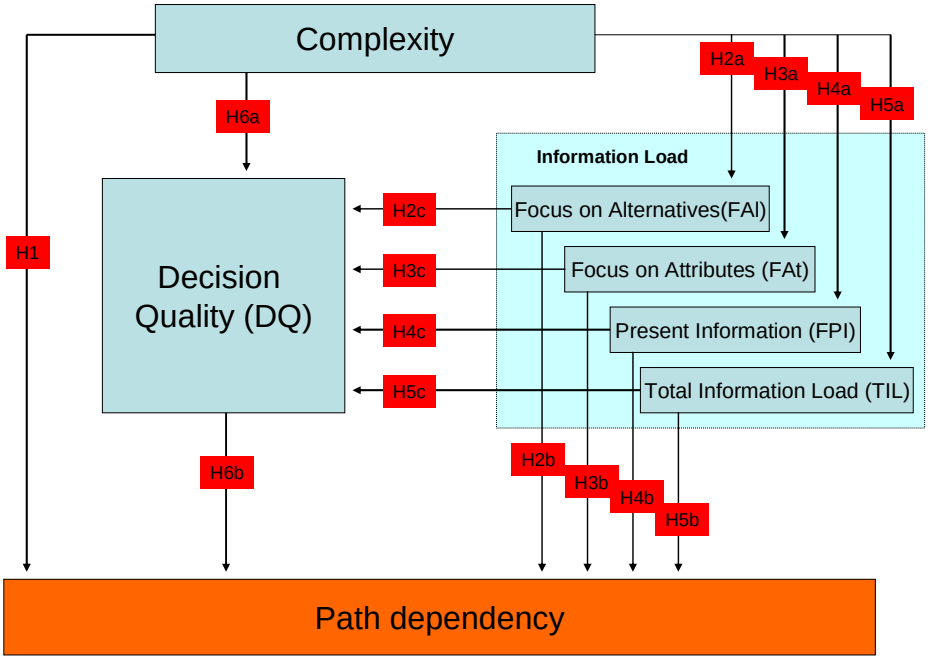
H3c: The more focused the information load is on specific attributes FAt (versus equally distributed over all attributes), the lower the decision quality (DC).

H4c: The more focused the information load is on present information FPI (versus future information), the lower the decision quality (DC).

H5c: The lower the level of total information load (TIL), the lower the decision quality (DC).

Figure 3 summarizes the hypotheses and gives an overview about the assumed relationships between the different variables.

Figure 3: Framework and set of hypotheses



Method

Overview

We apply an experimental design in order to test our hypotheses. The experiment is based on a one-factorial between-subjects design, manipulating the complexity of the decision environment on two levels (low vs. high complexity). Mobile service companies were used as student participants are familiar with buying decisions for mobile services. Furthermore, the purchase situation allows for settings of varying information complexity that are common to real life purchase situations for mobile services.

Participants and procedure

The experiment took place in a computer lab. We developed a software tool for the purposes of the experiment. 27 students volunteered to participate in the study (13 female, 14 male students; average age 22.7 years). Students were provided with a set of purchase information in order to make a decision for a service provider. Once a decision was made, new information was provided and the participants had to decide again. Altogether, they went through this procedure 25 times, i.e. they had to make 25 decisions (further on referred to as "decision rounds"). For each decision round, they had up to 60 seconds to browse the provided information. If they didn't make a decision within the given timeframe, the decision of the former decision round was kept.

The information provided in each decision round was:

- the participant's use of various mobile services in the present and following four decision rounds (e.g., telephone calls to house lines or from mobile to mobile in minutes),
- cost structure of services provided by four service providers for the present and following four decision rounds: basic fee, costs for calls to house lines (per minute), costs for calls from mobile to mobile (per minute), costs for foreign calls (per minute), costs for text messaging (per unit), costs for multimedia messaging (per unit), costs for WAP services (per minute). The total amount of information given differs over both experimental settings (see below).
- costs for placing a new contract with another provider ("switching costs") for the present and following four decision rounds.

