Complexity, Decision-Making and Cognitive Path Dependency: An Experimental Study

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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 also be affected by contextual factors such as different degrees of complexity. Up to now it is unclear whether and how complexity impacts 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. 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. The results are 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, this paper makes a further contribution by establishing experimental research for path-dependency issues.

Keywords

Complexity; Decision Making; Heuristics; Path dependency;

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 as well as the loose and diffuse links between action and outcomes render such settings inherently ambiguous and they are 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 fields it is quite unclear if and what kind of impact relates 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 is assumed as given and therefore kept constant. This does not mean that context is irrelevant, but is considered in the form of fixed premises (e.g., as a non-sponsoring rule (Arthur, 1989) which frame the process). Instead, in North's conceptualization of path dependency context provides a necessary precondition. Without imperfect markets and thus the occurrence of transaction costs there is no path dependency at least in cases where path dependency is 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).

Also in Pierson's consideration self-reinforcing effects are the crucial factors; nevertheless, he puts much more attention on the role of contextual influences on path dependency in order to underline his central argument of political systems being more prone to path dependency 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 conceptual and empirical research regarding that 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 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 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 could also 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 such a 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 provides an ex-post explanation (see also Mahoney, 2000). This is especially problematic for empirical studies based on single or just a 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; 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 of 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 the effect of this factor and to control for possible interferences on both the contextual level and the level of self-reinforcement. Focusing on complexity as a possible contextual impact factor for path dependency, we rely on crucial insights from complexity theory and especially from psychological research on decision-making heuristics.

The outline of the paper is as follows: 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 theory and psychological research on decision-making heuristics. Building on these insights, we deduce our hypotheses which are presented in the following section. Finally, we present and discuss the results of the study.

Path-dependency theory

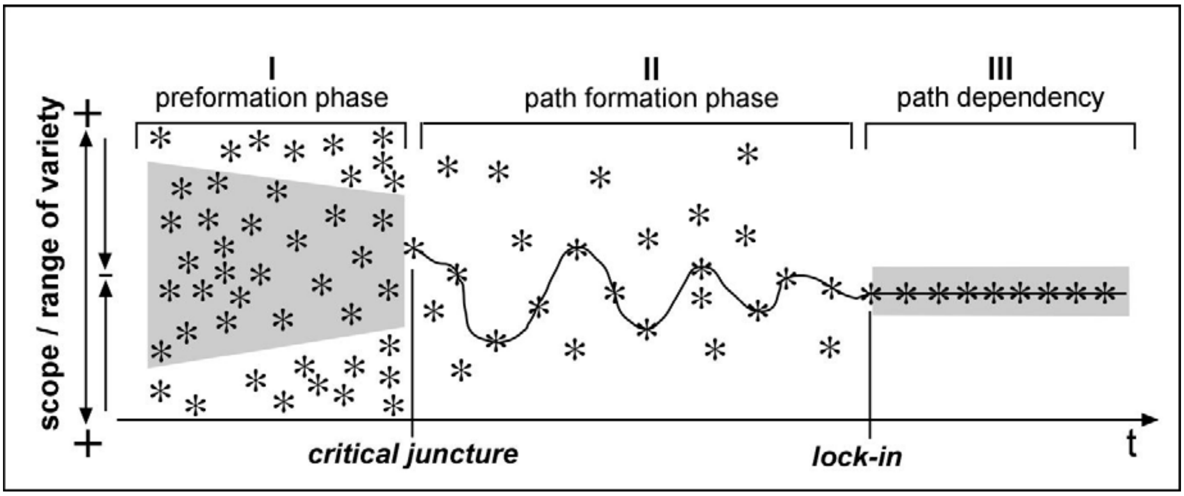
Path dependency is a dynamic theory assuming that initial decisions can increasingly restrain present and future choices. The theory originates in the historical studies of David (1985, 1986) who explored the development of QWERTY keyboard technology of. He shows how an inferior and inefficient technological 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 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, Schreyögg & Koch (2005) have reconceptualized this process in a 3-stage model (see Figure 1).

Figure 1: The constitution of a 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 constitute 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 guide them more and more in a particular direction. If this is the case, decision heuristics 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. Thus, the potential inefficiency refers to a rationality shift that indicates a relevant change in the environment and makes another choice more attractive while it is impossible for the focal system to make such a choice due to lock-in.[1] However, a rationality shift may occur even before a system is locked-in. It is likely 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 take advantage of the remaining range of variety in order to switch to the 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 still perceives itself as successful (see for instance Miller, 1993). 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 (Koch, 2008). 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.

