UNIVERSITY OF LEICESTER

COOPERATION IN REPEATED INTERACTIONS

Thesis submitted for the degree of

Doctor of Philosophy

At the University of Leicester

By

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January 2017

Abstract

Cooperation in Repeated Interactions

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This thesis systematically reviews empirical research on human cooperation in repeated reciprocal interactions, and reports 6 new studies that aim to verify, clarify and extend previous findings. As a research paradigm, Rosenthal's (1981) Centipede game is chosen because it provides a formal model of alternating reciprocal cooperation between two individuals. Despite potentially large gains to both players through long-term cooperation in the game, a logical argument based on backward induction shows that instrumentally rational players will never cooperate in this way. However, previous research showed reliable deviations from this rational game-theoretic solution in human decision makers. All studies reported in this thesis confirm this robust finding. Study 1, drawing on a qualitative design, further evidences a large variety of other-regarding experiences underpinning decision making in the game including previously neglected, low-level motives such as activity bias. Study 2 addresses inconsistencies across research designs reported in the literature, and suggests large effects of even subtle changes to the games' payoff functions. Studies 3 and 4 aim to increase the Centipede game's applicability to real-life decision contexts by increasing game length and introducing varying termination rules. It is found that human decision makers cooperate more frequently during longer decision sequences. When additionally faced with the uncertainty of an unknown end or the risk of random game termination, however, defection may increase. Studies 5 and 6 examine cross-cultural differences in cooperation and find that Japanese participants cooperate more frequently than European/UK participants, which is attributed to different, culturally-dependent types of trust. Drawing on the research presented, explanations for cooperation in repeated interactions are discussed including the possible invalidity of backward induction reasoning, the cognitive burden of backward induction, a possible breakdown of common knowledge of rationality, virtual bargaining theory, fuzzy-trace theory, and other-regarding preferences. Ultimately, it is suggested that other-regarding preferences provide the most persuasive explanation for cooperation.

Declaration

I hereby declare that this thesis has been composed by myself and that the research reported herein has been conducted by myself.

January 2017

Eva M. Krockow

The literature review provided in Chapter 1 is published in:

Krockow, E. M., Colman, A. M., & Pulford, B. D. (2016a). Cooperation in Repeated Interactions: A Systematic Review of Centipede Game Experiments, 1992-2016. *European Review of Social Psychology*. *27*(1), 231–282. doi:10.1080/10463283.2016.1249640

Study 1 is published in:

Krockow, E. M., Pulford, B. D, & Colman, A. M., (2016b). Exploring cooperation in the Centipede game with verbal protocol analysis. *European Journal of Social Psychology, 46*(6), 746–761. doi:10.1002/ejsp.2226

Study 2 is published in:

Krockow, E. M., Pulford, B. D, & Colman, A. M., (2015). Competitive Centipede games: Zero-end payoffs and payoff inequality deter reciprocal cooperation. *Games, 6*(3), 262-272. doi:10.3390/g6030262

Study 3 is under review:

Krockow, E. M., Colman, A. M., & Pulford, B. D (2016). Far but finite horizons promote cooperation in the Centipede game. Under review.

Study 4 is under review:

Krockow, E. M., Colman, A. M., & Pulford, B. D, (2016). Random game termination in the Centipede game. Under review.

Study 5 is under review:

Krockow, E. M., Takezawa, M., Pulford, B. D, Colman, A. M., Smithers, S., Kita, T., & Nakawake, Y. (2016). Commitment-enhancing tools in Centipede games: Evidencing European-Japanese differences in trust and cooperation. Under review (revised and resubmitted)

Study 6 is under review:

Krockow, E. M., Takezawa, M., Pulford, B. D, Colman, A. M., & Kita, T (2016). Cooperation and Trust in Japanese and British Samples: Evidence from Incomplete Information Games. Under review (revised and resubmitted)

Acknowledgements

Firstly I would like to thank my two supervisors Dr Briony Pulford and Professor Andrew Colman. Their support has been invaluable and has enabled me to advance not only my academic but also my personal development. Briony, I will never forget our adventures in Hong Kong and Boston. Andrew, thank you for some great evenings in the pub and countless inspiring conversations. I could not have had better supervisors, and you made this experience very enjoyable.

