Availability of Information and Representation Effects in the Centipede Game

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Abstract

The paper presents the results of a novel experiment testing the effects of environment complexity on strategic behavior, using a centipede game.

Behavior in the centipede game has been explained either by appealing to failures of backward induction or by calling for preferences that induce equilibria consistent with observed behavior. By manipulating the way in which information is provided to subjects we show that reduced availability of information is sufficient to shift the distribution of take nodes further from the equilibrium prediction. Similar results are obtained in a treatment where reduced availability of information is combined with an attempt to elicit preferences for reciprocity, through the presentation of the centipede as a repeated trust game.

Our results can be interpreted as cognitive limitations being more effective than preferences in determining (shifts in) behavior in our experimental centipede game. Furthermore our results are at odds with the recent findings in Cox and James (2012), suggesting caution in generalizing their results. Reducing the availability of information may hamper backward induction or induce myopic behavior, depending on the strategic environment.

JEL classification: C72, C73, C91

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1 Introduction

The effects on observed behavior of apparently superficial changes in presentation are generally referred to as framing effects. Their existence[1] suggests that the game agents play is hardly ever identical to the canonical representation assumed by the experimenter. There are two layers of the subject's representation that can be affected by those changes: in some cases, an institutional format may elicit preferences that another does not; in others, the institutional format affects the players' understanding of the structure of the game. In terms of extensive form games, utilities only are affected in the former case, the game form and, as a consequence, utilities in the latter. Obviously, both mechanisms may be at work at the same time.

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[1]See, in genera,l Tversky and Kahneman (1981); for an application to games, see Kreps (1990); Devetag and Warglien (2003).

We perform two institutional manipulations on the centipede game to gather insights on the commonly observed patterns of behavior in this game. In particular, by manipulating the presentation of information about payoffs, we achieve a preference-neutral and a preference-non-neutral variation on the standard game, which we use to identify what is effective in shifting aggregate behavior in the game, distinguishing between preference-related and cognitive factors. As our manipulated institutional formats are more complex than the standard format, we can isolate the effects on behavior of (marginal) increases in complexity in a simple sequential game.

The centipede game (Rosenthal, 1981) has attracted experimental investigation mainly due to its counterintuitive theoretical prediction. The original centipede game is a two-player, finite sequential game in which the subjects alternate choosing whether to end the game ("take") or to pass to the other player ("pass"). The payoff from taking in the current decision node is greater than that received in case the other player takes in the next one, but less than the payoff earned if the other player were to pass as well. The player making the final choice is paid more from taking than from passing, and would therefore be expected to take. Iterating this argument, backward induction leads to the unique subgame perfect equilibrium: the game is stopped at the first decision node.

Starting from the first experimental evidence (McKelvey and Palfrey, 1992; Fey et al., 1996), studies have found that players fail to comply with this extreme unraveling prediction, even after a number of repetitions.

Probably due to the combination of the simplest possible sequential structure, a clear-cut equilibrium prediction, and a still rich and subtle strategic environment, the centipede has become a workhorse for theory testing. As simple as it may seem, the identification of the motivations underlying behavior in the centipede turns out to be a challenging task. The list of possible reasons why players may take actions that diverge from subgame perfect equilibrium turns out to be long and often twisted.[2] Broadly speaking, we can identify different families of explanations regarding the roots of deviations from equilibrium, depending on whether they rely on preferences (e.g., Dufwenberg and Kirchsteiger, 2004), on bounded strategic thinking (e.g., Palacios-Huerta and Volij, 2009; Kawagoe and Takizawa, 2008)[3] or on a combination of the two (e.g., McKelvey and Palfrey, 1992; Maniadis, 2011; Zauner, 1999).[4]

In a recent paper, Cox and James (2012) found that a strategically irrelevant manipulation of the institutional format by which two, otherwise identical, centipede games are represented can have a significant impact on behavior. In particular, they found that framing the game as a sequential auction, where the players are informed about the payoffs if buying in the current node but have to compute the payoffs for future stages by themselves, triggers an unprecedented proportion of behavior observationally equivalent to subgame perfect strategies. They interpret this finding as an instance of myopia arising from making information about the game less available.

Others, preference-non-neutral manipulations that were used on different games can also be applied to the centipede game. In an early example of preference-eliciting institutional manipulation, Evans (1966) and Pruitt (1967) presented results on the decomposed Prisoner Dilemma. In their experiments, a standard PD is compared to a decomposed version where one player choosing a strategy directly determines an allocation to both players, which is then summed to

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[2]Levitt et al. (2011) provide a nice example of such a list. A partial attempt to disentangle those reasons can be found in Atiker et al. (2011).

[3]This category actually includes departures from common knowledge of rationality (or incorrect beliefs) and correct beliefs but an imperfect best reply.

[4]Other relevant papers featuring theoretical and experimental analyses on the centipede are Nagel and Tang (1998); Rapoport et al. (2003); Ponti (1996).

the allocation chosen by the other player. In general, the latter presentation achieves significantly higher cooperation: the presentation of the PD as a sort of simultaneous trust game, which makes the give-and-take nature of the game salient, elicits preferences, most likely related to reciprocity, that the traditional version does not.

We exploit the two abovementioned institutional formats to investigate the role of preferences and cognitive limitations in shaping taking behavior in the centipede game. In our baseline standard treatment (*Tree*), the players are shown the standard game tree displaying the final payoffs at every terminal history. The first manipulation (*Formula*) is preference neutral and traces the *Clock* treatment in Cox and James (2012): the players are informed only about the progression of the payoffs throughout the game; as they proceed they are told the final payoffs were the game to end at that node, but have to compute the final payoffs for future decision nodes (if they so wish). The second manipulation (*Decomposed*) is identical to that of Pruitt (1967): the payoffs are decomposed in stage payoffs, so that every pass entails some losses for the passing player and some gains for the other player. To compute the final payoffs, the players need to sum up the stage payoffs to each terminal history. As before, they are informed about the final payoffs, were the game to end at the current node. The final payoffs, the rules of the game and their description, together with all other details of the design are identical across treatments, and exactly the same amount of information is available to the players, although presented in a different way.