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.

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 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 encourage path-dependent processes as well (Pierson, 2004); see also (Beyer, 2005). We will now focus on complexity as such a potential contextual factor.

Complexity theory, decision making and path dependency

According to Anderson (1999) complexity can be understood as a structural variable that "can be equated with the number of different items or elements that must be dealt with simultaneously" (Anderson, 1999). Thus, complexity refers 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, 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 most important implication is that complexity leads to a situation where 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 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-defined, 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 bounded rationality, a decision-making system is unable to realize and to compute any possible relation between information elements in complex situations. 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. „The degree to which heuristics are used depends on the decision-making context“ (Åstebro & Elhedhli 2006). The higher the degree of complexity the faster and the more frugal heuristics have to be in order to work efficiently under such conditions (Rieskamp & Hoffrage, 1999).

There are many different forms of heuristics (for an overview Gigerenzer & Todd 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 that characterize a specific heuristic: (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 likely due to less information retrieved.

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 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 good decisions on the basis of less information. However, to the best of our knowledge there is no specific research on the functionality of heuristics under the conditions of increasing returns and rationality shifts. In a path-dependent process successful decision making requires the ability for detecting relevant changes while there is still positive feedback for an option chosen once previously. For that reason, we 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 becoming path dependent. Therefore, we assume:

H1: High (versus low) complexity enhances the probability that a decision maker becomes path dependent.

Besides testing the hypothesis of whether complexity indeed leads to path dependency, we further try to explore the way ***how*** complexity has an impact on path dependency. Referring to heuristic-based principles of decisions, 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.

(1) Information retrieval (IR)

When 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 attributes. Many studies have shown that a higher amount of alternatives leads to the increase of non-compensatory strategies (e.g., Billings & Marcus, 1983; Timmermans, 1993) which 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 refers to a further dimension: time. The distribution of retrieved information over time 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 the best of our knowledge this effect is not considered in studies dealing with heuristics and decision making and points to a research gap in that field. Assuming that future information has a higher degree of uncertainty, then the explanation of such an effect would be quite clear. When we consider the manipulation of complexity the assumption of an effect 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 the form of a minimum optimal quantum of information (for example, in order 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 decisions. 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 process information on future periods. Therefore, we assume that a higher level of complexity increases the focus on present information.

To sum up, we deduce the following three hypotheses:

H2a: High (versus low) complexity leads to higher focus of information load on specific alternatives FAl (versus equally distributed over all alternatives).

H3a: High (versus low) complexity leads to higher focus of information load on specific attributes FAt (versus equally distributed over all attributes).

H4a: High (versus low) complexity leads to higher focus of 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 that information retrieval is on one of the three dimensions (alternatives, attributes, and present time), the more probable a decision system is of becoming path dependent because of the more likely it is that relevant information may not be considered or may be considered too late. Therefore, we deduce that FAl, FAt, and FPI mediate the effect of complexity on path dependency such that complexity impacts those information-retrieval variables which impact path dependency. This reasoning results in the following three mediator hypotheses:

H2b: The focus of information load on specific alternatives FAl (versus equally distributed over all alternatives) mediates the effect of complexity on path dependency such that complexity impacts FAl which impacts path dependency.

H3b: The focus of information load on specific attributes FAt (versus equally distributed over all attributes) mediates the effect of complexity on path dependency such that complexity impacts FAt which impacts path dependency.

H4b: The focus of information load on present information FPI (versus future information) mediates the effect of complexity on path dependency such that complexity impacts FPI which impacts path dependency.

(2) Stopping rule (SR)

The second level regards the quantity of information retrieved which is regulated by a stopping rule (Gigerenzer & Todd 1999). Prior research has demonstrated that people who apply heuristics rely on different types of stopping rules to terminate information search (Browne & Pitts 2004). Stopping rules can be either cognitive (based on mental maps) or motivational (based on preferences, desires, incentives, deadlines and so on) in origin (see also for an overview of different types of cognitive stopping rules Browne, Pitts & Wetherbe 2007). In the present study, we refer to cognitive stopping rules in information search by keeping motivational aspects constant.

As we know from complexity and from information-processing theory (Anderson, 1999), complexity influences 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). A higher level of complexity may lead to an earlier stopping rule when time resources for making decisions are restricted. This is 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 that can be used for information retrieval. Thus, 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: High (versus low) complexity decreases the level of total information load (TIL).