Thank you to Dr Masanori Takezawa who provided help and advice during a truly memorable research visit at Hokkaido University, Sapporo, Japan.

I am also grateful to the whole Judgment and Decision Making Research Group and, in particular, Dr Caren Frosch and Dr Diana Pinto, whom I consider mentors and friends. Thanks so much for your patience and advice during many office chats!

I would like to thank the Friedrich-Naumann-Foundation for Freedom for awarding me with a three year PhD scholarship that made my PhD financially possible and allowed me to attend many interesting seminars and workshops organised by the Foundation. I have met a number of inspiring people, and enjoyed every trip to Gummersbach.

Finally, I would like to thank my friends and family. I am extremely grateful to my parents, Regina and Albrecht Krockow, who have provided me with unwavering support from Germany. Thank you also to all my friends—particularly to Dr Farrah Mushtaq—who endured too many conversations about centipedes. Finally, a special thank you goes to my partner Dr Jolyon Dales who has been there for me every step of the way. Thank you for never tiring of hearing about z-Tree crashes and computer issues.

I could not have done it without you.

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Chapter 1: General Introduction

Cooperation is one of the most fundamental forms of human social interaction, and it plays a significant part in many areas of interpersonal, economic, and political life. In his last address as President of the Royal Society, Lord Robert May (2006) expressed the view that "the most important unanswered question in evolutionary biology, and more generally in the social sciences, is how cooperative behaviour evolved and can be maintained in human or other animal groups and societies" (p. 109). Cooperation frequently displays a pattern of repeated interactions in which Person A rewards Person B in some way, then B reciprocates by rewarding A, then A reciprocates by rewarding B again, and so on through several or many cycles of reciprocal cooperation. It is often reasonable to assume that each rewarding action incurs some cost c to the person performing it, financially, materially, or in terms of time, effort, or inconvenience, but that this cost is no larger than the benefit b to the recipient, so that $c \leq b$. Typical everyday examples include next-door neighbours taking turns looking after each other's children to enable the parents to enjoy a night out, business associates taking turns providing each other with letters of recommendation for job applications, and academics taking turns providing feedback on each other's research grant applications.

The Centipede game, introduced by Rosenthal (1981), provides a game-theoretic model of this class of repeated reciprocal interactions. The game involves two players alternating in choosing between cooperation and defection, with their choices affecting payoffs to themselves and the co-player. Cooperation keeps the relationship going and benefits both players in the long run, whereas defection terminates the relationship with a favourable payoff to oneself.

Using a range of different methods and comparing different cultures, this thesis aims to investigate decision making in the Centipede game and to generalise the findings to a wide range of human interactions with a view to understanding and promoting cooperative behaviour.

This first chapter provides an introduction to the Centipede game and an overview of relevant research. Section 1.1 offers a detailed outline and theoretical discussion of the Centipede game. This is followed by a systematic literature review of all empirical research undertaken on the game to date in Section 1.2. Finally, Section

1.3 draws conclusions from the review's findings, and outlines a thesis plan based on the research gaps identified.

1.1: The Centipede game

This section provides a detailed introduction to Rosenthal's (1981) Centipede game. Section 1.1.1 outlines the rules and payoff function of the standard, linear Centipede game. Section 1.1.2 explores a number of Centipede game variations. Section 1.1.3 discusses the role of backward induction reasoning and the subgame-perfect Nash equilibrium solution in the context of the game.

1.1.1: The standard Centipede game

Formally, the Centipede game is a finite, *extensive-form* game (because players make their moves sequentially) with *complete information* (because they are fully informed about the specification of the game and about both players' payoff functions) and *perfect information* (because each player knows, when making a move, all previous moves in the game). It is usually represented by a game tree, such as the one depicted in Figure 1.1, its multi-legged appearance explaining its name, which is due to Binmore (1987).