Following Cox and James (2012), *Formula* could elicit myopia due to information being less available: facing some higher complexity, the players would focus only on the closest decision nodes and not consider the possible gains from passing. Note however that, in principle, the more complex environment could trigger an opposite effect: a player could find it harder (or more costly) to perform backward induction and pass through more nodes as she fails longer to recognize the strategic structure of the game.[5]

Those considerations apply as well to treatment *Decomposed*. On top of that, *Decomposed* could elicit preferences for reciprocity as the game is represented as a repeated trust game. If this is the case, and assuming additivity for the preference and the cognitive effect, then players should take later in *Decomposed* with respect to *Formula*.

We find two main novel results. With respect to the base treatment, both institutional transformations achieve later take nodes which are further away from the theoretical prediction: apparently, making information less available makes it more difficult for subjects to understand the strategic structure of the game,[6] with no evidence of myopia. We observed no difference between the preference-neutral *Formula* and the preference-non-neutral *Decomposed*: though we cannot properly separate cognition- and preference-based effects in *Decomposed*, it looks as if preference elicitation is ineffective in pushing the take nodes further away.

More notably, the first result is sharply at odds with results in Cox and James (2012): although we perform the same manipulation, our subjects take later where theirs take earlier. We interpret this gap as stemming from relevant differences in the base game: their centipede is extremely competitive and already complex in the tree format, whereas ours is a more standard, less competitive and simple game. Thus it looks reasonable that a reduction in the availability of information induces, in the former environment, no use of the information about distant nodes, resulting in myopic early takes, and only hampers backward induction (or reduced use of the information about distant nodes), in turn resulting in late takes in the latter. This apparent conflict suggests cautiousness about generalizations of the effects of complexity on strategic behavior and elicits

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[5]Both effects can be formalized following the *limited backward induction* approach in Mantovani (2012).

[6]Or, change the beliefs obout the others' ability to understand the strategic structure of the game.

new fascinating research questions on the topic.

The paper is organized as follows. In the next section, we describe the experimental design and present our main hypotheses. The actual implementation of the design in the lab is detailed in Section 3. Section 4 describes the results, and Section 5 concludes.

2   Experimental Design

We implement a twelve-legged centipede, with actions labeled "Stop" and "Continue". Terminal histories are ordered and assigned a number between 1 and 13 (Stop at first node: 1; ... ; Always continue: 13). The aggregate payoff at each terminal history is worth 5 times the corresponding number; the player choosing "Stop" gathers $\frac{4}{5}$ of the total value, while the opponent gathers the remaining $\frac{1}{5}$ (see Fig. 1).

The length and the linear increase in the joint payoffs distinguish our game from the most exploited experimental centipedes.

The length of the game is meant to allow more room for responses to relatively minor treatment variations to emerge and to enhance the relevance of sequential reasoning.

We chose an arithmetic progression with respect to the more common, geometric one (as in McKelvey and Palfrey, 1992) for two main reasons. The first, specific to our design, is that a linear increase (as a function of the decision node) makes the underlying formula easy to convey also to subjects with potentially low numeracy skills.[7] The second, more general, is to avoid the unpleasant choice the experimenter faces with geometric centipedes between a very short game, an exchange rate that makes initial payoffs economically irrelevant, or a geometric factor that makes the progression at first nodes virtually flat.[8] In our setting, it is possible to keep the range of payoffs in line with the literature while providing economic relevance to choices at all decision nodes, including the first ones. Our choice allows us to show payoffs directly in euro, with the first decision node entailing a payoff of $(4, 1)$ euro for the player controlling the node and the opponent, respectively, and a payoff of $(52, 13)$ euro if both players choose "Continue" at all decision nodes.

In this general framework, we implement three different ways of conveying the payoff information:

Tree: as is standard in the literature, subjects are shown the game tree that reports at each terminal history the final payoffs accruing to both players. The tree, as shown to subjects, can be seen in Figure 1. This condition replicates the standard way[9] to convey the centipede game in experiments.

Formula: the subjects are not shown the tree but only the formula to compute the payoffs. In particular, subjects are told that, when one player chooses "Stop", she earns four times the number of the current decision node, while the other earns an amount equal to the number of the decision node.

Decomposed: the subjects are shown the game tree, but, instead of final payoffs, the stage-payoffs, i.e., the variations with respect to the currently earned payoff, are shown for each

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[7]A pilot featuring a geometric progression was run, but proper understanding of the treatment "Formula" proved difficult, undermining the comparability of the results. All data and materials are available upon request.

[8]Rapoport et al. (2003) avoid the problem for a limited number of subjects in their "high stakes" treatment, bearing the risk of a potentially explosive budget. More commonly, the increase in payoffs at the first decision nodes is in terms of cents.

[9]In particular, the figure is identical to that in Palacios-Huerta and Volij (2009) and Levitt et al. (2011).

decision node. The tree, as shown to the subjects of the *Decomposed* condition, can be seen in Figure 2.

[Insert Figure 1 and 2 about here]

Thus the *Tree* and the *Decomposed* conditions conveyed infomation using a comprehensive visual representation of the game.[10] In the *Formula* condition, all information was conveyed by means of words.[11]

It should be noted that the players were given exactly the same amount of information under all treatment conditions, the only difference being its availability: in the *Formula* and *Decomposed* conditions, players have to compute endgame payoffs for future stages on their own. Given our payoffs, this step is, however, minimally demanding: it requires the computation of the four-times table or of simple integer sums, respectively.

Beyond being less available, the *Decomposed* structure presents the payoffs with a *give-and-take* frame, underlying the intrinsic nature of repeated trust game of the centipede and possibly eliciting reciprocal behavior.

