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Complexity Aversion: Influences of Cognitive Abilities, Culture and System of Thought

Kai Duttle
Institute of East Asian Studies, Mercator School of Management, University of Duisburg-Essen

Keigo Inukai
Institute of Social and Economic Research, Osaka University

Abstract

Complexity aversion describes the preference of decision makers for less complex options that cannot be explained by expected utility theory. While a number of research articles investigate the effects of complexity on choices, up to this point there exist only theoretical approaches aiming to explain the reasons behind complexity aversion. This paper presents two experimental studies that aim to fill this gap. The first study considers subjects' cognitive abilities as a potential driver of complexity aversion. Cognitive skills are measured in a cognitive reflection test and, in addition, are approximated by subjects' consistency of choices. In opposition to our hypothesis, subjects with higher cognitive skills display stronger complexity aversion compared to their peers. The second study deals with cultural background. The experiment was therefore conducted in Germany and in Japan. German subjects prefer less complex lotteries while Japanese are indifferent regarding choice complexity.

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Contact: Kai Duttle - kai@kai-duttle.de, Keigo Inukai - inukai@iser.osaka-u.ac.jp.

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1. Introduction

Every decision we make in our daily lives is the result of a cost-benefit analysis of competing actions. Most of these decisions are made intuitively without us even realizing there were different options to choose from. Our brains have developed such that they rule out less efficient alternatives from the start, those demanding higher effort leading to the same outcome. While this concept is intuitive and well-documented in science for physical effort, only recently experimental evidence proved that it can also be applied to cognitive demand (Kool *et al.* 2010).

Quite naturally, systematical avoidance of cognitive demand can not only be found in automated choice assessments. A common marketing tool is the deliberately complex arrangement of products and prices. Kalayci (2015) shows in his experimental study that due to their bounded rationality, consumers' surplus decreases with more complex price structures. That is the result of inefficient product choices in the face of an overwhelming and intransparent market supply. Hayashi, Nakamura and Gamage (2013) extend this price partitioning framework to the labor market and examine the effects of wage surcharges on willingness to work. They find strong evidence for a negative partitioned pricing effect on workers' motivation, and that this effect results from cognitive limitations and complexity aversion.

The first attempt to explain this specific type of violation to the expected utility theory came from Neilson (1992). His model assumes that subjects build their preferences over the number of outcomes of a lottery and prefer less complex options. Humphrey (1998) extends this model and incorporates alternative explanations. As such, he considers non-linear probability weighting (Harless & Camerer 1994), a theory that is based on a model of lottery dependent utilities where the probability weighting function gets more concave as the complexity of the underlying lottery increases. As a second point he introduces event-splitting effects (Starmer & Sugden 1993; Humphrey 1995) into the model of Neilson (1992). An event-splitting effect occurs when an event is separated into two or more sub-events and this increases the relative attractiveness of the former lottery. This effect is a seemingly robust violation to the expected utility theory and largely consistent with Neilson's original explanation. Later experimental studies confirm the existence of a complexity aversion effect in subjects' decision making (Huck & Weizsäcker 1999; Sonsino & Mandelbaum 2001; Sonsino, Benzion & Mador 2002).

While a number of research articles investigate the effects of complexity on choices, up to this point there exist only theoretical approaches aiming to explain the reasons behind complexity aversion. The present paper presents two studies that aim to fill this gap. The first study considers subjects' cognitive ability as a potential driver of complexity aversion. The second study deals with subjects' cultural background. Both their nationality and their predominant system of thought are considered as explanatory variables. In cognitive psychology, members of Western societies are identified as more analytic thinkers while East Asians are found to reason more holistically. Analytic thinking involves understanding a system by thinking about its parts and how they work together to produce larger-scale effects. Holistic thinking on the other hand involves understanding a system by sensing its large-scale patterns and reacting to them.

2. Study 1: Cognitive Abilities

The experimental study outlined in this section approaches the question in how far cognitive skills play a role in decision behavior involving complexity. This research question is motivated by the works of Camerer & Hogarth (1999) and Rydval & Ortmann (2004) who point out the importance of participants' cognitive capital, in addition to monetary incentives, in the evaluation of laboratory studies' results. As for a methodological framework involving complexity aversion we build on Wilcox (1993) who also includes a cognitive costs parameter in his decision cost theory.