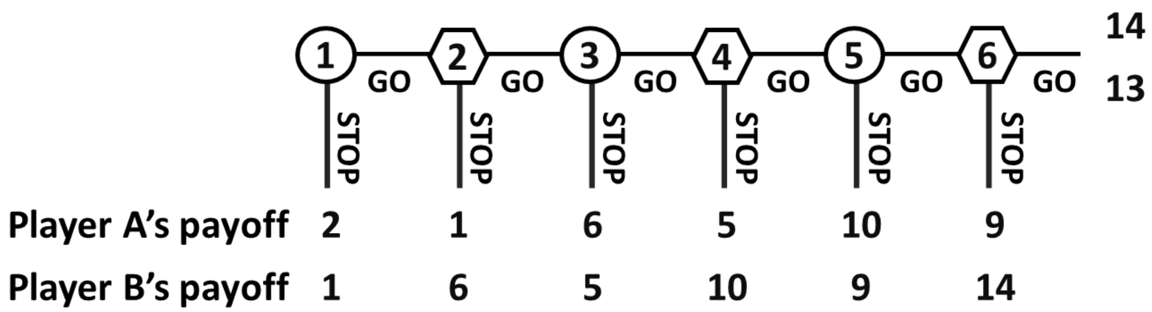


Figure 1.1. Linear Centipede game; Player A's decision nodes are presented as circles, Player B's as hexagons.

In this two-player Centipede game, the top row shows a sequence of six *decision nodes*, represented by circles for Player A and hexagons for Player B, numbered in the order in which moves are made. Player A begins by deciding at the first decision node at the left whether to STOP the game immediately by choosing the line extending downward from the decision node, or to GO on with the game by choosing the line extending to the right, thereby handing the second move to Player B. If Player A stops the game at the first decision node, then the payoffs to Players A and B are 2 and 1 respectively, as shown in the first *terminal node* containing this pair of payoffs in the bottom row. If Player A decides to keep the game going by choosing a cooperative GO move, then Player A incurs the cost of cooperation *c* while benefitting Player B by an amount *b*. Player B can then either stop the game at the second decision node, with payoffs of 1 to Player A and 6 to Player B as shown in the second terminal node below, or continue the game by cooperating and handing the move back to Player A for a decision at the third decision node, and so on. If the game continues as far as the sixth and final decision node, and Player B chooses GO at that point, then the game comes to a natural end at the last terminal node on the right, with a payoff of 14 to Player A and 13 to Player B.

In formal game theory, the payoffs represent *von Neumann–Morgenstern utilities* that, by definition, reflect the players' true preferences, incorporating all selfish, altruistic, generous, grateful, spiteful, and other considerations that might influence their choices; but it is common to interpret the numbers informally as pounds sterling, US dollars, euros, or other monetary units. When the Centipede game is used as an experimental game, the payoffs can only represent money or some other objective rewards, because experimenters have no access to players' subjective preferences and predilections. This problem is not considered fatal to experimental research, because it is generally assumed that monetary values reflect utilities fairly closely—at least for small amounts.

1.1.2: Varieties of Centipede games

In the Centipede game shown in Figure 1.1, a GO move always decreases a player's payoff by one unit and increases the co-player's payoff by five units, hence $c = 1$, $b = 5$. This is an example of a *linear* Centipede game, because the payoff pot (the joint payoff of the player pair) increases linearly from one terminal node to the next—by four units in this case. This type of payoff structure corresponds to the type of reciprocal cooperation between next-door neighbours, business associates, or academics in the examples outlined earlier. The costs and benefits remain constant, but the pot increases linearly, because the *accumulated* joint payoff increases by a fixed amount after each move. The payoffs shown in Figure 1.1 represent these accumulated costs and benefits, and it is a merely technical aspect of the formalisation that the payoffs are realised only when one of the players stops the game.