The proposed game is the same in all treatments and the presentation variations are minimal. Considering these features, combined with the well-known learning dynamics in the centipede game, we opted for a pure between subjects design.[12]

Within each experiment, subjects repeated the game 12 times in a perfect stranger matching, implemented by using the turnpike protocol. This matching allows us to assure subjects that they will never play the same partner twice, and that their partners will never play one another, thus ensuring absence of contagion effects. Repetitions were meant to allow for learning, though still focusing on first response behavior. We also chose to keep the roles fixed across repetitions to restrict the confounding effects of identification.

In the following we formulaite our hypothesis. A first set of them regards the effect of the availability of information, thus comparing the *Formula* and *Decomposed* conditions to the *Tree* condition. As mentioned in the Introduction, one possibility is that the reduced availability of the consequences of passing in the *Formula* and *Decomposed* treatments may trigger myopic behavior (or beliefs of myopic behavior): subjects do not use information about efficiency gains and focus on immediate decision nodes, taking as early as possible. On the other hand, information being less available may not induce subjects to disregard it but only hamper their ability to reason backwards.[13] If that was the case, we would observe later "Stop" decisions.

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[10]The subjects, identified by color, were shown the full length of the tree and (final or stage) payoffs at each node. Moreover, every decision node was numbered and intuitively assigned to a player/color. The images in Figures 1 and 2 were both given to the subjects in a printed version as part of their instructions and presented on screen at every decision node; in the screen version, the red arrow would move to indicate the current decision node; moreover, all past decision nodes would gray out on screen. Both active and inactive players were shown the same set of pictures, the difference being that the inactive player faced no choice but was reminded of the choice that the matched player was considering at that moment.

[11]The part of the screen regarding the current decision node was identical to the *Tree* condition; with respect to the latter, a description of the rules of the game (including the formulas to compute the payoffs) took the place of the visual representation.

[12]The between subjects is a robust choice if the samples for the two treatments do not differ in underlying characteristics. This can be guaranteed either by a high number of subjects, or, alternatively, relying on subject's randomization. We chose to enlist a mid-sized sample but introduced several controls that allowed us to check whether a set of relevant subject charchatistics (age, gender, risk and trust attitudes) showed any particular bias across treatments.

[13]Our manipulations are close to cognitive load experiments (Shiv and Fedorikhin, 1999; Swann, 1990; Cappelletti et al., 2011, e.g.) in that we manipulate the level of cognition imposing or not imposing (computational) burdens on otherwise identical tasks. The hypothesis that reducing the availability of information may reduce subjects' strategic ability to reason backwards is consistent with the results in this literature, as reported by Devetag and Warglien (2003) and Duffy and Smith (2012).

Hypothesis 1.1. In conditions *Formula* and *Decomposed*, the subjects choose "Stop" earlier than in the *Tree* condition, due to myopia.

Hypothesis 1.2. In conditions *Formula* and *Decomposed*, the subjects choose "Stop" later than in the *Tree* condition, due to hampered backward induction.

Besides these cognitive effects, the *Decomposed* treatment should elicit more reciprocal behavior, resulting in the subjects passing longer in the game with respect to the *Formula* condition.

Hypothesis 2. In condition *Decomposed*, the subjects choose "Stop" later than in the *Formula* condition, due to enhanced reciprocity.

3 Experimental Procedure

The computerized experiment was run in Jena in June 2012, involving 210 subjects distributed over 8 experimental sessions. Seventy-two subjects took part in the baseline *Tree* sessions; a further 74 subjects participated in the *Formula* and 64 in the *Decomposed* conditions. The experiment lasted about 1 hour, and average payoff across all sessions and conditions amounted to 11.8 euro, including a 2.5 euro show-up fee.

All sessions followed an identical procedure. After subjects were allowed into the lab, instructions were read aloud and extra time was given to the subjects to go through them on their own. Then all subjects had to correctly answer a set of control questions before being allowed to proceed. The number of mistakes recorded in the questions, and the time needed to clear the control questions screen, were both recorded and used as an objective measure of the complexity of the treatment. During this phase, subjects could – and many did – ask help from the experimenters with going through the control questions.

After all subjects had cleared their control questions, the experiment started. Subjects were randomly assigned to their roles ("White" or "Black"), randomly matched, and proceeded to play the game. The same game was repeated 12 times, in a perfect stranger matching design. The pairs were allowed to proceed each at their own pace within the 12 decision nodes of the game but had to wait for all the other pairs between repetitions.

After completing the 12th repetition, subjects were paid according to the results of a randomly drawn repetition, and were asked to fill in a questionnaire. We gathered qualitative information about the expectations from the game and the opponent, the strategy followed, and the belief on the opponent's behavior. Moreover, we elicited self-reported quantitative measures of trust and risk aversion (using the SOEP German Panel trust and risk questions. For the risk question, see Dohmen et al., 2011) and of the perceived complexity of the task.

The experiment was conducted in German. The English version of the experimental instructions is available in Appendix C.[14]

4 Results

Aggregate behavior

Consistently with the bulk of the literature on the centipede game, the players did not adhere to the Subgame Perfect Nash Equilibrium but played on into the game. Moreover, there was

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[14] The original German instructions, along with the experimental software (developed using zTree, Fischbacher, 2007) and the raw data from the experiment, are available upon request.

some unraveling of the game: in all conditions, the average endnode became significantly lower with the repetitions (WRST, repetition 12 *vs.* repetition 1: *Tree*, *Formula* and *Decomposed*, all p-values < 0.001). This trend is monotone and qualitatively similar in all conditions,[15] with the partial exception of *Decomposed* where unraveling is reversed in the last two repetitions, in which the average endnode slightly (though not significantly) increased.[16] The average endnodes by repetition and treatment are summarized in Figure 4; the distribution of endnodes in the first and second 6 repetitions for all conditions is instead represented in Figure 3.