The intuition behind our research question is very straight forward. Higher cognitive abilities presumably decrease the mental effort needed to evaluate complex alternatives, and therefore they are likely to also decrease a bias towards the more simple option. In support of this hypothesis, Jones (2014) for instance finds that subjects with high ACT (American College Test) scores are more likely to use relatively complex strategies in a repeated prisoner's dilemma game. Furthermore, when presenting their subjects two alternative lines of action with different levels of cognitive demand, Kool et al. (2010) find a strong bias in favor of the less demanding course of action (law of least mental effort). Individual differences in cognitive ability thereby correlate with differences in avoidance behavior.

Three different complexity types are applied in this experimental study. For the first type, probabilities are presented as complex mathematical fractions instead of percentage values. So-called event-splitting is the second type of complexity. Thereby some or all events of a lottery are split such that the lottery gets larger. While a number of previous studies find an increase of perceived likelihood of a split event (Tversky & Koehler 1994; Rottenstreich & Tversky 1997; Fox & Tversky 1998), several other studies found the opposite effect (Sonsino *et al.* 2002; Redden & Frederick 2011) or no effect at all (Sloman *et al.* 2004). The third type is closely related to event-splitting. However, instead of presenting the split events as one single lottery, final payout events are the results of a multiplication of two distinct lotteries.

Cognitive abilities are measured using the cognitive reflection test (CRT; Frederick 2005). Despite its simplicity CRT scores quite accurately predict cognitive abilities, in particular with respect to mathematical skills. The CRT was designed to assess a specific cognitive skill, which is individuals' ability to suppress an intuitive and spontaneous wrong answer in favor of a reflective and deliberative right answer. The CRT was used in a number of studies to measure the effect of cognitive abilities on behavior (Oechssler, Roider & Schmitz 2009; e.g., Hoppe & Kusterer 2011). Like in the original study, this test is not incentivized but its questions are part of the final questionnaire that has to be completed by all subjects after the last stage of the experiment. Consistency of choices is found to be correlated with IQ-test results (Burks *et al.* 2009), students' GPA (Eckel 1999) and other types of cognitive ability measures (Chen *et al.* 2013). It is used as an additional proxy of cognitive abilities.

2.1. Experimental Design

The experiment was programmed in z-Tree (Fischbacher 2007) and sessions were conducted at elfe, the Essen Laboratory for Experimental Economics of the University Duisburg-Essen in Germany. 66 participants (44 male and 22 female) were recruited with ORSEE (online recruitment system for economic experiments; Greiner 2004) on a random basis among students with a major in economics or related subjects. During the experiment participants made a total of twelve independent investment decisions. The order of decisions was randomly determined for each subject. One randomly selected decision was paid out at the end of the experiment. All payout events were labeled with points instead of monetary values, with an exchange rate of 375 points = 1 Euro that was stated in the instructions at the beginning.

In each decision subjects can assign their budget endowment to a fixed payout, a risky investment option, or a mix of both. To be precise, they can assign between 0 and 100 percent of their endowment to the risky investment, while the rest of the budget remains as fixed payoff. Instead of an investment however, decisions are presented to subjects as choices of *preference*. Subjects do not invest their endowment, but they specify their preferences among a risk-free payout and a risky option. This neutral framing of the task is used in order to avoid a potentially negative perception of the term *investment*.

On top of the lotteries presented in this study the experiment also incorporated an additional number of lotteries that were equal in terms of payout events but differed in probabilities, such

that the expected value varied.[1] The risk-free payout was the same for all investment decisions and always smaller than the expected value of the risky option.

Risky options are constructed in order to compare decisions that differ in complexity while being equivalent in terms of payouts and probabilities. These lotteries consist of different payoff events with respective outcome probabilities. Table 1 displays all four types of risky options: a baseline lottery and three complex variations. The first complex variation presents payoff probabilities as numerical fractions instead of percent values. The event-splitting variation splits the lower payout events and presents each event as two or three distinct events with accordingly lower probability. The last complex variation consists of two lotteries, where the final payout equals the product of a multiplication factor determined by the first lottery and the payout determined by the second one. During the experiment subjects were equipped with a calculator.