The two principal alternative payoff functions for Centipede games are the *exponential* and *constant-sum* versions shown in Figure 1.2 (a and b respectively). In exponential Centipede games (McKelvey & Palfrey, 1992), the pot increases exponentially, doubling (or increasing by some other fixed proportion) from one terminal node to the next. In constant-sum Centipede games (Fey, McKelvey, & Palfrey, 1996), the pot remains constant and GO moves generate no social gains, but the players' shares become increasingly asymmetric, with the player who stops the game earning an ever-increasing share of the pot. Another less frequently studied version, the *Take-it-or-leave-it* Centipede game (Reny, 1992), also called *Take or pass* game (Huck & Jehiel, 2004), is shown in Figure 1.2c. In this version, whether the payoff function is linear or exponential, a player who defects invariably receives the entire payoff pot, leaving nothing for the co-player.

It is worth mentioning that any of the Centipede games outlined so far could be modified by setting both payoffs at the last terminal node to zero. This modification, introduced by Aumann (1992), ensures that the players face the problem of deciding *when* to defect (before a deadline), without having to consider *whether* to defect, because the option of cooperating at every opportunity is effectively ruled out, but in other respects the basic strategic properties remain the same.

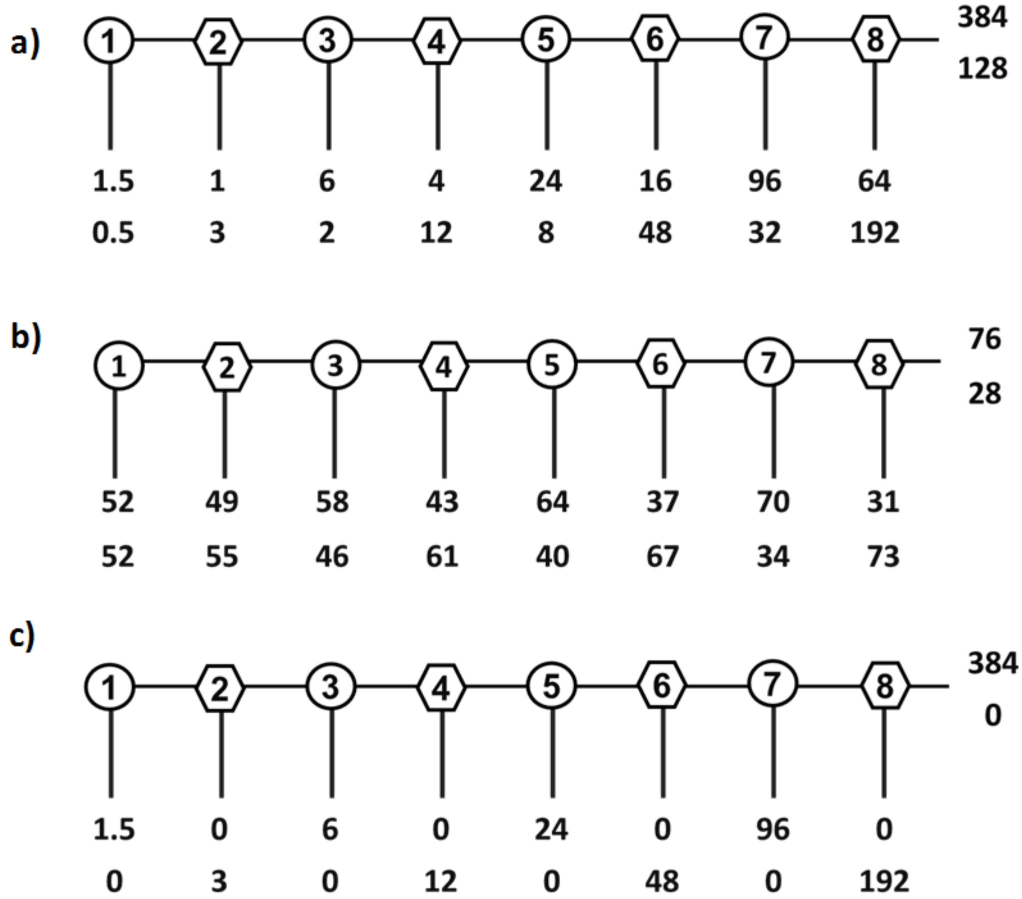


Figure 1.2. Principal payoff function variations of nonlinear Centipede games: (a) exponential, (b) constant-sum, (c) Take-it-or-leave it (exponential version).