[Insert Figures 3 and 4 about here]

[Insert Table 1 about here]

Result 1: *In all conditions, the players do not adhere to the SPNE, reaching, on average, slightly more than a third of the game in the first stages. We observe slow but constant unraveling of the game toward the SPNE as repetitions are played.*

It should be noted that, with respect to the bulk of existing literature, the distance from equilibrium in our experiment is, on average, relatively low. Although it is hard to perform a direct comparison, this is consistent with Rapoport et al. (2003), in which imposing relatively high stakes from the first decision nodes resulted in closer-to-equilibrium play.

Treatment effects and test of hypotheses

In the following, we analyze treatment effects by making use of the hypotheses laid out in Section 2.

First both *Formula* and *Decomposed* result in *later* take nodes with respect to the baseline *Tree*. We hence find support for a lower incidence of backward induction (Hypothesis 1.2) and have to reject instead that choices are driven by myopia (Hypotheses 1.1).

When comparing the *Tree* and *Formula* conditions, we find a significant and strong treatment effect. In the *Formula* condition subjects stop the game about $\frac{2}{3}$ of an endnode later than in the *Tree* condition. This is true both when computing the overall mean across all repetitions (4.08 vs. 3.52, WRST p-value < 0.001) and when considering each single repetition: the average endnode of *Formula* is stably more than half a stage above *Tree* in each period, though not always significantly different (WRST, p-value < 0.05 in all but repetitions 1,11 and 12).

Moreover, a paired histogram of the distribution of endnodes in both conditions (Fig. 5) readily shows that the distribution for the *Formula* condition is shifted to the right with respect to the *Tree* distribution; testing equality in distribution (Kolmogorov-Smirnov 2-sample test, p-value < 0.001) confirms the significance of the difference.

[Insert Figure 5 about here]

Result 2: *In the Formula condition, subjects exit significantly later than in the Tree condition.*

The comparison between the *Tree* and *Decomposed* conditions reveals a similar pattern to the one between *Tree* and *Formula* but with slightly less statistical significance. This is due to the

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[15]Average reduction by repetition: 0.21, 0.24 and 0.22 in *Tree*, *Formula* and *Decomposed*, respectively

[16]More tests: WRST, repetition 6 *vs.* repetition 1: *Tree* p-value $= 0.024$, *Formula* p-value $= 0.014$, *Decomposed* p-value $= 0.198$; repetition 12 *vs.* repetition 7: *Tree* and *Formula*, p-values < 0.001, *Decomposed* p-value $= 0.06$. As discussed below, *Decomposed* generally shows a higher variance in behavior, which explains why significance is harder to achieve there.

fact that the variance of behavior is much higher in the *Decomposed* condition, especially in the first repetitions (see Fig. 3), possibly reflecting the higher self-reported and objective difficulty encountered by subjects in understanding the game (see below).

In the *Decomposed* condition, the average endnode is about $\frac{2}{3}$ of an endnode higher with respect to the *Tree* sessions, considering the overall average (4.17 vs. 3.52, WRST, p-value < 0.001;), but it is statistically significantly higher only in repetitions 3,5,6,11, and 12.

A paired histogram of the distribution of endnodes (Fig. 5) readily shows that the distribution in *Decomposed* stochastically dominates that in *Tree*; this is confirmed by a KS test (p-value < 0.001).

Result 3: *In the Decomposed condition, subjects exit significantly later than in the Tree condition.*

We find no support for Hypothesis 2: there is no statistical difference between the *Formula* and *Decomposed* conditions, once we discount the higher initial variance of the *Decomposed* condition. The mean endnode across all repetitions is not statistically different (WRST, p-value = 0.796). Moreover, the endnode is not statistically different in any of the single repetitions (WRST, all p-values > 0.356) apart from the last, in which unraveling stops in *Decomposed* but continues in *Formula* (WRST, p-value = 0.006).

In distribution, the two conditions are not statistically different (KS, p-value = 0.728).

Result 4: *The Formula and Decomposed conditions do not differ statistically.*

In Figures 3, 4 and 5 we observe an impressive similarity between *Formula* and *Decomposed*. Nevertheless, in the latter we observe a higher variance, concentrated especially in the first repetitions. This is likely related to the higher level of perceived complexity, as documented next.

Controls

The above results could be due to systematic differences in the composition of subjects taking part in the between treatments. Moreover, the questionnaire answers and the statistics gathered on the control questions allow us to see if and to what extent the treatment differences can be ascribed to comprehension problems. This section addresses these issues.

First, treatments did not differ for all the characteristics that we controlled for (age, gender, attitudes toward risk and trust). Treatments did not differ in terms of trust (WRST, all p-values > 0.12) and risk attitudes (WRST, all p-values > 0.08) of the subjects involved. The composition of the treatment also did not differ statistically by gender (WRST, all p-values > 0.64) and age (WRST, all p-values > 0.38). Hence, the treatment effects cannot be said to depend on heterogeneity in the observed subjects' characteristics.

Result 5: *Participants in the different treatments do not differ, on average, by age, gender, attitudes to risk, and indicators of trust in others and the society at large.*

In order to evaluate the complexity of each treatment, we both directly asked subjects to rate the perceived complexity and measured the number of errors in the answers to the control questions and the time spent completing the control questions screen. The game was significantly more difficult to understand for subjects in the *Decomposed* condition (Table 2), while there was no significant difference between *Formula* and *Tree* in both self-reported complexity (Wilcoxon Rank Sum Test, p-value = 0.444) and the number of errors (WRST, p-value = 0.253); in the *Tree* condition, though, subjects answered the control questions significantly faster than in the *Formula* condition (WRST, p-value = 0.007). On the other hand, *Decomposed* proved significantly

more complex in all indicators with respect to both *Tree* (WRST p-values: complexity = 0.034, errors 0.068, time 0.000) and *Formula* (WRST p-values: complexity = 0.003, errors 0.005, time 0.000).

