Testing Two Explanations for the Disjunction Effect in Prisoner's Dilemma Games: Complexity and Quasi-Magical Thinking

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Abstract

The paper explores the disjunction effect in the Prisoner's dilemma game using behavioral experiments with eye-movement recordings. An experiment was designed to explore the complexity hypothesis about the appearance of the disjunction effect. The results show that in games with payoffs which are simpler to perceive and compare, the disjunction effect disappears, while it is present when more complex payoffs are used. In a second experiment, the participants were told that the moves of the computer opponent had been made before the game session. This manipulation led again to the disappearance of the disjunction effect even. We interpret this result as a suppressing of a possible quasi-magic reasoning by stressing the fact that participants' own moves cannot influence the move of the opponent. The results from the experiments point to information processing complexity as a major factor for the disjunction effect contrary to the conclusions in some previous research.

Keywords: disjunction effect, eye-tracking, Prisoner's Dilemma, decision making

Introduction

The Prisoner's dilemma (PD) game is one of the most extensively studied social dilemmas. PD is a two-person game. The payoff table for this game is presented in Figure 1. In the PD game the players simultaneously choose their moves – C (cooperate) or D (defect), without knowing their opponent's choice.

In order to be a Prisoner's dilemma game, the payoffs should satisfy the inequalities T > R > P > S and 2R > T+S. Because of this game structure a dilemma appears – there is no obvious best move. On one hand, the D choice is dominant for both players – each player gets larger payoff by choosing D than by choosing C no matter what the other player chooses. On the other hand, the payoff for mutual defection (P) is lower than the payoff if both players choose their dominated C strategies (R for each player).

As PD game is used as a model for describing social dilemmas and studying the phenomena of cooperation, there is a great interest in the conditions that could promote or diminish cooperation. The *cooperation index* (CI), computed as CI = (R–P)/(T–S) (see Rapoport and Chammah, 1965) is assumed to indicate the degree to which a player can be motivated to cooperate (choose move C).

The disjunction effect in Prisoner's Dilemma has attracted considerable interest and has been investigated in several experimental and theoretical studies without reaching consensus about its explanation (e.g. see Shafir & Tversky, 1992; Croson, 1999; Busemeyer et al. 2006; Li, Taplin & Zhang, 2007; Hristova & Grinberg, 2008). The disjunction effect can be summarized as follows: experiments with one-shot PD games show that players choose move D more often when they know the move of their opponent whatever it is (C or D) than when they don't know it. The logical expectation is that if participants choose a particular strategy for any of the two possible moves of the opponent, they should have the same strategy when they don't know their opponent's move. However, people do not act as expected and cooperate more in the latter situation, i.e. when the opponent move is uncertain.

		Player II	
		C	*D*
Player I	C	R, *R*	S, *T*
	D	T, *S*	P, *P*

Figure 1: Payoff table for the PD game. In each cell the comma separated payoffs are the Player I's and Player II's payoffs, respectively.

Several explanations for the disjunction effect have been put forward in the PD literature. Shafir and Tversky (1992) are accounting for the disjunction effect using their theory for reason-based choice: people need a reason in order to make a choice. Thus, when they know that their opponent will play C, they defect to get the higher payoff; and if they know that she will play D, they defect in order to avoid the lowest payoff and punish the opponent (see Figure 1). But when the move of their opponent is not known, they don't have a particular reason to make a move and this changes the situation contributing to the disjunction effect. Additional explanations, discussed in the same paper, claim that people cannot account properly for all alternatives of the game, or if they do, due to the uncertainty about the opponent's move, they cannot establish clearly their own preferences. Thus, depending on what outcome they focus on, they can choose to cooperate or defect. When people are made aware of their choices the disjunction effect disappears (Tversky & Shafir, 1992).

An alternative explanation is related to the change of participant's perspective (individualistic vs. collectivistic) about the PD game (see Shafir & Tversky, 1992). When their opponent's move is known, people can be tempted to defect as the outcome of the game depends only on their choice and they have to consider only one column in the game matrix (see Figure 1). In this case, they adopt an individualistic point of view and defect. On the other hand, when the opponent's move is unknown, they have to consider the whole game matrix, the outcome depends on their and their opponents moves, and the collectively optimal decision of mutual cooperation becomes more attractive. This is supported by the fact that the CC outcome (payoff R) is better than the DD outcome (payoff P) for both players (as R>P; see Figure 1).