Table 1. Risky options: baseline lottery and three complex variations.

Option		Probability	Payout (points)	Expected value (points)
Baseline		0.16	6000	3255
		0.12	4500	
		0.36	3000	
		0.18	2250	
		0.18	1500	
Fractioned probabilities		56/350	6000	3255
		21/175	4500	
		18/50	3000	
		27/150	2250	
		81/450	1500	
Event-splitting		0.09	1500	3255
		0.16	6000	
		0.05	2250	
		0.16	3000	
		0.06	1500	
		0.20	3000	
		0.11	2250	
		0.12	4500	
		0.03	1500	
		0.02	2250	
2-factor multiplication		0.30	750	3255
		0.30	1125	
		0.40	1500	
	multiplied by 2	0.60		
	multiplied by 4	0.40		

Info: All lotteries are equivalent in terms of payouts, probabilities and risk. Payout of the risk-free option was always 3000 points.

Complexity attitude of participants is determined by the difference in their investments in the respective lotteries. The investment in the baseline option thereby represents a reference point. If the investment of a subject in a certain complex variation of this baseline option is lower than the reference value, this implies an aversion towards the respective complexity type. Likewise, if the investment in the complex variation is higher than the investment in the baseline lottery, this implies an affinity towards the respective complexity type.

2.2. Results

For the subsequent first part of the analysis participants are divided in two groups according to their performance in the cognitive reflection test. Thereby those subjects with zero or one

[1] The risky baseline option (including respective complex lotteries) presented in this study was selected based on a high variance in investments and a low number of extreme (0 or 100 percent) choices. Results remain the same qualitatively if other lotteries are used for analysis.

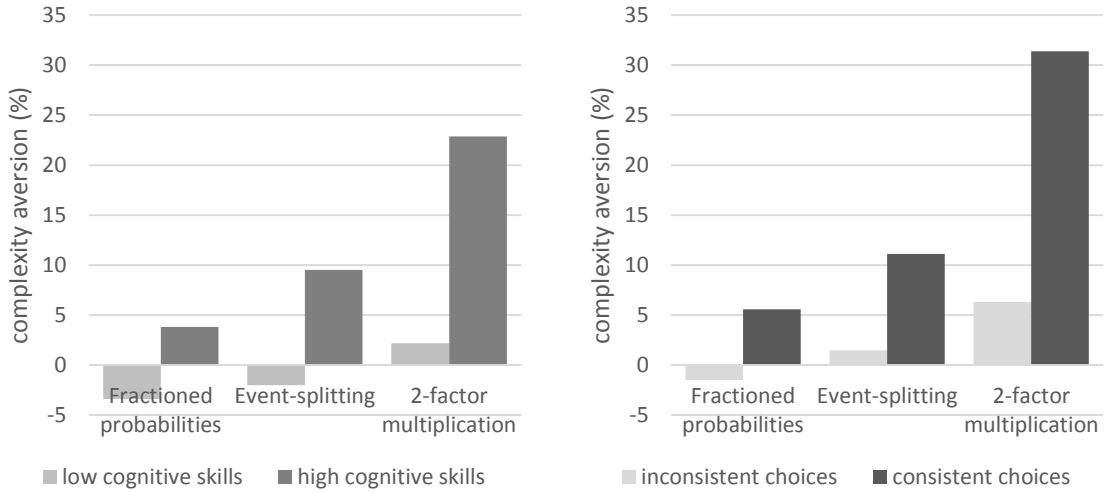
correct answer are assigned to the low cognitive skills group, while the remaining subjects with two or three correct answers are assigned to the high ability group. Table 2 summarizes the distribution of test scores for the 66 German subjects of Study 1, and the distributions for German and Japanese male participants that are discussed in Study 2, section 3.2. For a second part of the analysis subjects are grouped with respect to their consistency of choices. Subjects were entirely consistent in their choices with respect to the invested amount in risky options if for the baseline and all complex variations the investment in a certain lottery type was smaller or equal for lower expected payouts. The remaining subjects were inconsistent in their investments regarding at least one of the lottery types.