The information was presented by buttons on the computer screen such that participants had to click on those buttons in order to receive the particular information. In each round, participants received feedback (F) in terms of a bill that showed the sum of all costs of past rounds.

The information settings were created in order to provide an optimal decision path as well as the possibility of a lock-in, i.e. a situation where a suboptimal decision could not be changed anymore. Because of the design of the data settings (see below) the optimal path, rationality shift, and path-dependency occurred at the same decision rounds in both high and low complex settings. We define an optimal decision by referring to the cost structure, i.e., an optimal decision is the one with the lowest all-over costs. Taken all costs together, a specific alternative is superior in every decision round during the course of the experiment. By providing price and demand information on a present round and the following four decision rounds, participants were enabled to come up with an optimal decision in each round. To rule out any influences of decision making under uncertainty, the settings were designed in a way that an optimal decision (decision under certainty) was possible by considering all available information on the actual and the upcoming four decision rounds. In order to create a rationality shift, the superior alternative changes once in the course of the experiment. The optimal change from one alternative to another alternative is in the 17th decision round. After that, participants still could change to the favorable alternative until the 21st decision round. Thereafter, they could no longer shift (unless they have chosen the optimal alternative) to another alternative as the switching costs became higher than the provided budget of 100 units per round.

The change of the cost structure was mainly designed on three different kinds of costs: so called "focus costs" (basic fee, costs for calls to house lines, and costs for calls from mobile to mobile) and so called "hidden costs" (costs for WAP services) while the rest of the costs (for foreign calls, short messaging, multimedia messaging) remained rather stable. The differentiation between "focus costs", "hidden costs" and "stable costs" is analytical and is as such not directly perceptible for the participants (i.e., the cost categories are not labeled as such).

While focus costs were decreasing all the time, favoring alternative A (Figure 4), the "hidden costs" were increasing for alternative A, favoring alternative B (Figure 5). The "Total costs" were lowest for alternative A until round 17, and lowest for alternative B in the following rounds. Alternatives C and D were dummies as their "total costs" were always slightly higher (Figure 6). "Switching costs" were increasing over time (Figure 7), leading to a lock-in for those who stayed with alternative A until decision round 20.

Figure 4: "Focus costs"

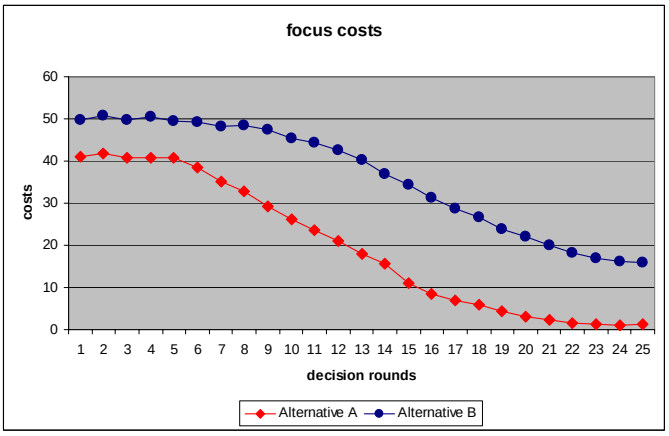


Figure 5: "Hidden costs"

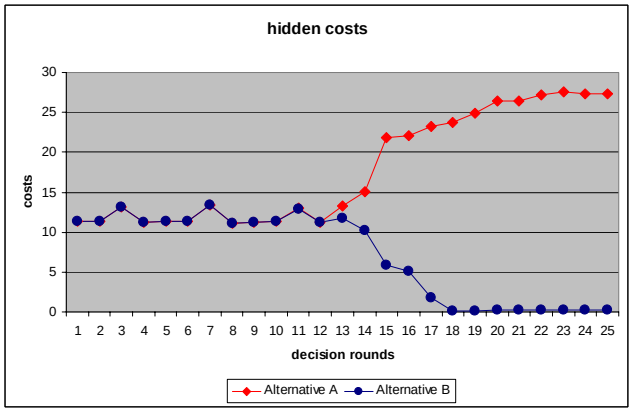


Figure 6: "Total costs"