These variations provide models of reciprocal interactions with different payoff structures (static costs and benefits, increasing costs and benefits, increasing conflict over a finite resource, winner-takes-all conflicts, and reciprocal cooperation with deadlines) reflecting many everyday strategic interactions. To illustrate how they could arise in real-life strategic interactions, we offer the following hypothetical scenarios. For simplicity and comparability, our examples all focus on medical research, but the game-theoretic models are potentially relevant to any area of strategic interaction.

First, consider two hypothetical researchers who are collaborating on the development of a new drug. They take turns in running experiments to study treatment efficiency and side-effects. Each experiment is costly to the researcher who performs it in time and resources (e.g., laboratory supplies and research staff). However, the prospective value of the drug increases with each experiment. At any point during this continuing interaction, either of the researchers has the option to defect by ending the collaboration, writing up the results and publishing them, retaining the privilege of first authorship. Although the personal benefit from the research project is larger for the defector, both researchers receive some benefit and, crucially, both are ultimately better off as a result of their collaboration. In this example, it appears reasonable to assume that the researchers' costs and benefits remain more or less constant, but the accumulated value of the research findings increases steadily with every experiment conducted. If these assumptions are met, then the scenario could be modelled by a Centipede game with a linearly increasing payoff function, as in Figure 1.

Second, consider a slight variation of the scenario above. Imagine a different research project, such as the development of a revolutionary new cancer drug. Let us suppose that the potential value of the drug is initially small, because of the high probability of failure, but that each successful experiment increases it exponentially, doubling its potential value at each stage, for example. Given this accelerating increase in value, the risk associated with cooperation and the loss resulting from the collaborator's defection are larger than in the previous scenario, and both increase after each step in the process. But if the two researchers cooperate nevertheless, the ultimate benefits to both are larger than before. A scenario with this incentive structure could be modelled by a Centipede game with an exponentially increasing payoff function (Figure 2a).

Third, consider the following scenario. A university Dean of Medicine has a small pot of money available for research, and he offers to split it equally between two departments, Neurology and Cardiology. The heads of both departments argue that a half share is too small to be put to any tangible use, and each argues for a larger share of the pot. In an effort to be fair and transparent, the Dean decides to make a sequence of proposals for splitting the pot, the first slightly favourable to Neurology, the second slightly more favourable to Cardiology, and so on, each proposal offering a more unequal split than the last. The Dean explains that as soon as one of the department heads accepts a proposed split, it will be implemented immediately, and the other will have to accept it. A scenario of this kind could be modelled by constant-sum Centipede game (Figure 2b).

Fourth, consider the following variation of the second scenario. Once again, two researchers are collaborating on the development of a new drug and obtaining findings that are increasing its potential value exponentially. However, instead of the temptation to publish, the researchers are faced with lucrative offers from industry. A pharmaceutical company offers them increasingly large sums of money for the rights to their discovery and its commercialization. Assume that as soon as one of the researchers defects by accepting an offer, the drug development is terminated and the defector is the only one to benefit from the scientific discovery. This is a more competitive variation of the two previous examples, and the closest game-theoretic model would be a Centipede game with winner-takes-all payoff function (Take-it-or-leave-it game), as illustrated in Figure 2c.

Fifth and last, consider the following variation of the first scenario. Once again, two researchers in the UK are working on a medical research project that yields a higher payoff to the one who defects first by publishing the findings, but in this version both receive zero payoffs to both if a deadline is missed. Let us assume that a Swiss laboratory, working to a published schedule, is racing to develop a similar drug, and that if this rival laboratory publishes its findings first, then the work of the UK researchers immediately loses all value and becomes unpublishable. In this scenario, the two researchers know that one of them must defect and publish before the deadline if they are to avoid a highly deterrent outcome with zero payoffs to both. This type of scenario might be best modelled by a Centipede-type incentive structure with a deadline (zero payoffs at the end).