[Insert Table 2 about here]

Result 6: *The Decomposed condition is more difficult to understand than both the Tree and Formula conditions, taking into account both self-reported and objective measures of complexity.*

Discussion

Our results are small in magnitude but significant and robust, especially when compared to our minor treatment variations: our subjects are all playing exactly the same game, having the chance of experiencing it 12 times, but despite this, differences persist consistently across repetitions.

Result 2 shows that a simple reduction in the availability of information can shift take nodes further away from the equilibrium with no sign of convergence through repetitions. Cox and James (2012) found exactly the opposite, performing the same manipulation: their centipede game is presented either in tree format or as a sequential Dutch auction, where subjects know the current price and are informed about future price decrements. Their result is interpreted as an instance of myopia, i.e., not using information about future nodes, while we interpret our result as evidence of more limited backward induction, i.e., reduced use of information about future nodes.

The apparent conflict can be defused by considering differences in the base game. Cox and James (2012) use an incomplete information game which is strategically identical to a centipede game under any belief about the opponent's payoffs. Moreover, the player who does not take always earns a payoff of zero, while the increase in the payoff, for the player who takes is relatively low. Those elements build up a setting that is both extremely competitive (strict efficiency gains are not possible) and complex even in the standard tree format. Facing a further increase in complexity due to the reduced availability of information, subjects stop exploring the strategy space deep into the game and just "take the money and run."[17] The same effect is not granted under games that are cognitively less demanding and exert less competitive pressure, as it is the case in our centipede game. Subjects are still affected by reduced availability of information, as they find it harder to reason backward and reduce the depth of their strategic thinking. However, this results in later take nodes.

If this interpretation holds, it suggests cautiousness in generalizing the effects of institutional format manipulations on strategic reasoning: behavior may react in different ways, depending on the underlying strategic environment. In particular, consistently with the results in Devetag and Warglien (2003), the observer should consider whether the game is complex enough for a marginal increase in the cognitive load to be able to trigger a shift to a simple heuristic (e.g., myopia) or just throw sand in the gearbox of strategic thinking.

Since in *Decomposed* we may be eliciting preferences for reciprocity, while reducing the availability of information, an immediate interpretation, combining results 3 and 4, is that cognitive limitations are more effective than preferences in shifting behavior in the centipede game. Indirectly, this would question interpretations of the results in the standard centipede game as

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[17]The manipulation in Cox and James (2012) also includes a language shift: in the auction, in order to take, the player must "Acquire" a good at a certain "Price", with the payoff being the difference between his private value for the good and the realized price.

driven by preferences, given that we know the same manipulation to shift behavior in games where preferences for reciprocity are relevant. However, we should be cautious with respect to this interpretation as it relies on a series of reasonable but additional hypotheses; namely that the effects of preference elicitation and reduced availability of information are additive and that preferences are not endogenously affected by marginal (pure) increases in complexity.

5 Conclusion

The failure of subgame perfect equilibrium in the centipede game has attracted a number of scholars, their explanations focusing either on cognitive limitations that hamper backward induction or on preferences that mandate different equilibrium strategies.

In this paper, we made small institutional changes to a centipede game that vary the way in which information is provided to the subjects, performing a preference-neutral and a preference-non-neutral manipulation. We show that making information about future payoffs less available is sufficient, on average, to significantly delay the decision to take. As this can be attributed to a more limited ability to backward induct, this result supports the potential of cognitive limitations to determine behavior in the centipede game.

On the other hand, highlighting the repeated-trust-game nature of the centipede game, i.e., by presenting the payoffs in a *give-and-take* frame, has apparently no further effect.

Our results are starkly at odds with those in Cox and James (2012), where performing a manipulation similar to our preference-neutral one significantly anticipated the decison to take. Given that our baseline game widely differs from theirs – woth our game presenting a much simpler strategic environment – this conflict suggests that reducing the availability of information can hamper backward induction (i.e., cause reduced use of the information about some future nodes) or induce myopic behavior (i.e., cause nonuse of the information about some future nodes), depending on the circumstances. Exploring which factors lead to which of the two outcomes is an exciting research question to be explored by future work.

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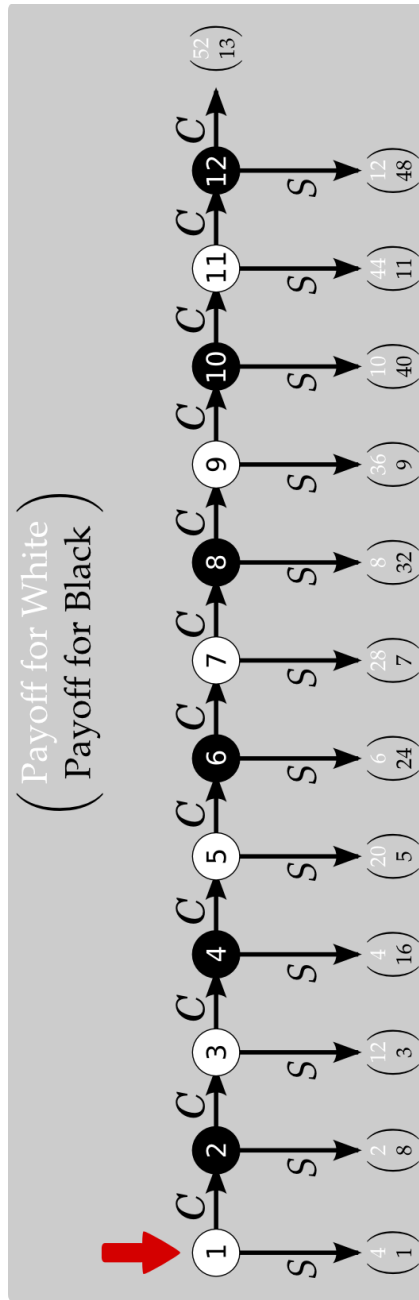
A Figures