H5b: The level of total information load (TIL) mediates the effect of complexity on path dependency such that complexity impacts TIL which impacts path dependency.

(3) Decision (D)

Finally, also the decision itself in terms of decision quality may be affected by complexity. It is assumed that information search influences the size and quality of the consideration set of alternatives as well as the alternative that is eventually selected (Bazerman 2006). Even if very fast and frugal heuristics could lead to good decisions that equal decisions of 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 undermines the quality of decisions. The worse the decisions are, the higher the probability is for a decision maker to become path dependent. Therefore we assume:

H6a: High (versus low) complexity decreases decision quality (DQ).

H6b: The decision quality (DQ) mediates the effect of complexity on path dependency such that complexity impacts DQ which impacts path dependency.

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 FAl, FAt, FPI and TIL as mediators. These effects are basically important with regard to a possible impact on decision quality.

H2c: FAl mediates the effect of complexity on DQ such that complexity impacts FAl which impacts DQ.

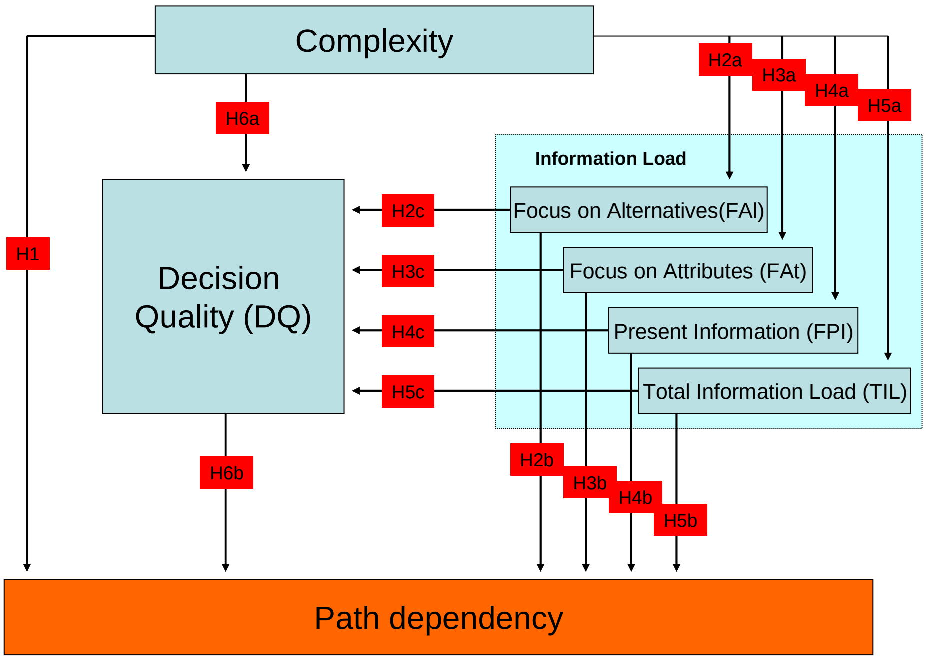
H3c: FAt mediates the effect of complexity on DQ such that complexity impacts FAt which impacts DQ.

H4c: FPI mediates the effect of complexity on DQ such that complexity impacts FPI which impacts DQ.

H5c: TIL mediates the effect of complexity on DQ such that complexity impacts TIL which impacts DQ.

Figure 2 summarizes the hypotheses and gives an overview about the assumed relationships between the different variables.

Figure 2: 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 different complexity settings due to varying offers of information 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) and were randomly assigned to the experimental groups. 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 fixed 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 fixed lines (per minute), costs for calls from mobile to mobile (per minute), costs for international 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 corresponding information. In each round, participants received feedback 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. Thus, we conceptualized path dependency in terms of a resource related form of lock-in. 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. Hence, none of the decisions is a decision under uncertainty. 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 could still 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 (i.e., path dependency is a resource related form of lock-in).

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, and multimedia messaging) remained rather stable. The differentiation between “focus costs”, “hidden costs” and “stable costs” is an analytical one and not obvious to the participants (i.e., the cost categories are not labeled as such).

While “focus costs” were decreasing all the time, favoring alternative A (Figure 3), the “hidden costs” were increasing for alternative A, favoring alternative B (Figure 4). 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 5). “Switching costs” were increasing over time (Figure 6), leading to a resource-related form of lock-in for those who stayed with alternative A until decision round 20.