Experiments show that sometimes participants act as if they believe that their moves can influence the game outcome, although they know this is impossible. In Shafir & Tversky (1992), this is called quasi-magical thinking. Quasi-magical thinking, applied to PD, would imply that if people cooperate more when they are uncertain about the other player move, this means that the CC outcome is preferred by them, and by playing C they expect to elicit the same choice in the other player.

In the account of Shafir & Tversky (1992), the possibility of complexity to be an explanation of the disjunction effect is discarded and it is claimed that 'the failure to reason consequentially may constitute a fundamental difference between natural and artificial intelligence.' Croson (1999) tested the complexity explanation and the conclusion was that complexity plays no role and the reason-based choice explanation should hold. However, the test was performed using games which are not dilemmas as the PD game. Recently, inspired by the above conclusions, alternative explanations have been put forward even involving quantum probability theory and logic (see Busemeyer et al., 2006).

Li et al. (2007) used the so-called 'equate-to-differentiate' approach to explain the disjunction effect. This approach seems to involve the complexity hypothesis by assuming that when people have ambiguous alternatives concerning their own payoffs, they can equate them and take the perspective of their opponent. Moreover, the eye-tracking study of Hristova & Grinberg (2008), has shown longer information acquisition in PD games when the opponent's move is uncertain than when it is known by participants, reflecting the difference in the complexity of the task in the two cases.

One of the goals of the present study is to explore to what extent the complexity of decision making can lead to the disjunction effect in PD games. The approach adopted here, is different from the one followed in Croson (1999). Instead of using games with different structure, in our experiments we manipulated the payoffs by keeping their ratio and cooperation index the same. Participants in one experimental condition played PD games with payoffs which were two digit numbers with the second number *different* from zero. Participants in another experimental condition, played games with two-digit numbers with the second digit *equal* to zero. The idea was that, while equivalent from a game-theoretical point of view, the payoffs from the first condition are more difficult to perceive and compare than the numbers in the second condition. Thus, the complexity of the former case was assumed to be higher than the complexity of the latter case.

The second goal was to try to evaluate the influence of quasi-magical thinking discussed above on the disjunction effect in PD games. This has been done by using exactly the same experimental design as the one described above but with an additional manipulation – a sentence in the instruction which says that the computer program, playing against the participants, had chosen its moves before the beginning of the game session.

In both experiments eye-movements have been recorded in the hope to discern differences in the four conditions which could shed additional light on information processing involved based on the experience of Hristova & Grinberg (2008).

Experiment 1 – Testing the complexity explanation

Goals and hypothesis

The goal of the present experiment is to test the complexity explanation for the disjunction effect, namely that the effect appears because of the complexity of the game. When the opponent's move is not known, the situation is complex and the players are not able to analyze it well and to choose the appropriate move. To test this, in the current experiment we manipulate the complexity of the payoffs that are presented. The prediction is that if we make the game simpler (by using simple round payoffs) the disjunction effect will be smaller.

Stimuli

A set of 6 Prisoner's dilemma games was used in the experiment (see Table 1). Although the payoffs were different, the cooperation index of all the games was equal to 0.7 (as discussed above, cooperation index is an important predictor of the cooperation rate). Three of the games were with simple round payoffs, and 3 games were with 'complex' payoffs.

Table 1: PD games used in the experiment

	T	R	P	S
simple payoffs	100	90	40	30
	90	80	30	20
	80	70	20	10
complex payoffs	106	94	41	32
	91	83	34	22
	83	75	24	12

Each of the 6 PD matrices was presented 3 times during the game playing: the computer move in not known yet, the computer move is known to be cooperation, the computer move is known to be defection. These 18 payoff matrices that are later used in the analysis were intermixed with 62 other games resulting in a total of 80 games. The 18 PD games were pseudo-randomly distributed between the 4th and the 78th game.

. Care was taken as one and the same PD game to appear in the first, second, and third part of the game sequence. Playing games with different strategic structure was used to introduce the PD games as one-shot games and prevent subjects for using strategies applicable in the repeated play of PD.