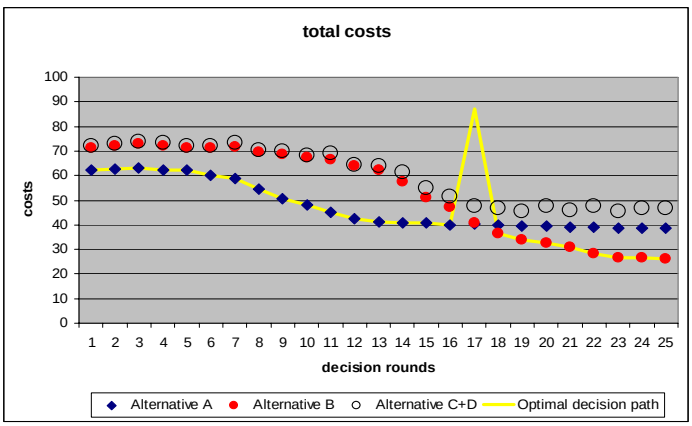
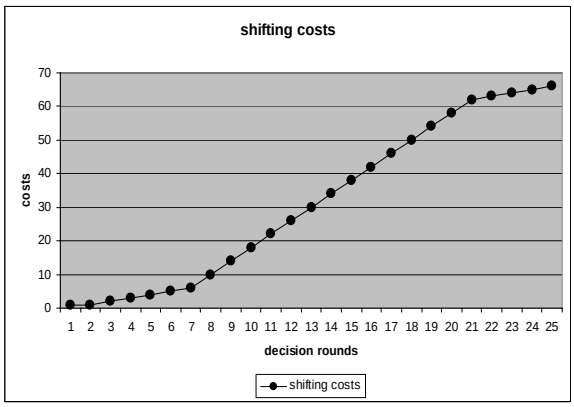


Figure 7: "Switching costs"



After arriving at the lab, the students were instructed how to use the software and informed about the basic idea of the experiment. In an initial test decision round that lasted 300 seconds, they became accustomed to the software tool. Students were given 10 Euros each for participating in the study. In order to ensure that participants kept motivation in order to screen the given information in each round, three of the students with the best overall result (i.e., the lowest percentage of budget used) were given an additional 10 Euros each after completing the study.

Manipulation

Complexity was manipulated by providing an information display matrix on the cost structure of the four alternatives with a varying number of service attributes. In the low complexity (lc) setting, information was provided on costs for all calls (per minute), costs for text messaging (per unit) and costs for WAP services (per minute). In the high complexity (hc) setting, costs for all calls were split up into basic fee, costs for calls to house lines (per minute) and costs for calls from mobile to mobile (per minute). Furthermore, costs for text messaging (per unit) were split up into three service attributes in the hc setting: costs for text messaging (per unit) and costs of multimedia messaging (per unit) and costs for foreign calls (per minute). Altogether, the low complex setting provides an information display matrix of four alternatives by three attributes, while the high complex setting provides a matrix of four alternatives by seven attributes. The data was designed in a way that every alternative has exactly the same cost structure in both lc and hc setting: Technically some of the costs in lc setting were split up into different parts in the hc setting, with the sum of the split-up costs in the hc setting being equal to the corresponding cost in the lc setting. This design implies not only that using the same alternative in both hc and lc settings will result in the very same "total costs" (for that specific decision round); it also creates a similar level of dynamics in price changes in both settings. By this, the data guarantee that a discrepancy in decision making is caused by different levels of complexity only.

In a pretest, 50 students were asked to evaluate the complexity of both information settings on a 9-point complexity scale. The information situation with less information was evaluated as significantly less complex than the alternative information setting ($t = 2.228$, $p = .031$).

Dependent variables

The dependent variables were path dependency, decision quality and information retrieval in terms of focus on alternatives, focus on attributes, present information, and total information load.

Path dependency was measured by a dummy variable that distinguished between choosing the optimal alternative in the last round versus choosing a non-optimal alternative.