Multi-player versions (with three or more players) of any of the games so far discussed have also been devised in which a player who chooses STOP receives a larger payoff than the co-players, who in turn typically receive equal smaller payoffs (e.g., Rapoport, Stein, Parco, & Nicholas, 2003). All Centipede games share fundamental strategic properties in common, encapsulating varieties of repeated reciprocal cooperation that are familiar features of myriad social relationships. They provide more realistic models of reciprocal cooperation than the frequently studied Prisoner's Dilemma game, because decisions in a Centipede game are sequential, and players have knowledge of their co-players' moves—properties that are common to most everyday reciprocal interactions—whereas the Prisoner's Dilemma is a static game in which each player makes a single decision without knowledge of what the co-player has chosen. Some of these shortcomings are overcome in iterated or repeated Prisoner's Dilemma games, but in a series of identical one-shot Prisoner's Dilemma games with the same co-player, decisions are still made simultaneously. This property renders the game an unsuitable model of the type of sequential reciprocal cooperation being considered here. The repeated Prisoner's Dilemma game is also different in other ways. Defection does not terminate the entire interaction, as in the Centipede game, and retaliation through strategies such as Tit for Tat is possible in the Centipede game but not in the repeated Prisoner's Dilemma. Finally, the payoffs of the repeated Prisoner's Dilemma game remain constant throughout the decision sequence and therefore cannot model the same variety of dynamic incentive structures as the Centipede game.

The Centipede game, in all its varieties, induces both cooperative and competitive motives in players, because at every decision node, opting to continue is a cooperative move benefitting both players if cooperation is reciprocated, and opting to stop the game is an uncooperative defecting move, because it benefits only the player who stops. It is obvious that both players benefit in the long run from reciprocal cooperation, because joint payoffs increase as the game continues (except in constant-sum versions); but it is also clear that a player always earns a better payoff by defecting than by cooperating if the co-player defects at the next decision node. In order to maximise their own payoffs when interacting with untrustworthy partners, players need to get their defection in first, and it is thus clear that trust, trustworthiness, risk-taking, and cooperation are key psychological factors at work in any Centipede game.

1.1.3: Backward Induction

What interests game theorists most about the Centipede game is its highly paradoxical—in fact, almost unbelievable—game-theoretic solution. The solution is arrived at through a form of reasoning called *backward induction* (BI) because of its resemblance to mathematical induction. The BI argument is based on two assumptions: (a) that both players are instrumentally rational in the sense of invariably choosing an option that maximises their own payoff; and (b) that the rationality of both players and the specification of the game are *common knowledge* (Aumann, 1976; Lewis, 1969), in the sense that both players know them, both know that both know them, both know that both know that both know them, and so on *ad infinitum*. In fact, a player needs only one iteration of common knowledge less than the number of decision nodes in the game to solve it, but full common knowledge implies infinite iterations.

From the seemingly innocuous assumptions (a) and (b) it turns out, astonishingly, that Player A will defect at the first decision node in Figure 1.1, with payoffs of only 2 to Player A and 1 to Player B. The argument applies equally to any of the games in Figure 1.2, in which the players would forgo even larger payoffs, and even to games with zero payoffs at the last terminal node, but for simplicity it will be explained here using the game in Figure 1.1 as the example. The argument begins by examining what would happen if the final decision node were to be reached. The first assumption (a) ensures that Player B would defect at Node 6, because that would maximise Player B's payoff, given that STOP results in a personal payoff of 14 whereas GO results in a payoff of 13. If the fifth decision node were to be reached, then the second assumption (b) implies that Player A would know that a cooperative move would result in Player B defecting at the following (sixth) node, and the first assumption (a) ensures that Player A would therefore defect and stop the game immediately, because that would maximise Player A's payoff, given that the personal payoff of 10 at Terminal Node 5 is greater than the payoff of 9 at Node 6. The argument unfolds in the same vein, step by step, with one additional level of common knowledge required at each successive backward step, until it forces the conclusion that Player A would defect and stop the game at the very first decision node. Although a payoff of 2 is meagre compared to those on offer further to the right, a cooperative opening move by Player A would result in Player B defecting at the second decision node, and defecting is therefore better for Player A because 2 > 1. Defection at the first decision node is the unique *subgame-perfect* (because it is proved by BI) *Nash equilibrium* of the game, a Nash equilibrium being an outcome in which neither player could have done better by choosing differently, given the strategy chosen by the co-player.