Eye Movements Recordings

Eye movements were recorded using the Tobii 1750 remote binocular eye-tracker with 50 Hz sampling rate. The accuracy of the gaze position record is about 0.5 degrees visual angle. The game was presented on the Tobii monitor (17", 1280x1204 pixels). Each box containing payoffs or moves occupied about 1 degree visual angle on the screen. The distance between two adjacent boxes was at least 1 degree visual angle to ensure stable distinction between eye-fixations belonging to respective zones. The schematic game interface is presented in Figure 2.

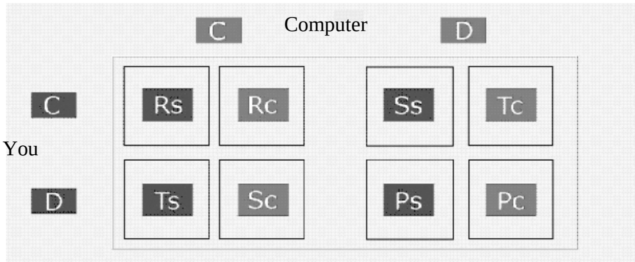

Figure 2: Schematic representation of the game interface. During playing, the actual payoffs and moves are presented. The superscript 's' refers to the subject, and 'c' to the computer opponent.

Procedure

After the eye-tracking calibration, subjects received instructions and were tested for understanding the instructions. Then each subject played 5 training games, and next the 80 games described above.

The game was presented in a formal and a neutral formulation. On the interface, the cooperation move was labeled '1' and the defection move was labeled '2'. However, further in the paper, for convenience, we will continue to use *cooperation* instead of move '1' and *defection* instead of move '2'.

Subjects were instructed to try to maximize their payoffs and not to try to 'beat' the computer. After each game the subjects got feedback about their and the computer's choice and payoffs in the current game. This information was visible for 3 seconds and then the next game automatically appeared. To ensure that players are following the instruction, three participants that got most points were promised and given a reward. In such a way we were trying to emphasize the importance of getting more points (and not trying to get more points than the opponent). Participants were not told their total number of points until the end of the game.

It is explained to the participants that the computer makes its choices trying to maximize the payoff in each game. They were also told that the computer is not aware of the participant's choice. In fact the computer's moves were randomly generated in advance and were the same for all participants.

Participants

33 subjects with normal or corrected to normal vision took part in study. Playing behavior of all subjects was analyzed, however, due to technical difficulties, eye-tracking data of only 22 of the subjects were analyzed.

Playing results

The number of cooperative choices for PD games was used as a dependent variable characterizing the participants' playing and choices. If the disjunction effect is present, the cooperation rate in the unknown move condition will be higher then either the defect (D) or cooperate (C) known move condition. If no disjunction effect is observed, the cooperation rate for the unknown move condition is expected to be equal or between the cooperation rates for D and C. This is the reason to compare the unknown move condition against the known D and C conditions separately and not against the aggregated data.

For the games with *complex* payoffs the expected pattern for a disjunction effect appeared in the data (see Figure 3). Participants cooperated in 27 % of the PD games in which the computer move was not known, in 11 % of the games that the computer move was known to be cooperation, and in 12 % of the games that the computer move was known to be D defection. Cooperation rate when the computer move is not known is significantly different ($p < 0.05$) from the cooperation rates when the computer move is known to be cooperation or defection.

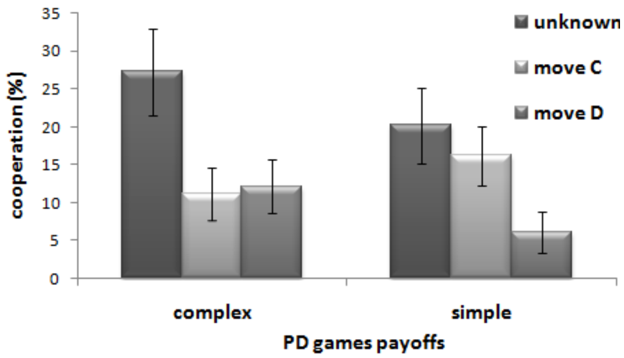

Figure 3: Mean cooperation (%) in Experiment 1 for *complex* and *simple* PD games when the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*move C*); the computer's move is known and it is defection (*move D*). Error bars represent standard error of the mean.