Figure 3: “Focus costs”

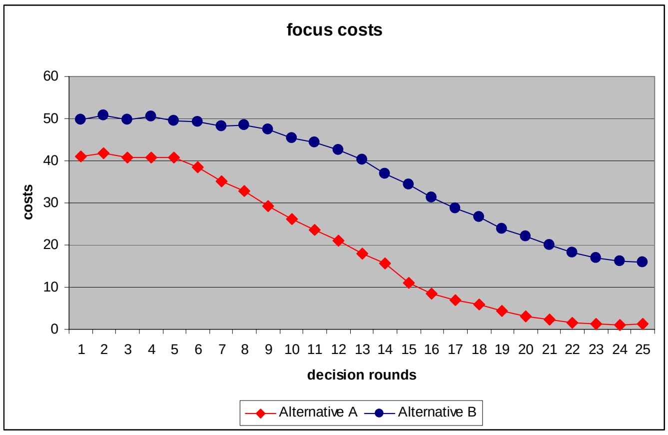


Figure 4: “Hidden costs”

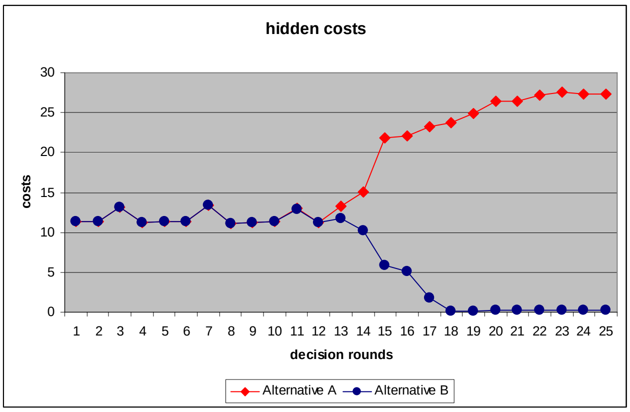


Figure 5: “Total costs”

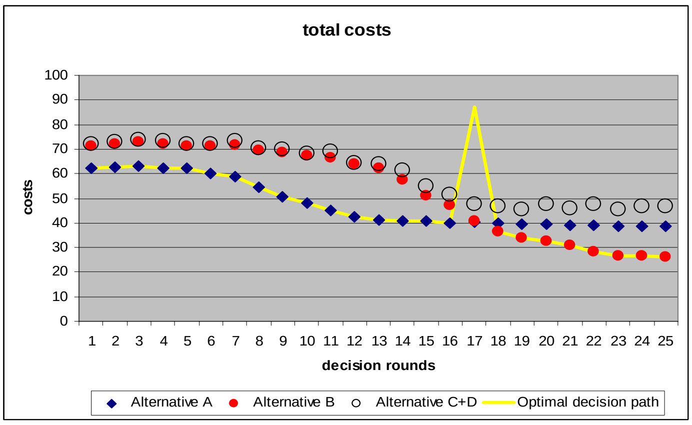
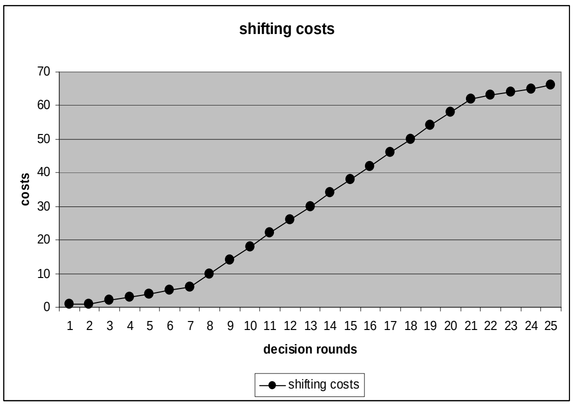


Figure 6: “Switching costs”



After arriving at the lab, the students were instructed on 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 each given 10 euros for participating in the study. In order to ensure that participants were kept motivated 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 fixed 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 international calls (per minute). Altogether, the lc setting provides an information display matrix of four alternatives by three attributes, while the hc 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 and the sum of the split-up costs in the hc setting were 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 and not confounded by other factors.

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 (DQ) and information retrieval in terms of focus on alternatives (FAl), focus on attributes (FAt), focus on present information (FPI), and total information load (TIL).

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.