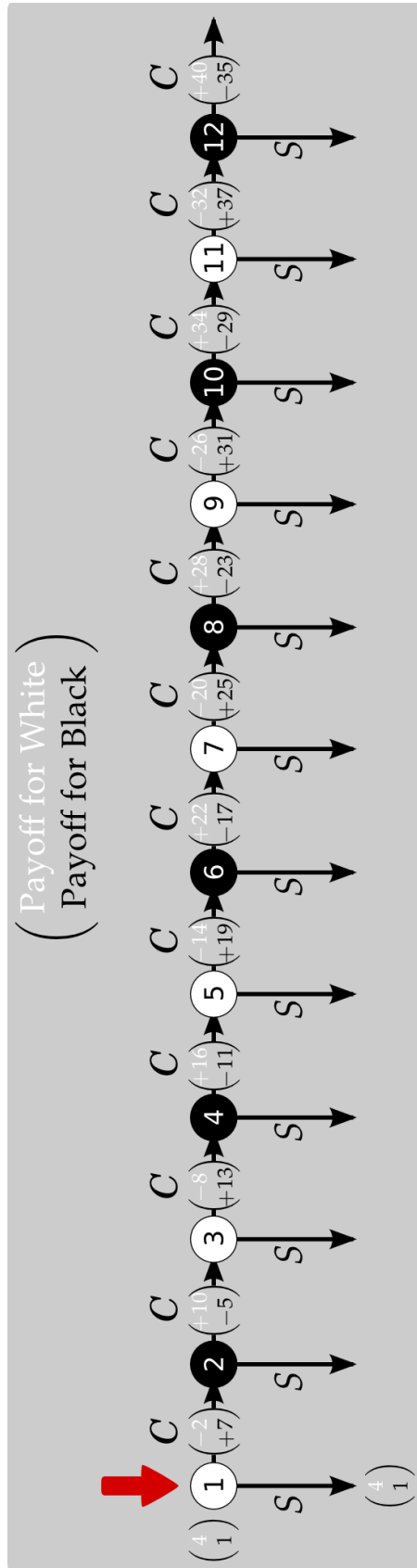Figure 1: The game representation in the *Tree* condition, payoffs in euro

Figure 2: The game representation in the *Decomposed* condition, payoffs in euro
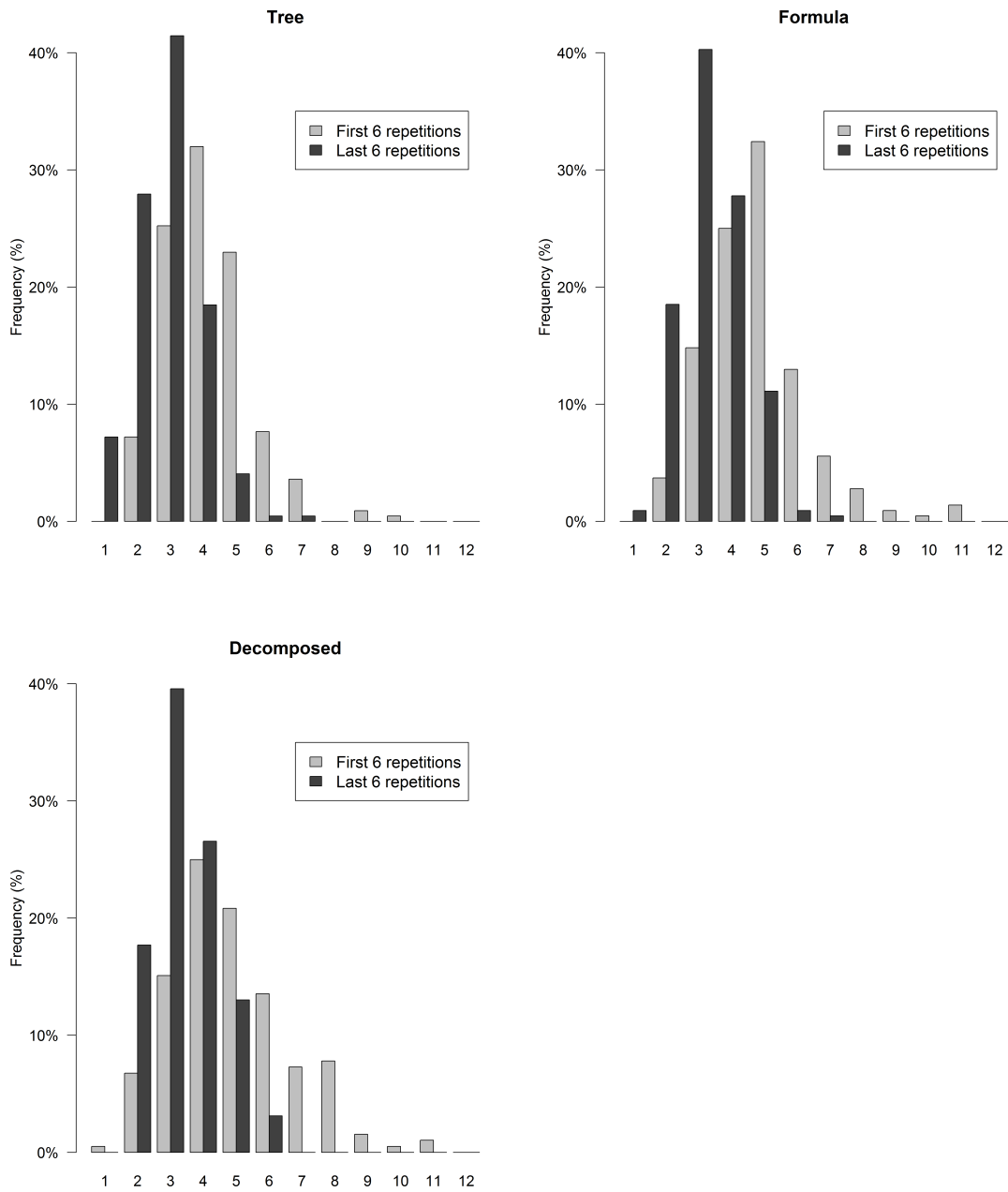
Tree