For the games with *simple* payoffs the disjunction effect was not so prominent (see Figure 3). Participants cooperated in 20 % of the PD games in which the computer move was not known, in 16 % of the games that the computer move was known to be cooperation, and in 6 % of the games that the computer move was known to be defection. Although the trend is present, there is no significant difference in the cooperation rates when the computer move is unknown or when the computer move is known to be cooperation. Cooperation rate when the computer move is known be defection is significantly different ($p < 0.05$) from the cooperation rates when the computer move is not known or is known to be cooperation.

In summary, when the payoffs were complex, a clear disjunction effect appeared. However, the effect was not statistically significant when the payoffs were simple. It seems that these results support the complexity explanation for the disjunction effect because change in the complexity of the payoffs changes the participants' choices and the disjunction effect diminishes.

Eye-movements results

We defined several areas on the screen that are interesting in studying information acquisition during PD game playing. Each Area of Interest (AOI) contains the box in which the information is presented and a small region around it. Here we present the analysis of the eye-tracking data for the four AOIs containing the subject's possible payoffs These AOIs are referred to as T_S, R_S, P_S, and S_S (see Figure 2). We used the gaze-time (sum of all fixation durations on each AOI) as a measure of attention devoted to it (Rayner, 1998).

We expect that when the computer's move is known, the subject's attention will be directed to the possible payoffs corresponding to the computer's choice. So, for each game we computed the aggregate gaze-times in the zones containing subject's possible payoff if the opponent cooperates (R_S and T_S) and in the zones containing subject's possible payoff if the opponent defects (S_S and P_S). These data are analyzed in a repeated-measures analysis of variance with the computer's move (not known, known to be cooperation, and known to be defection) as a within-subject factor. Two such analyses were performed: for the PD games with complex payoffs and for the PD games with simple payoffs.

For the games with *complex* payoffs when subjects knew that the computer's move was defection they attended less to the AOIs denoted as T_S and R_S compared to the games when the computer's move was not known ($p = 0.018$) or it was known to be cooperation ($p = 0.055$) (see Figure 4). When subjects knew that the computer's move was cooperation they attended less to the AOIs denoted as P_S and S_S compared to the games when the computer's move was not known ($p = 0.004$) or when it was known to be defection ($p = 0.002$) (see Figure 4).

For the games with *simple* payoffs when subjects knew that the computer's move was defection they attended less to the AOIs denoted as T_S and R_S compared to the games when the computer's move was not known ($p = 0.018$) or it was known to be cooperation ($p = 0.02$) (see Figure 4). When subjects knew that the computer's move was cooperation they attended less to the AOIs denoted as P_S and S_S compared to the games when the computer's move was not known ($p < 0.001$) or when it was known to be cooperation ($p < 0.001$) (see Figure 4).

In summary, the eye-tracking data show that when the opponent's move is known, the eye-movement patterns are changed in both types of games (*complex* and *simple*). When the computer's move is D, the subject's possible payoffs are S_S or P_S and they do not pay attention to the other payoffs (R_S and T_S). When the computer's move is C, the subject's possible payoffs are R_S or T_S and they do not pay attention to the other payoffs (S_S and P_S).

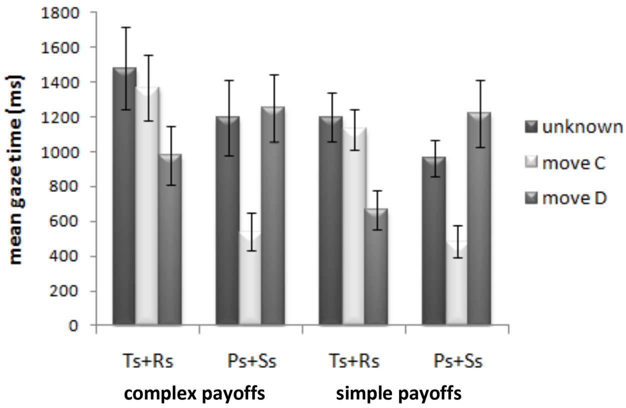

Figure 4: Average gaze-time for AOIs containing subject's possible payoffs **(**T_S, R_S, P_S, and S_S) when the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*move C*); the computer's move is known and it is defection (*move D*). Error bars represent standard error of the mean.