DQ was measured by a dummy variable indicating whether participants were choosing the single best alternative in a decision round or not. For each participant and for decision rounds 1 to 20 (where participants were still able to choose without being forced to a make a particular decision due to 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 piece of information on the screen (e.g., WAP costs for alternative 1 in the present round).

FAl and *FAt* are 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).

FPI was measured by the ratio of information related to the present rounds to all information that were retrieved per round.

TIL 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 lc setting besides one have switched to the favorable alternative within 25 rounds, only two participants of the hc setting succeeded in switching. The probability of lock-in differs significantly over both groups ($\chi^2 = 16.385$, $p < .001$), supporting hypothesis 1.

(1) Information retrieval (IR)

FAl 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.

FAt 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 lc setting is more equal than in the hc setting. The results support hypothesis 3a.

FPI differs between both groups considering information related to the present decision round and information related to future decision rounds. Participants in the lc situation show less *FPI* than participants in the hc 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 *FAl*, *FAt*, and *FPI*.

The mediating effect assumed in H2b is not supported as there is no support for H2a which is a necessary condition for a mediation effect.

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

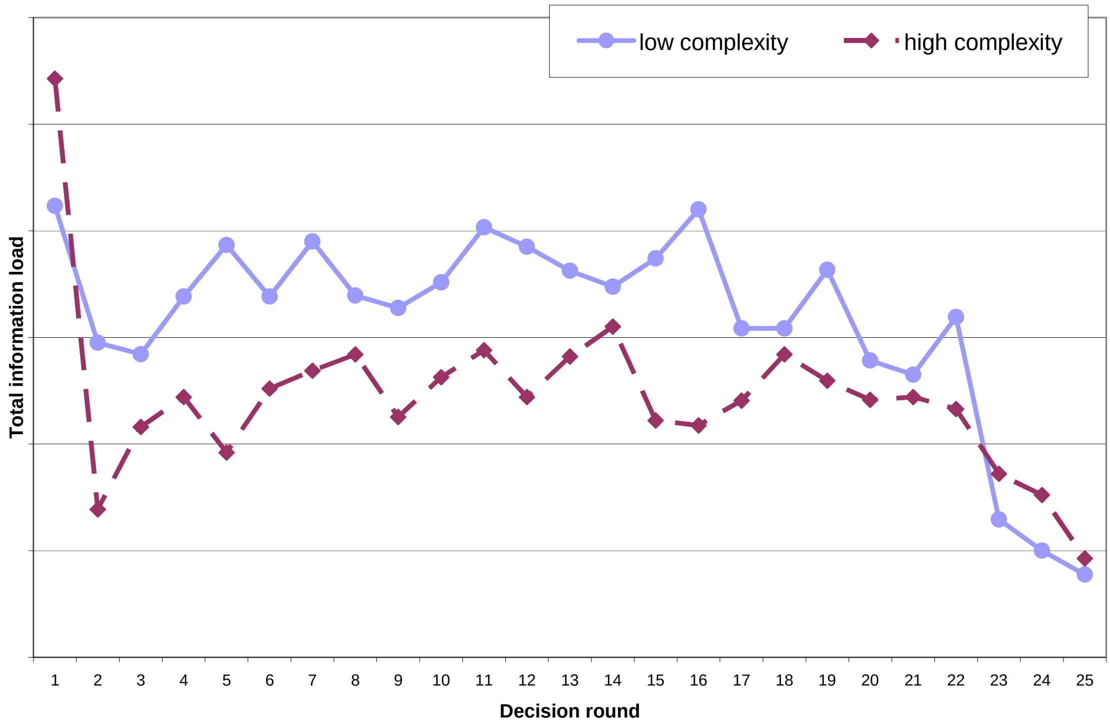
FPI does not function as mediator to path dependency, as the mediating variable is not significantly related to “path dependency” when both complexity and *FPI* are predictors of path dependency (b = 2.164, se = 2.846, $Wald$ = .578, p = .447). Thus, hypothesis 4b is not supported by the data.

(2) Stopping rule (SR)

The data show an overall tendency such that participants in a lc 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 *TIL* for each decision round (see Figure 7). Hence, hypothesis 5a is only partially supported by the findings.

TIL does not function as mediator, as the mediating variable is not significantly related to “path dependency” when both complexity and *TIL* 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 (TIL) per decision round in lc versus hc settings



Note: High TIl in the first round is due to the initial test decision round that lasted 300 seconds whereas all other rounds lasted 60 seconds.