Formula

Decomposed

Figure 3: Endnode in the first and second half, by treatment
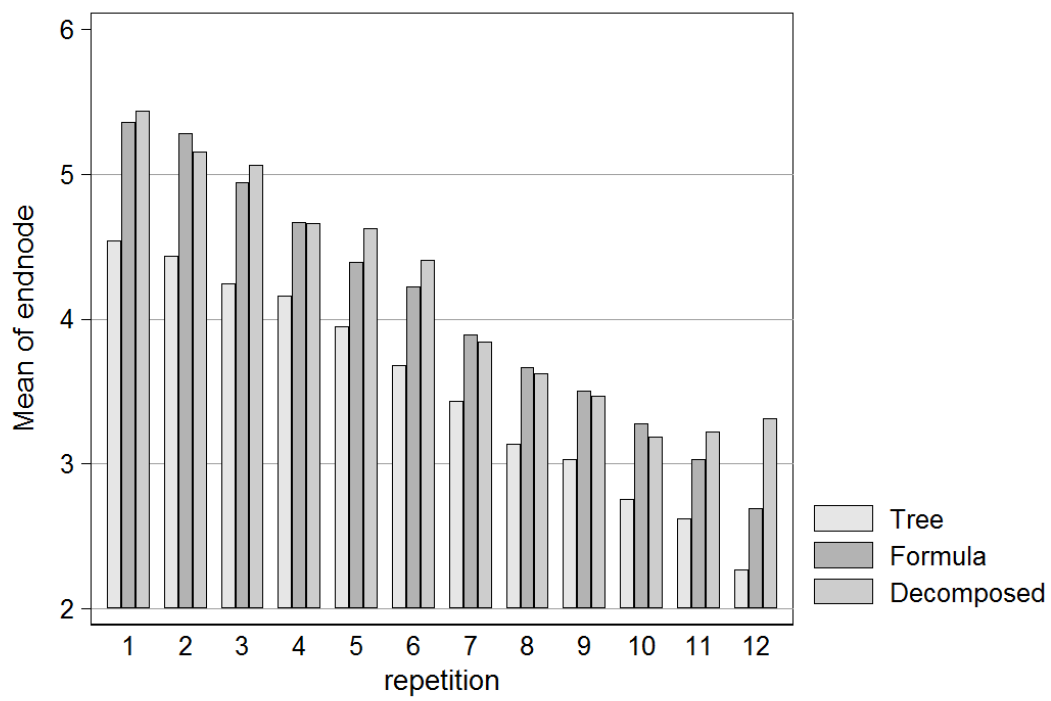
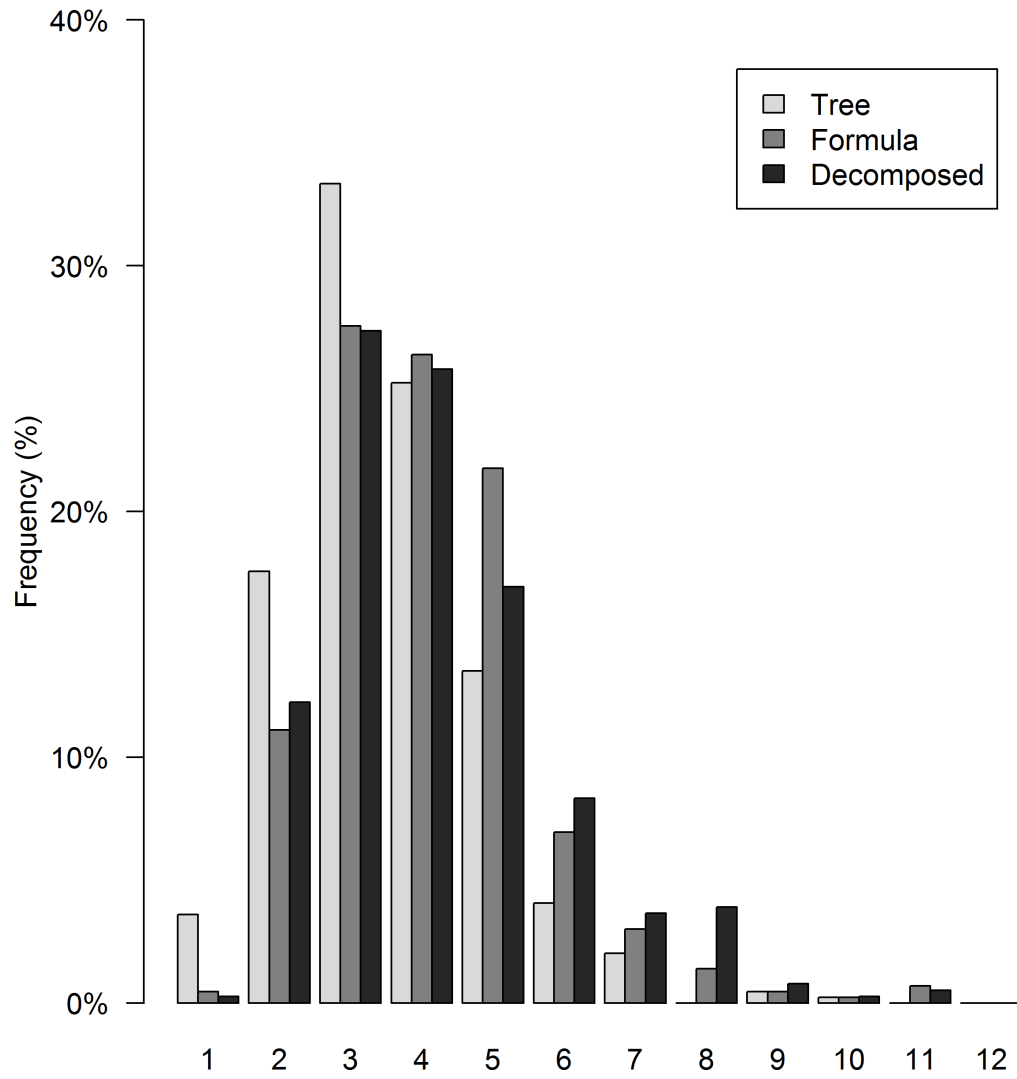Figure 4: Mean endnode by treatment and repetition