Another measure analyzed is the total gaze-time in the four AOIs containing the subject's possible payoffs. The analysis shows that when the payoffs are complex players spend more time looking at their them (mean 2270 ms) than when the payoffs are simple (mean 1880 ms), $p = 0.04$. This result indicates that *simple* payoffs are indeed easier to process than the *complex* payoffs.

Summary and discussion for Experiment 1

All these results are in accordance with the complexity explanation of the disjunction effect. When complexity of the PD game is reduced (by using payoff that are easy to process) the disjunction effect is reduced. Eye-movements data also support this explanation. When the computer's move is known, the eye-movement patterns are changed – players are paying less attention to the payoffs that are not relevant for the already revealed opponent's move. Eye-movement data also give evidence that the intended reduction in complexity of the game is successful.

Experiment 2 – Testing the quasi-magical thinking explanation

Goals and hypothesis

The goal of this experiment is to test the explanation that the disjunction effect arises due to the so called 'quasi-magical thinking'. The explanation is that the players behave as if they believe that their choices could influence the other

player's choices (although they know that in fact the other player is not aware of their choice while making his).
To test this explanation in this experiment we use a novel manipulation consisting in telling the subjects that the computer's moves are determined in advance. When this fact is known the above stated 'quasi-magical beliefs' should be diminished and the disjunction effect should disappear.

Stimuli and Procedure

Game and procedure were the same as in experiment 1. Change was made only in the information given to the participants in regard to the computer's move. It is said not only that the computer tries to maximize its payoff in each game but also that the computer has determined all of its moves in advance, before the start of the sequence of 80 games.

Participants

27 subjects with normal or corrected to normal vision took part in study. Playing behavior of all subjects was analyzed, however, due to technical difficulties, eye-tracking data of only 16 of the subjects were analyzed.

Playing results

For the games with *complex* payoffs participants cooperated in 21 % of the PD games in which the computer move was not known, in 12 % of the games that the computer move was known to be cooperation, and in 7 % of the games that the computer move was known to be defection (see Figure 5). Cooperation rate when the computer move is not known is significantly different ($p < 0.05$) from the cooperation rate when the computer move is known to be defection. All other differences are non-significant. Although the trend is present, there is no significant difference in the cooperation rates when the computer move is unknown or when the computer move is known to be cooperation.

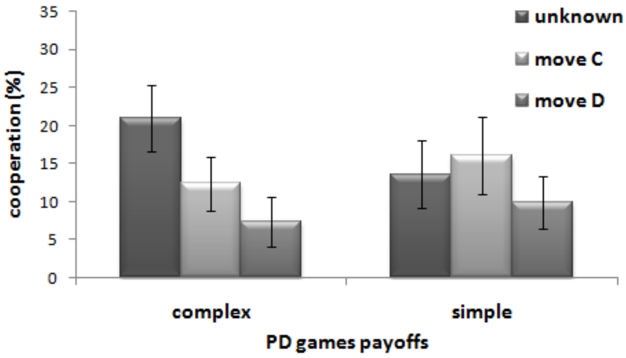

Figure 5: Mean cooperation (%) in Experiment 2 for *complex* and *simple* PD games when the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*move C*); the computer's move is known and it is defection (*move D*). Error bars represent standard error of the mean.

For the games with *simple* payoffs no disjunction effect was found (see Figure 5). Participants cooperated in 14 % of the PD games in which the computer move was not known, in 16 % of the games that the computer move was known to be cooperation, and in 10 % of the games that the computer move was known to be defection. There is no significant difference between these three cooperation levels.

In summary, when the players know that the computer moves are determined before the start of the sequence of games, the disjunction effect is smaller or absent. Especially when the PD games payoffs are easy to be processed and compared, no such effect is observed.

Eye-movements results

For the games with *complex* payoffs when subjects knew that the computer's move was cooperation they attended more to the AOIs denoted as T_S and R_S compared to the games when the computer's move is not known ($p = 0.009$) and it is known to be defection ($p = 0.003$). They also attended less to the AOIs denoted as P_S and S_S compared to the games when the computer's move is not known ($p < 0.001$) and it is known to be defection ($p < 0.001$) (see Figure 6).