(3) Decision (D)

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

DQ is a mediator for the effect of complexity on path dependency: regressing path dependency on both complexity and *DQ* shows that complexity has a significant impact on path dependency (b = -3.860, se = 1.500, *Wald* = 6.624, p = .010) and *DQ* 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.

Do *FAl*, *FAt*, and *FPI* mediate the effect of complexity on *DQ*? The mediating effect for the focus on alternatives as assumed in H2c is not supported as there is no support for H2a.

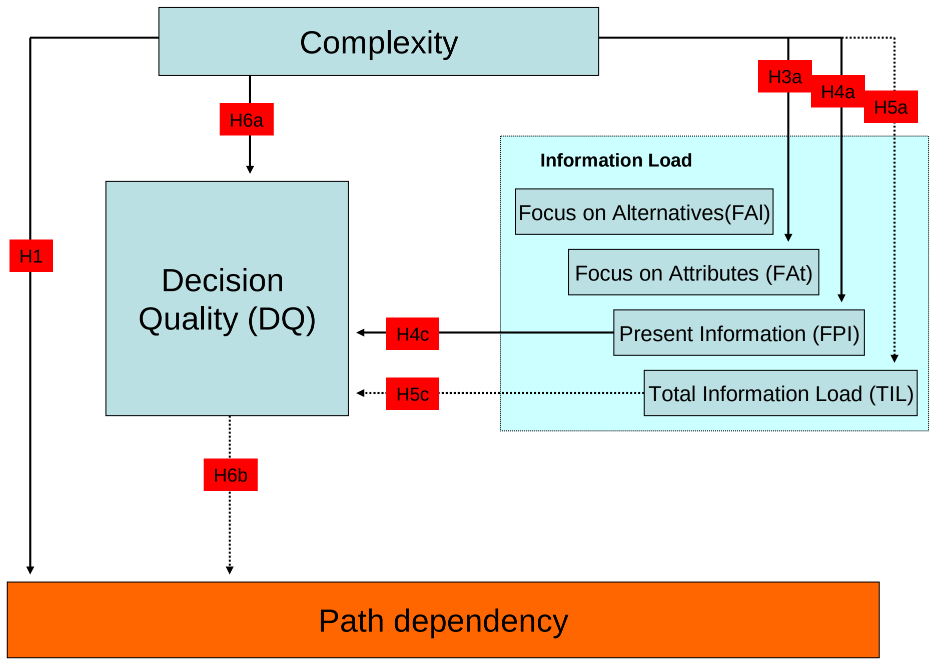
There is no mediation effect for the *FAt* as assumed in H3c as the effect of the Gini coefficient in the regression model where both complexity and the Gini coefficient are used as predictors is not significant (b = 8.785, se = 6.202, t = 1.416, p = .169).

However, *FPI* which depends on complexity as shown above fully mediates the effect of complexity on *DQ*: Regressing *DQ* on *FPI* and complexity reveals a significant effect of *FPI* (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 *DQ* on *TIL* and complexity reveals marginal significant effects for both predictors (complexity: b = -2.368, se = 1.280, t = 1.849, p = .077 and *TIL*: b = -.004, se = .002, t = 1.795, p = .085). The effect of complexity on *DQ* 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 *TIL* as shown above (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



Note: Bold arrows indicate significant relationships (p < .05) and dotted arrows indicate marginally significant relationships (p < .10) with p = .097 for H5a (and the mediation test in H5c) and p = .063 for H6b.

Discussion

The results show that complexity has an impact on path dependency. 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 the 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 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 necessarily lead to path dependency. Up to now the research on decision-making heuristics is focused on one-period decision-making situations and explores information-retrieval strategies in the dimensions of alternatives and attributes. Introducing a time dimension opens a new perspective in order to better understand decision making in the real world.

Further on, the investigation of heuristics under the condition of increasing returns provides a new subfield of research on decision making. Obviously the functioning of heuristics relies on what is called “thumb rules”, sometimes also called “gut feelings”. In particular situations as analyzed by Gigerenzer (1999), these thumb rules may even increase the quality of decisions in comparison to decision making relying on more information. The logic of path-dependent processes, however, is to trigger and to pull decision-making systems in a specific direction by providing initially increasing positive feedback and hence triggering specific decisions. In our experiment participants in low versus high complexity situations applied different heuristics in terms of information retrieval and stopping rule that resulted in varying decision quality. Hence, there are different qualities of heuristics and not every heuristic is obviously able to prevent the path-dependency trap.