The number of decision nodes in this game could be extended to any finite number, with enormous riches available to players who cooperate reciprocally, and the BI argument would still hold, apparently proving that rational players would never cooperate, nor would they cooperate in any of the games in Figure 2 or extensions of them. Aumann (1992) described this conclusion as "among the most disturbing counterintuitive examples of rational interactive decision theory" (p. 219), and the validity of BI has attracted much theoretical and mathematical discussion (e.g., Aumann, 1995, 1998; Ben-Porath, 1997; Binmore, 1987, 1994, 1996; Broome & Rabinowicz, 1999; Busemeyer & Pleskac, 2009; Colman, Krockow, Frosch, & Pulford, 2017; Kuechle, 2009; Reny, 1992; Stalnaker, 1998; Sugden, 1992; Zauner, 1999). This thesis is not concerned with this normative problem but focuses instead on experimental evidence related to the positive or descriptive question of how human decision makers actually behave in experimental Centipede games, irrespective of the validity or otherwise of the BI argument.

1.2: Systematic literature review

It is striking that approximately four times as many articles in peer-reviewed journals in the *Social Science Citation Index* have been devoted to discussing theoretical issues surrounding the Centipede game than in reporting relevant experimental findings. Up to the time of writing this review, data from 25 peer-reviewed Centipede experiments have appeared, and a number of unpublished studies have also been located. Most experimenters have collected data in laboratory testing sessions with many participants present at the same time. Most (but not all) have studied repeated or iterated Centipede games with anonymous pairing—players kept ignorant of the identity of their co-players—and among these, most (but not all) have used random re-pairing after each repetition or round. In studies that have used anonymous and random re-pairing, it is not always clear from the written reports whether the best practice of *perfect stranger matching* was used. In perfect stranger matching, players know that the probability of being matched more than once with the same anonymous co-player is zero, and this removes any incentive to manage their reputations by acting in particular ways in one round in the hope of influencing their co-players' behaviour in a later round.

The experiments that have been reported all show wild deviations from the subgame-perfect solution of defecting at the first decision node. Very few participants in the role of Player A defect immediately, and frequent cooperation is typically observed. A conspicuous minority of players even cooperate at the last decision node, without any possibility of personal gain. Cooperation at the last decision node is of special theoretical interest, because it meets both of the standard definitions of *altruism* in the scientific literature. According to a widely accepted psychological definition, altruism is behaviour motivated solely to benefit another individual; and according to the standard biological and economic definition, altruism is paying a cost to provide a benefit to another individual (Clavien & Chapuisat, 2013). Cooperating at the last decision node—or at the penultimate decision node in games with zero payoffs for both players in the last terminal node—is altruistic according to either of these definitions.