Decision quality was measured by a dummy variable indicating whether participants were chosing the single best alternative in a decision round or not. For each participant and decision rounds 1 to 20 (where participants we able to decide without being forced to a decision by lock-in) we assigned either 0 (wrong alternative chosen) or 1 (best alternative chosen) as value for the variable.

Using log file analysis, we were able to track the whole process of information retrieval by each participant over all 25 decision rounds.

An information unit is defined as the retrieval of one piece of information, i.e., each access to a particular information on the screen (e.g., WAP-costs for alternative 1 in the present round).

Information retrieval regarding different *alternatives* and different *attributes* is analyzed by showing how much the distribution of information load deviates from an even distribution which would represent information retrieval of a rational decision maker. For instance, an even distribution over the four alternatives would lead to 25% of units of information per alternative. Deviations from this pattern indicate that an information seeker tends to focus information of a particular alternative at the expense of information of other alternatives. We analyze the (in)equality of distribution by calculating Gini coefficients. The coefficient is defined as a ratio with values between 0 which corresponds to perfect equality and 1 which corresponds to perfect inequality (Gini, 1921).

Focus on *present information* was measured by the ratio of information related to the present rounds to all information.

Total information load is the sum of all information units retrieved per round.

Results

The results confirm the overall impact of complexity on path dependence. While all of the participants in the low complexity setting besides one have switched to the favorable alternative within 25 rounds, only two participants of the high complexity setting succeeded to switch. The probability of lock-in differs significantly over both groups ($\chi^2 = 16.385$, $p < .001$), supporting hypothesis 1.

Information retrieval

The distribution of retrieved information over alternatives does not differ between both complexity settings (G_{lc} = .039 vs. G_{hc} = .095, t = 1.579, p = .127). Hence, hypothesis 2a is not supported by our data.

The distribution of retrieved information over attributes reveals Gini coefficients that show a significant difference between both complexity settings (G_{lc} = .044 vs. G_{hc} = .249, t = 5.134, p < .001): information distribution in the low complexity setting is even more distributed than in the high complexity setting. The results support hypothesis 3a.

The information retrieval behavior differs between both groups considering information related to the present decision round and information related to future decision rounds. When comparing the ratio of information related to the present rounds to all information, participants in the low complexity situation use a significant lower proportion than participants in the high complexity setting (M_{lc} = .361 vs. M_{hc} = .685; t = 3.633, p = .001). H4a is supported by the findings.

A mediation test procedure that considers categorical variables was applied (Baron & Kenny, 1986; MacKinnon, Fairchild, & Fritz, 2007) in order to test the influence of complexity on path dependency mediated by information retrieval variables.

The mediating effect assumed in H2b is not supported as there is no support for H2a.

The distribution of retrieved information over attributes does not function as mediator, as the mediating variable is not significantly related to “path dependency” when both complexity and the distribution of retrieved information over attributes are predictors of path dependency (b=7.314, se=5.314, Wald = 1.895, p = .169). Thus, hypothesis 3b is not supported.

The ratio of present to all information does not function as mediator to path dependency, as the mediating variable is not significantly related to “path dependency” when both complexity and the ratio of present to all information are predictors of path dependency (b=2.164, se=2.846, Wald = .578, p = .447). Thus, hypothesis 4b is not supported by the data.