Figure 5: *Tree vs. Formula*

B Tables

	Repetition											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Tree	4.54	4.43	4.24	4.16	3.94	3.67	3.43	3.13	3.03	2.76	2.62	2.27
Formula	5.36	5.27	4.94	4.67	4.39	4.22	3.89	3.67	3.5	3.28	3.02	2.69
Decomposed	5.43	5.15	5.06	4.65	4.62	4.41	3.84	3.62	3.46	3.18	3.22	3.31

Table 1: Mean endnode by treatment and repetition

	N	**Complexity (0-10)**	**Errors (num)**	**Time (sec)**
Tree	74	2.32	0.51	104
Formula	72	2.44	0.55	148*
Decomposed	64	2.89*,**	0.95*,**	257*,**

significant with respect to: * row above; ** two rows above

Table 2: Self-reported and objective measures of complexity

C   Experimental Instructions

In the following, the English instructions for condition "Tree" are reported. In brackets are detailed the changes made to adapt the instructions to condition "Formula" (F) and "Decomposed" (D). The original German instructions are available upon request.

Introduction: common to all conditions

Welcome and thanks for your participation to this experiment. Please remain silent and switch off your mobile phone. Please do not talk and raise your hand if there are any specific questions during the experiment: an experimenter will come to your place and answer your concerns individually. If you violate these rules, we will have to exclude you from the experiment and all payments.

You receive a 2.5 euro show-up fee for taking part in the experiment. Please read the following instructions carefully. Prior to the experiment, you will have to answer a few questions testing your comprehension of these instructions. Please note that, for convenience, the instructions are written in male gender, but refer to both genders equally.

During the experiment you are going to use ECU (Experimental Currency Units). At the end of the experiment, earned ECU will be converted into euros at an exchange rate of

$$1 \text{ euro} = 1 \text{ ECUs.}$$

You will take part in a game played by two persons, white and black. You will be randomly assigned the role of white or black, which you will keep for the whole experiment.

The game consists of 12 ordered decision rounds (first round: round=1, ..., last round: round=12). The players play sequentially. When it is his turn to play, each player can choose between STOP and CONTINUE.

If a player chooses STOP, the game ends.

If a player chooses CONTINUE, the game continues, and the other player faces a choice between STOP and CONTINUE.

White plays first; if he chooses STOP, the game ends, but if he chooses CONTINUE, black is called to play and decide whether to STOP or CONTINUE, and so on. Thus each player has at most six choices, with white choosing at round 1, 3, 5, 7, 9, and 11 and black choosing at round 2, 4, 6, 8, 10, and 12. The sequence of choices continues until one player chooses STOP. If both players choose CONTINUE in every decision round the game ends at round = 13.

Payoff information: different across conditions

Tree

Below you can see a representation of the game. The game starts from the utmost left. The color of the circles identifies which player has to decide; the numbers in the circle represent the decision round; the numbers in the brackets represent the final payment, in ECU, obtained by each action. In white you see the payoff of white, in black the payoff of black.

[The image shown to the subjects is reproduced above in Figure 1]

Formula

When a player chooses STOP at round = r, the value for him is 4 times the current round, that is:

$$V_{STOP} = 4 \cdot r$$

The value for the other player is 1 times the current round, that is

$$V_{OTHER} = 1 \cdot r$$

Decomposed

Below you can see a representation of the game. The game starts from the utmost left. The color of the circles identifies which player has to decide; the numbers in the circle represent the decision round; the numbers in the brackets represent the change in payments, in ECU, on top of what you have already earned, resulting from each action. The amount you have earned so far will always be visible on your screen. In white you see the payoff of white, in black the payoff of black.

[The image shown to the subjects is reproduced above in Figure 2]

Actual play of the game and payment (differences in brackets)

When it is your turn to play, you will see a screen that:

1. reminds you of the current round of the game,

2. shows you the amount you and your partner earn if you choose STOP and

3. asks you to choose between STOP and CONTINUE.

You have 30 seconds to reach a decision. You can revise your choice at any time within the 30 seconds. The choice is final when you press OK.
When it is not your turn to play, you will see a screen that:

1. reminds you of the current round of the game and

2. shows you the amount you and your partner earn if your partner chooses STOP

Your partner has 30 seconds to make a decision as well. The game continues until one player chooses STOP or if the last decision round {*Tree, Decomposed*: on the right of the above representation} is reached.

{*Tree*: When the game finishes, payoffs are assigned according to the values in the picture above. You will be paid according to the values that appear at the point in which the game stops.}

{*Formula*: When the game finishes, payoffs are assigned according to the formula detailed above. You will be paid according to the decision round in which the game stops.}

{*Decomposed*: You start with a payoff of 4 if you are white, 1 if you are black. After each decision, your earnings will be updated according to the values that appear in the picture above. You will be paid what you have earned up to the point at which the game stops.}

You will play the game 12 times. Each time, you will form a couple with a new player chosen at random from the other participants in this room. You will never play the same partner twice. Your partners will never play one another.

Only one game of the 12 you play will be paid. At the end of the experiment, one number between 1 and 12 will be selected at random by the computer, and the corresponding game will be paid.

For the chosen game the result of you and your partner's action will be shown on the screen, and your final payoff will be computed.

Should you have any questions, please raise your hand now. An experimenter will come to your place and answer your questions in private.