Table 2. Distribution of cognitive reflection test scores.

CRT score	0	1	2	3	mean	*N*
Germany: all subjects	24 %	23 %	24 %	29 %	1.58	66
Germany: male subjects	11 %	21 %	27 %	41 %	1.98	44
Japan: male subjects	2 %	11 %	23 %	64 %	2.48	44

Our hypothesis based on theoretical models and previous experimental results states that subjects with higher cognitive abilities should be less affected by complexity in choices. Figure 1 displays average values of complexity aversion for both high and low abilities groups, and for all three types of complexity. Thereby complexity aversion gives the difference in percent value investment of the risk-free endowment between the baseline lottery and the respective complex variation. Positive values denote aversion, negative values indicate an affinity towards the more complex option.

Figure 1. Average aversion to three complex variations. Left figure: by high or low performance in the cognitive reflection test; right figure: by consistency or inconsistency of choices.



Info: Number of observations is 66. Low cognitive skills group subjects scored 0 or 1 on the cognitive reflection test (*N*=31), members of the high cognitive skills group answered 2 or 3 questions correctly (*N*=35). Choices of 18 subjects were entirely consistent, while 48 subjects were inconsistent in their choices to some degree.

The results of our experiment do not support the hypothesis drawn from the literature. Quite the contrary, the expected patterns are exactly reverse. Preferences of subjects with lower cognitive abilities (based on CRT results) are not significantly affected by complexity. However, participants from the high abilities group are significantly averse towards the event-splitting (one-sided t-test, p=0.043) and 2-factor multiplication (one-sided t-test, p=0.001) types of complexity. Furthermore their complexity aversion is significantly higher compared to the low cognitive skills group for all three complex variations: fractioned probabilities (one-sided t-test, p=0.096), event-splitting (one-sided t-test, p=0.053), and also 2-factor multiplication (one-sided

t-test, p=0.011). By focusing on consistency of choices as a proxy for cognitive skills we observe the exact same pattern. Consistent decision makers that are presumably more intelligent than their inconsistent peers display much greater complexity aversion than these.

An additional correlation analysis does without dichotomizing cognitive reflection test scores and holds the same results. CRT scores are significantly correlated with the fractioned probabilities type of complexity aversion (0.23, p=0.06), with the event-splitting type (0.27, p=0.03), and also with the 2-factor multiplication type (0.31, p=0.01). We have to note that CRT scores are in general highly correlated with gender, such that male subjects typically perform better in the test than females. This correlation is also found in our data (0.5, p<0.001). In order to rule out the possibility that our results are driven by a gender bias rather than by differences in cognitive abilities, we repeated the above analysis for the larger male group (N=44) from our sample and found the same pattern. Subjects with higher cognitive abilities are more averse to complexity in choices than their peers with lower cognitive skills.

2.3. Conclusion

The results from this study are rather counter-intuitive and contradictory to previous literature results. Although all lotteries are equivalent in terms of payouts and probabilities, subjects with higher cognitive abilities prefer less complex lotteries while preferences of their peers with lower skills are not affected by complexity. One possible answer to this puzzle is that cognitively skilled subjects over-interpret the information given in this comparatively little demanding task and thus overestimate the amount of risk attached to the complex variations. Allred, Duffy and Smith (2013) find that subjects under a high cognitive load tend to exhibit behavior consistent with the reduced ability to compute the optimal decision. Therefore it would be interesting to investigate the impact of cognitive load on complexity aversion in a controlled experiment.