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 path dependency when the effect of a focus on present information is compensated over time. This has to be tested by expanding the time span between rationality shift and lock-in. 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 within restricted time frames, the assumption of a restricted number of decision rounds between rationality shift and lock-in situations 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. This is why we were also carefully interpreting results that are described as marginally significant: above all, the effect from decision quality on path dependency that is a main result of our study, is based on an effect size that reveals a *p*-value of .063, i.e., a value that slightly misses the usual cut-off criteria of .05. Although small group sizes are not uncommon in complex experimental designs, future research should rely on bigger samples (with group sizes of at least 20 participants) which would lead to more clear-cut results in the analysis. Nevertheless, our analysis provides a couple of significant findings in line with our assumptions as well as some interesting hints on the underlying mechanisms of path-dependent decision making.

Future perspectives: Towards a path-dependent decision-making model

The lack of an impact of further information-retrieval behavior (besides FPI) on path dependency is indeed a very surprising result, because that could mean 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 may be able to detect the relevant information even with a more focused information load on FAt and FPI and a lower TIL.

Results of an additional analysis provide preliminary support for this assumption. During the experiment, participants provided additional information on information-processing behavior in the form of verbal protocols. Participants were asked to describe in a few words how they came up with a decision after each decision round. In order to test our assumption, two of the authors coded independently whether a participant mentioned the *relevant costs* (i.e., costs for WAP services that need to be processed in order to detect the rationality shift) or not. Coding consistency was achieved in 95.31% of the cases (i.e., each round per each participant). Inconsistencies were resolved through discussion. Then, we counted the number of rounds in which the relevant costs were mentioned in rounds 11 to 25 (i.e., those rounds where the relevant costs differ between alternatives, see Figure 4). The ratio of the mentions of the relevant costs during those decision rounds does not differ between low and high complexity settings (M_{lc} = .576 vs. M_{hc} = .433; t = 1.322, p = .199). Hence, there seems to be no difference in recognizing the relevant costs depending on the level of complexity. However, we find a significant difference when we compare the mentions in round 17 to 20, i.e. the rounds between rationality shift and lock-in (M_{lc} = .909 vs. M_{hc} = .515; t = 2.229, p = .040). In these rounds the awareness of the relevant cost structure leads to dissonant information for participants who do not change to the now better alternative. Hence, there could be a special type of dissonance-reduction strategy (Festinger, 1957) in terms of a "crowding out effect" which leads to a "corruption of awareness": the recognition of relevant costs is suppressed. This effect may occur as the development of the relevant costs and the decisions taken in the past now run into conflict. However, this explanation has to be tested further in future studies. This could be done by manipulating the strength and endurance of increasing returns.

Still, our results show that complexity has no impact on path dependency in a classical sense of "myopia" (Miller, 1993; see also Tripsas & Gavetti, 2000), 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 despite of less total information load and higher focus on information on attributes and present information. Although this phenomenon needs further proof, our results provide preliminary evidence that complexity as such could not be considered a stand-alone driving force for path dependency. This effect has to be further explored in future studies 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 necessarily lead to differences in information quality (in terms of the availability of relevant information that indicate a rationality shift) but in decision quality. This may explain why some of the participants in the high complexity setting—even if they are aware of the rationality shift—did not switch to a better alternative. This effect is mediated by information load in terms of FPI and a lower TIL and these differences in the information load seem to have an impact on how decisions are made. Such effects are difficult to explain and have to be tested in future research. From the results of our study the explanation for that relationship could be twofold and both aspects could also be complementary and may in turn reinforce each other.

Firstly, even if participants are aware of the relevant costs they may weight the available information differently due to complexity which impacts the focus on present information.

Secondly, in path-dependent processes we 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 F is increasingly positive and it provides an accessible environment for the decision maker, whereas DE is less accessible the when complexity increases. 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 may increase the decision makers´ orientation to F. Now, with the occurrence of a rationality shift the inference validity decreases but nevertheless the decision makers in a high complexity setting may stick with their decision, whereas the decision makers in the low complexity setting switch to the more attractive alternative.

In this vein, it is very plausible to 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: With increasing complexity, 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.