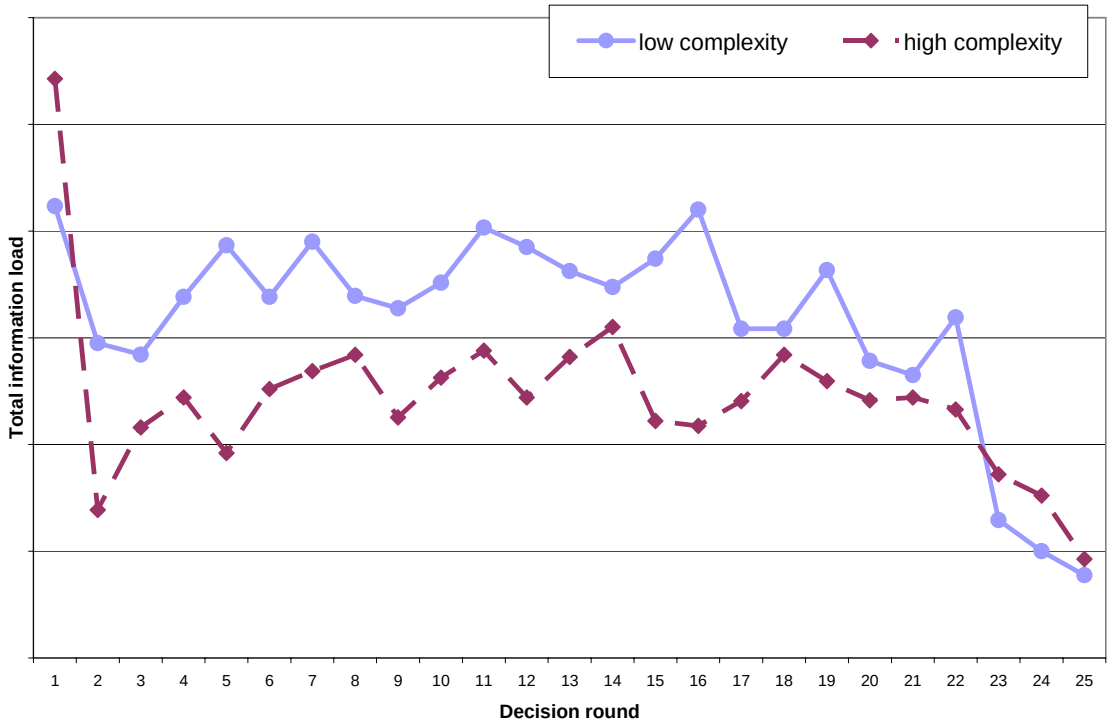
Stopping rule

The data show an overall tendency such that participants in a low complexity environment retrieve more information, although the difference between both experimental groups reveals only marginal statistical significance using a two-sided test (M_{lc} = 791.583 vs. M_{hc} = 610.800; t = 1.722, p = .097). This pattern is rather consistent when comparing the retrieved

information for each decision round (see Figure 7). Hence, hypothesis 5a is only partially supported by the findings.

Information load does not function as mediator, as the mediating variable is not significantly related to "path dependency" when both complexity and information load are predictors of path dependency (b=.001, se=.002, Wald = .028, p = .868). Hence, hypothesis 5b is not supported by the data.

Figure 7: Total information load per decision round in low vs. high complexity settings



Decision

Complexity impacts decision quality. Between round 1 and 20 (i.e., those rounds where participants are able to switch between alternatives without being locked-in), participants in the low complexity setting make more often the right decision than participants in the high complexity setting (M_{lc} = 18.250 vs. M_{hc} = 15.133; t = 2.467, p = .021). Hypothesis 6a is supported by the data.

Decision quality is a mediator for the effect of complexity on path dependency: regressing path dependency on both complexity and decision quality shows that complexity has a significant impact on path dependency (b=-3.860, se=1.500, Wald = 6.624, p = .010) and decision quality has a marginal significant impact on path dependency (b=-.596, se=.322, Wald = 3.428, p = .064). The effect of complexity on path dependency is higher when

dropping the mediator (b=-4.270, se=1.291, Wald = 10.931, p = .001) which indicates partial mediation (Baron & Kenny, 1986). Hypothesis 6b is supported by the data.

Does information retrieval mediate the effect of complexity on decision quality? The mediating effect for the focus on alternatives assumed in H2c is not supported as there is no support for H2a.