3. Study 2: Culture and System of Thought

This second study examines the effects of cultural background and the system of thought on attitude towards complexity. A large set of literature deals with differences in thought processes among Western and East Asian cultures. While members of Western societies tend to focus on salient pieces of information and consciously apply analytic reasoning, East Asians more heavily rely on contexts and can be described as intuitive and holistic thinkers. Westerners more often use rules and categorization in their way of thinking, whereas similarities and relationships are more important for East Asians. For example, Norenzayan et al. (2002) show that Westerners more often judge similarities among objects and categories based on a unidimensional norm, whereas East Asians tend to choose the category which is more similar to the target object holistically and on family resemblance angle. Masuda and Nisbett (2001) also found evidence for East Asians to think more context-dependent and holistic than Westerners do. In their study, Japanese and Americans had to describe animated vignettes of underwater scenes. Japanese more likely made statements about the relationships between objects and the context, whereas Americans more often described focal objects and salient attributions. By testing differences in their eye movements, Chua, Leu and Nisbett (2005) confirm the finding that Westerners and East Asians actually see different things when looking at the same picture. Chinese participants made more rapid eye movements all over the picture including the background compared to Americans, who more frequently fixated the focal object and concentrated longer on it. Also the physical environment in Asian countries is found to afford more holistic cognitive processes (Miyamoto, Nisbett & Masuda 2006)

There is no direct literature on how holistic or analytic thinkers perform in complex choice environments. One hint may be that in many Asian cultures, including China, Japan and Korea, social success depends on attentiveness to subtle social cues in complex interpersonal environments (Buchtel & Norenzayan 2009), which promotes holistic thought strategies and

potentially decreases complexity aversion. In addition, holistic and analytic thinking is found to be closely related to the dual process theory (Kahneman 2011) described by cognitive psychologists. This theory distinguishes between System I, the intuitive-affective thought strategy, and System II, the deliberative-analytic strategy. In a number of studies Dijksterhuis and colleagues (Dijksterhuis 2004; Dijksterhuis *et al.* 2006; Dijksterhuis & Nordgren 2006) develop the unconscious thought theory which states that in complex choice environments unconscious (intuitive-affective) thinking leads to better results than an analytic, conscious thought strategy. Although it is also subject to heavy criticism, this theory is supported by numerous experimental evidence (e.g., Dijksterhuis *et al.* 2006; Usher *et al.* 2011).

In the aggregate, previous literature thus predicts that Asians, and more holistic thinkers in general, are less affected by complexity in choices than Westerners and analytic thinkers. Two hypothesis derived from these findings are tested in this study. The first hypothesis states that Japanese subjects will be less affected by complexity in choices than German participants. The second hypothesis states that more holistic thinkers will be less affected by complexity than subjects applying an analytic system of thought.

3.1. Experimental Design

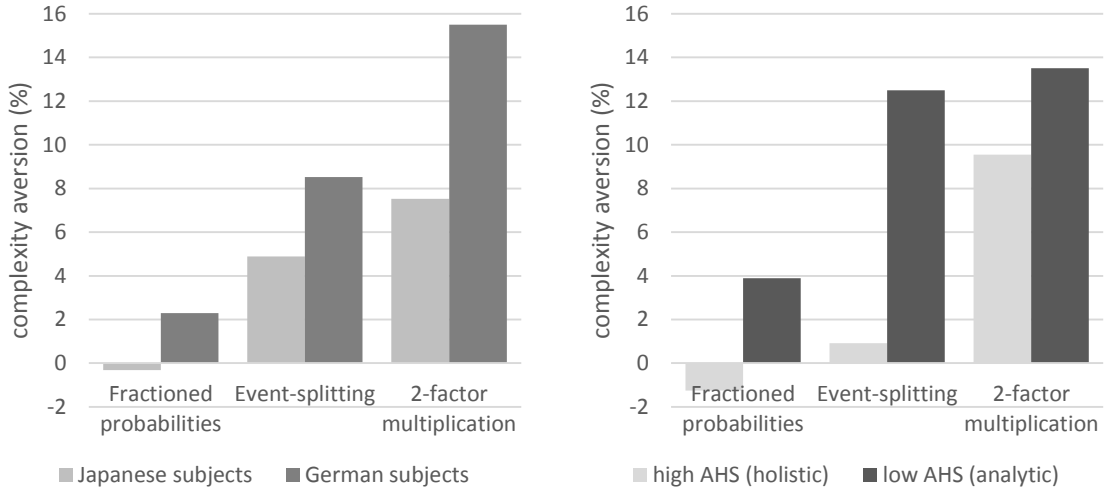
The experimental procedure of this study was similar to that of Study 1. In order to rule out a potential gender bias only male subjects were recruited for this experiment. Part of the data analyzed in this section is the same as in Study 1, namely the observations of the 44 male participants from Germany. Furthermore a total of 44 male subjects were recruited on a random basis among Osaka University students with a major in economics or related subjects. Sessions in Japan were conducted at the Institute of Social and Economic Research (ISER) at Osaka University. In line with common practices in cross-cultural experimental research, instructions were back-translated from German to Japanese by two independent native speakers. Furthermore local sessions were run only by the author of respective nationality in order to minimize potential experimenter demand effects. All payouts were labeled with points instead of monetary values, with an exchange rate of 375 points = 150 JPY that was stated in the instructions at the beginning. The 1 Euro : 150 JPY rate was based on average wages of student assistants in the two countries.