Heuristics rely on only a few important cues and they make choices possible that are accurate and appropriate and provide ecological rationality by fitting to particular information structures (Todd 2007). „The central concept of simple heuristics is that of ecological rationality: how decision mechanisms can produce useful inferences by exploiting the structure of information in their environment.“ (Todd, Fiddick & Krauss 2000: 375)

In path-dependent processes the correlation between relevant cues and the to-be-inferred criterion is high (see also Richter & Späth 2006) only at the beginning of the decision process. The counterintuitive effect of “less is more” does not occur under conditions of increasing returns. Path-dependent decision-making processes resemble a multi-criteria decision process where conflicts between attributes emerge over time and the relevance of each attribute changes. Simple heuristics, however, require stability with regard to these factors (Fasolo, McClelland & Todd 2007). Therefore, fast and frugal decision making is appropriate only at the beginning of the decision process. In a similar vein also more recent studies challenge this „less-is-more" perspective (Bröder 2003; Newell, Weston & Shanks 2003; Newell & Shanks 2003; Garcia-Retamero, Hoffrage & Dieckmann 2007) and raise the argument that recognition enters inferences just like any other probabilistic cue (Pachur & Hertwig 2006).

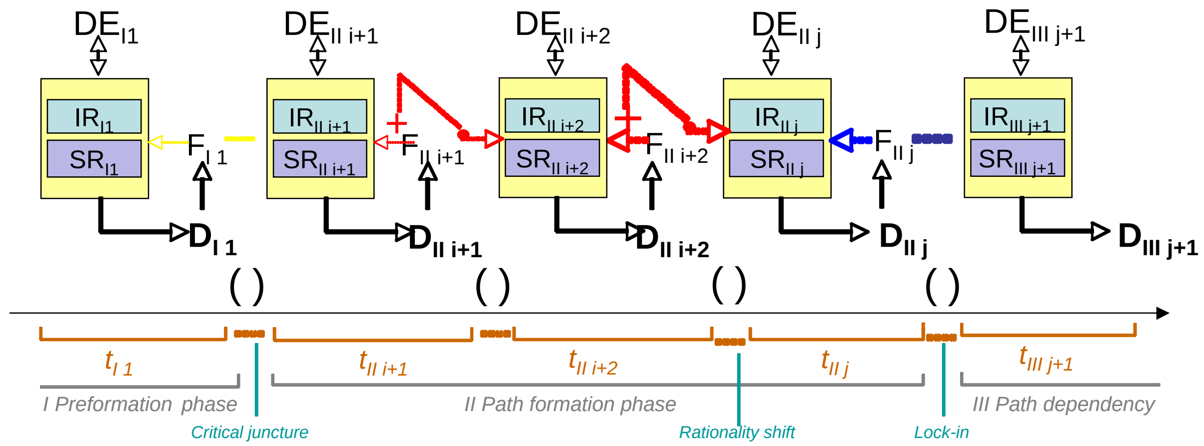
The probabilistic aspect also leads to the emotional side of path-dependent decision making. So far, only a few studies in the field of heuristics have paid close attention to specifying the complex ways in which emotion may shape decision-making processes (Muramatsu & Hanoch 2005). Introducing the idea of path dependency into this field of research would provide very fertile ground for future research.

As a guide for future research, we combine these insights with the theory of path dependency depicted in Figure 1 and provide 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 path formation phase; 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 i, i+1 to j, and j+1 to k)
- IR_{pt}: Information Retrieval in pt (for p = I to III and t = 1 to i, i+1 to j, and j+1 to k)
- SR_{pt}: Stopping Rule in pt (for p = I to III and t = 1 to i, i+1 to j, and j+1 to k)
- D_{pt}: Decision taken in pt (for p = I to III and t = 1 to i, i+1 to j, and j+1 to k)
- F_{pt}: Feedback perceived in pt (for p = I to III and t = 1 to i, i+1 to j, and j+1 to k).

The process of path-dependent decision making is depicted in Figure 9.

Figure 9: The process of path-dependent decision making



Note: 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 this model we refer to a rationality shift in phase II which will give decision makers the possibility to anticipate and prevent path dependency.

The model indicates the assumed double effect of F, not only by confirming an already taken decision but also by influencing future decisions as F impacts the whole processing of decision-making systems. Future research will have to investigate further this intriguing role of F in different settings of DE. The results from our study already indicate that the effect is itself complex rather than simple. Due to the fact that path dependency occurs unintentionally, it is also very difficult to further detect and reveal the cognition processes, due not at least to the threat of probably occurring Hawthorne effects: only by making participants aware of their cognitions are they able to describe them. Such awareness, however, may lead to follow-up decisions that differ from decisions that are made when participants have not been made aware of such cognitions.

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