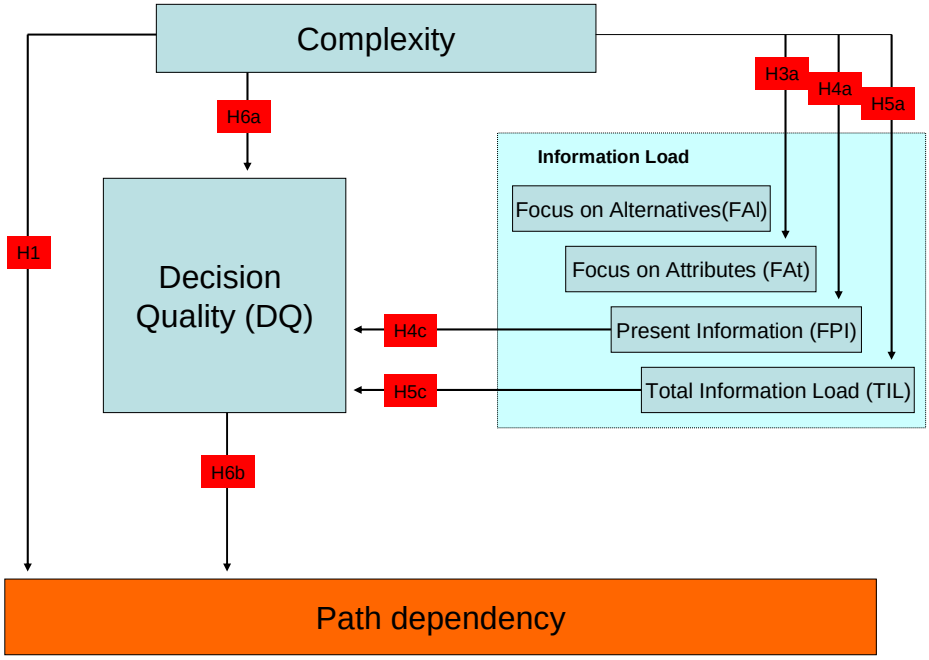
There is no mediation effect for the focus on attributes as assumed in H3c as the effect of the Gini coefficient in the regression model where both complexity and the Gini coefficient are used as predictors is not significant (b=8.785, se=6.202, t=1.416, p = .169).

However, the proportion of present information which depends on complexity as shown above fully mediates the effect of complexity on decision quality: Regressing decision quality on the ratio of information related to the present rounds to all information and complexity reveals a significant effect of the ratio of present information to all information (b=-7.186, se=2.487, t=2.889, p = .008) but a non-significant effect of complexity (b=-.785, se=1.373, t =.572 p = .573). The data support H4c.

Regressing decision quality on information load and complexity reveals marginal significant effects for both predictors (complexity: b=-2.368, se=1.280, t=1.849, p = .077 and information load: b=-.004, se=.002, t = 1.795, p = .085). The effect of complexity on decision quality is higher when dropping the mediator (b=-3.117, se=1.263, t = 2.467, p = .021). However, such mediation effects should be interpreted with caution as complexity has only a marginal significant effect on information load (t = 1.722, p = .097). Hence, H5c is only partly supported by the data.

Figure 8 summarizes the confirmed hypotheses.

Figure 8: Framework and set of confirmed hypotheses



Discussion

The results show that complexity leads to path dependence. This finding can be more thoroughly explained by mediating mechanisms. Decision quality is a mediator that explains the effect of complexity on path dependency. Furthermore, information retrieval explains how complexity leads to varying decision quality. The effect is fully mediated by retrieval of information related to either present or future: the proportion of information related to the present differs between decision makers in low and high complexity settings as decision makers in high complex settings use a significant higher proportion of information on present rounds. As a result, decision quality depends on that particular kind of information retrieval behavior. Hence, path dependency results from poor decisions that are due to the fact that people in highly complex situations tend to neglect future developments at the expense of information on present situations. All other kinds of information retrieval behavior do not show such an effect, although the results for total information load indicate a marginal significant mediator effect. To the best of our knowledge, previous research has neglected such a focus-on-now-heuristic. While there may be a variety of heuristics that can be successfully applied in order to reduce complexity, not all of them lead necessarily to path dependency. Up to now the research on decision making heuristics is much focused on one period decision making situation by exploring information retrieval strategies in the

dimensions of alternatives and cues. Introducing a time dimension opens a new perspective in order to better understand decision making in the real world.