In order to control for the mode of thinking on top of cultural background we introduce an additional explanatory variable which is based on the Analysm-Holism Scale developed by Choi, Koo and Choi (2007). This scale is based on a 24-items questionnaire and measures four analysm-holism thinking dimensions: locus of attention (parts vs. whole), causal theory (dispositional vs. interactional), perception of change (linear vs. cyclic), and attitude toward contradictions (formal logic vs. naïve dialecticism). Subjects completed this questionnaire at the end of the experiment.

3.2. Results

Figure 2 displays the results from the analyses of the two hypotheses derived from previous studies. The left part shows average values of complexity aversion grouped by subjects' nationality, i.e. Japanese or German. The right part groups observations based on subjects' scores on the Analysm-Holism Scale. More holistic thinkers scoring above the median of all observations are assigned to the high AHS group, while more analytic thinkers scoring below the median belong in the low AHS group.

Figure 2. Average aversion to three complex variations. Left figure: by nationality of participants; right figure: by high or low Analysm-Holism Scale score.



Info: Number of observations is 88, with 44 male subjects from Germany and 44 male subjects from Japan. High AHS group subjects scored above the median on the Analysm-Holism scale and can be categorized as holistic thinkers (N=44). Low AHS group members scored below the median and thus tend to reason analytically (N=44).

Choice behavior of Japanese is not significantly affected by complexity. However, German subjects are significantly averse towards the event-splitting (one-sided t-test, p=0.030) and 2-factor multiplication (one-sided t-test, p=0.006) types of complexity. Differences between the groups are not significant such that we cannot statistically validate our first hypothesis. However qualitatively these results indicate that there is certainly something behind our assumptions. The same pattern also shows in the analysis of hypothesis two. Holistic thinkers are qualitatively much less affected by complexity in choices than analytic thinkers. This difference is significant for the event-splitting type (one-sided t-test, p=0.024). We can rule out cognitive abilities as a driving force in this context. Table 2 shows that, on average, Japanese perform much better on the cognitive reflection test than Germans which would suggest a reverse pattern from what we find in the cross-cultural comparison.

3.3. Conclusion

This study investigates the effects of cultural background and system of thought on complexity aversion. Our hypotheses state that the preference for a less complex option should be lower for Asians than for Western subjects, and that analytic thinkers are more affected by complexity in choices than holistic thinkers. The patterns found in our experimental data are very consistent with both hypotheses, yet by reason of our comparatively small sample size we can verify them only partly with statistical methods.

4. General Discussion

This paper presents two studies aiming to improve our understanding of a certain type of violation to the expected utility theory, which is complexity aversion. It describes the preference for less complex options that cannot be explained by expected payoff. The literature on this topic holds important implications for practical implementation. Complexity is commonly used as a marketing tool and also finds frequent application in banking and finance (e.g. savings plans, investment products). Therefore it is essential to know the effects of different types of complexity on subjects' preferences, but also the determinants of positive or negative attitudes towards complexity. International differences, as outlined in Study 2, may be of particular interest in this context.

The present work also provides several contributions to the scientific literature. Although in general subjects with high cognitive abilities are found to be less prone to behavioral biases, the aversion to certain types of complexity might state a robust exception. Future research on this topic will hopefully dissolve the puzzle outlined in Study 1. The analysis of holistic and analytic thinking in Study 2 contributes to the flourishing field of cross-cultural research in economics and psychology, and it is a good starting point for further research on the relationship between complexity aversion and the system of thought.

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