For the games with *simple* payoffs, when subjects knew that the computer's move was D, they attended less to the AOIs denoted as T_S and R_S compared to the games when the computer's move was not known ($p = 0.044$) and when it was known to be C ($p = 0.08$). They also attended less to the AOIs denoted as P_S and S_S compared to the games when the computer's move was not known ($p = 0.001$) and when it was known to be C (< 0.044) (see Figure 6).

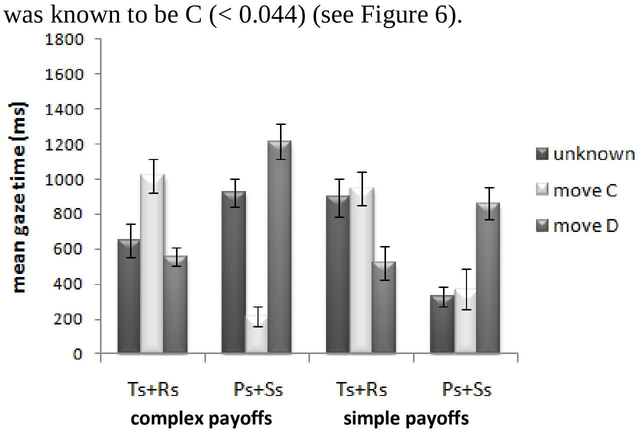

Figure 6: Average gaze-time for AOIs containing subject's possible payoffs (T_S, R_S, P_S, and S_S) in Experiment 2 when the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*move C*); the computer's move is known and it is defection (*move D*). Error bars represent standard error of the mean.

In summary, the eye-tracking data show that in both types of games (*complex* and *simple*) the eye-movement patterns are changed. When the computer's move is known, the subjects pay more attention to their possible payoffs in the corresponding column and they don't pay attention to the other payoffs.

Again we analyzed the total gaze-time in the four AOIs containing the subject's possible payoffs. The analysis shows that when the payoffs are complex players spend more time looking at their payoffs (mean 1525 ms) than when the payoffs are simple (mean 1309 ms), p = 0.036. Total gaze time in these four AOIs is less in Experiment 2 (mean 1417 ms) than in Experiment 1 (mean 2079 ms), p = 0.034.

Summary and discussion for Experiment 2

As expected, when the subjects are told that the computer moves are already decided, the disjunction effect is reduced and even disappears when games with lower complexity are played. These results are in accordance with the quasi-magical thinking explanation of the disjunction effect and also give further support for the complexity explanation.

Discussion and Conclusions

The paper presents an experimental study of the disjunction effect in PD games based on behavioral experiments with eye-movement recordings. The experiments were designed to explore the complexity hypothesis about the appearance of the disjunction effect which seems to have little support in the literature. However, our study showed that without changing the structure of the game (and its cooperation index), but by just using payoffs which can be easily processed, the disjunction effect can disappear. We interpret this result as an indication that despite the arguments and evidences that have been discussed in the literature (see Shafir & Tversky, 1992; and Croson, 1999) the role of complexity should not be underestimated and deserves further attention and exploration.

One possible interpretation of the findings from Experiment 1 can be that participants have difficulties in the comparison of alternatives in the complex payoff condition and cannot come out with clear preferences. In the simple payoff condition, outcome comparison is simpler and participants can chose their move in a similar way as when the move of their opponent is known.

In the second experiment, the participants were told that the moves of the computer opponent had been made before the game session. Such a manipulation hasn't been used before. This manipulation led again to the disappearance of the disjunction effect even in the complex payoff condition. We interpret this result as a suppressing of a possible quasi-magic reasoning by stressing the fact that participants own moves cannot influence the move of the opponent. Interestingly, the manipulation led also to considerable decrease in the payoff processing time which deserves further exploration.

The results from the two experiments point to information processing complexity as a major factor for the disjunction effect contrary to the conclusions in previous research.

The eye-movement data support the complexity explanation described above. They show a change in the dynamics of the information acquisition in relation to the experimental manipulations of the complexity of the payoffs, and of the information about the opponent's move. As has been suggested in Busemeyer et al. (1993), the deliberation process can play a crucial role in decision making, especially when participants cannot attend at once to the full information available but can compare alternatives based on selected features.

A further systematic experimental and theoretical investigation of the results presented in this paper is under way and will be presented in the future.

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