The lack of further information retrieval behavior on path dependency is indeed a very surprising result, because that means that the significant differences in the information load do not lead to a lower information quality in terms of unrecognized relevant information ("hidden costs"). In other words, also in the high complexity setting participants were able to detect the relevant information even with a more focused information load on FAt and FPI and a lower TIL. We analyzed the verbal protocols in order to test this counterintuitive result by coding for each decision round whether a participant mentions the relevant costs (i.e., WAP costs which are most relevant to detect the rationality shift) or not. We calculated the ratio of rounds where the relevant costs were mentioned to all rounds. As our results show no significant difference between low and high complexity groups, there seems to be no difference in recognizing the relevant costs depending on the level of complexity.

Therefore, we assume that complexity has no impact on path dependency in a classical sense of "myopia", meaning that a higher level of complexity leads directly to lower quality of information which in turn increases the probability of getting path dependent. Obviously, also the participants in the high complexity settings have applied an information load heuristic which provides sufficient information quality and that on the basis of less total information load and higher focused information on attributes and present information. Definitely this phenomenon needs further exploration, nevertheless it is already a first indicator that complexity as such could not be considered a stand alone driving force for path dependency. This effect has to be tested in future research by manipulating complexity in settings with and without increasing returns.

Decision quality is directly influenced by complexity and works as a mediator on path dependency. Hence, complexity does not lead to differences in information quality (in terms of the availability of relevant information indicating the rationality shift) but in decision quality. That means that participants in the high complexity setting – even if they are aware of the rationality shift – do not switch over to a better alternative. This effect is mediated by information load in terms of FPI and a lower TIL and hence these differences in the information load obviously have an impact of how decisions are made. The explanation for that relationship is twofold but both aspects are complementary and may reinforce each other.

Firstly, even if participants are aware of a rationality shift they may weight the available information differently due to complexity, because they are also aware about their information

gap (recognized with the ratio between gathered information and total available information) and their focus on present information which both increase with complexity.
Secondly, in path dependent processes we can distinguish two types of information: the first type is defined by the decision environment (DE) containing all the relevant information on the present and the future; the second type of information is feedback (F) which provides only information about the past. In path dependent processes the feedback is increasingly positive and it provides an accessible environment for the decision maker, whereas DE is less accessible the more complex DE will be. Now, for making decisions only DE is relevant but if decision makers have a limited access to DE due to complexity then they have to infer DE by relying probably on F and assuming a correlation between DE and F (Goldstein & Gigerenzer, 1999). Consequently they infer future information by relying on past information. If this inference occurs complexity increases the decision makers´ orientation to F. Now, with the occurrence of a rationality shift the inference validity decreases but nevertheless the decision makers in the high complexity setting stay with their decision, whereas the decision makers in the low complexity setting switch to the more attractive alternative.

Therefore we can assume that a higher degree of complexity under the condition of increasing returns leads to the application of a decision heuristic in which the inference validity (built up by increasing returns) becomes constitutive even for making decisions in changing environments. This may result in two complementary effects of complexity on path dependency: The more complex DE the more decision makers have to infer DE and the more they infer DE the less likely they revise the inference validity. Also this phenomenon needs further exploration and has to be tested in future research by manipulating the strength and endurance of increasing returns in different complexity settings.

Limitations

Although the results provide several new insights into mechanisms underlying path dependent decision making, the study is preliminary as there are some limitations. We choose a rather arbitrary number of five decision rounds between the rationality shift and path dependency.. The likelihood of switching to the superior alternative and avoiding path dependency may depend on the number of rounds between both events: with an increasing number of decision rounds, also participants in high complex settings could be able to overcome the lock-in if the effect of a focus on present information (FPI) is compensated over time. This has to be tested by expanding the time span between rationality shift and path dependency. Hence, a trade-off

between time and complexity seems a reasonable assumption, such that time may be able to compensate the effect of complexity. However, as real decision making usually takes place in complex environments and restricted time frames, the assumption of a restricted number of decision rounds between rationality shift and path dependency seems a reasonable one in order to provide insights into real decision making. Another limitation is certainly the small group size which reduces power in the analysis. Although small group sizes are not uncommon in complex experimental designs, future research should rely on bigger samples which probably would lead to more clear-cut results of the analysis. Nevertheless, our analysis provides a couple of significant findings in line with our assumptions.

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