The most frequently examined dependent variable has been the mean exit node, early exiting or defection being interpreted as evidence of game-theoretic rationality and late defection indicating (formally irrational) cooperation. When the Centipede game is played using the traditional *direct response method* which includes players taking turns making choices and receiving real-time feedback on their co-players' moves the sequential-move structure and interdependence of players' decisions mean that even the most cooperative player can never reach late exit nodes when paired with an early-defecting co-player. Consequently, exit nodes provide accurate information about only the defecting player's cooperativeness. For the co-players, exit nodes can provide only minimal values indicating the lower limits of their cooperativeness. Eight studies included in this review used different methods to elicit exit moves that yielded different data sets. Le Coq, Tremewan, and Wagner (2015), for example, used Selten's (1967) *strategy method*, requiring participants to specify in advance their planned moves at each decision node in the game, the resulting strategy vector providing full information about each participant's planned decision profile showing what move the player would make in every situation that could arise in the game. This methodology omits any actual sequential interaction and yields independent data points for all players, rather than just for the earlier defector in each pair. Using a variation of this strategy method, Nagel and Tang (1998) and Baghestanian and Frey (2014) presented Centipede games in *reduced normal form,* asking players to indicate their preferred exit node in the game as opposed to their full strategy vector. The two methods—the direct response method and the strategy method (with its variations)—have disadvantages as well as advantages as discussed in previous literature (e.g., Brandts & Charness, 2011), and specific aspects will be highlighted when these studies are reviewed.

A further word of caution is in order regarding the interpretation of moves in a Centipede game. Although a move that continues the game is commonly labelled *cooperate* and a move that stops the game *defect*, there are several motives that can lead to these moves. This comment could also be made about the Prisoner's Dilemma game, in which the same labels (cooperate and defect) have become conventional. In the Centipede game, early exiting may be motivated by competitiveness, lack of trust, or fear, among other motives, and late exiting by considerations far removed from cooperativeness, including a purely individualistic motive to maximise personal payoff by defecting as late as possible.

The remainder of this section is structured as follows. Section 1.2.1 explains the method adopted in this review, Section 1.2.2 provides an analysis and evaluation of the results, and Section 1.2.3 concludes with a discussion drawing the threads together and presenting some general conclusions about why people cooperate in repeated reciprocal interactions.

1.2.1: Method

This section sets out by explaining the methodology used for accessing the relevant experimental studies and the criteria used for inclusion in the review (Section 1.2.1.1). Section 1.2.1.2 defines payoff functions that are characteristic of Centipede games, and Section 1.2.1.3 outlines the independent and dependent variables that have been investigated.

1.2.1.1: Search procedure and inclusion criteria

This review summarises, structures, and evaluates all Centipede game experiments that were located with specific search criteria. Relevant publications were initially retrieved through systematic online searches via Google Scholar, the Social Sciences Citation Index, EconLit, and PsycINFO, using the search term *Centipede game*. Following this initial trawl, a citation search was performed for articles that have cited McKelvey and Palfrey (1992), the first published report of a Centipede experiment. Finally, the author contacted every email-accessible Centipede researcher identified through previous searches and enquired about any further unpublished experiments.

Both published and unpublished experiments are included in the main text of this review, but unpublished experiments are excluded from the quantitative comparisons and key statistics. To minimise the risk of including unreliable or untrustworthy data, the calculations of underlying quantitative measures are based exclusively on the results of experiments reported in published, peer-reviewed articles. Appendix A contains a comprehensive synopsis of all retrieved studies, distinguishing between published and unpublished experiments and indicating the sources.

To be included in this review, a study had to report empirical findings from a Centipede game using human participants. To qualify as a Centipede game, a game had to be characterised by the type of sequential move structure outlined above and to have a payoff function satisfying the formal properties defined in the subsection that follows. Only games with at least three decision nodes and fixed payoff functions were included. Centipede games share many features in common with iterated Trust games (e.g., Güth, Ockenfels, & Wendel, 1997; Ho & Weigelt, 2005) and iterated Ultimatum games (e.g., Güth, Ockenfels, & Wendel, 1993; Ochs & Roth, 1989), but most of these have only two decision nodes, and/or lack the predetermined payoffs at each terminal node that are characteristic of Centipede games.

Dynamic games with Centipede-like payoff functions have also been investigated in the area of social and developmental psychology, where they have been used to infer beliefs about co-players and theory of mind in adults (e.g., Goodie, Doshi, & Young, 2012; Hedden & Zhang, 2002; Meijering, van Rijn, Taatgen, & Verbrugge, 2012; Zhang, Hedden, & Chia, 2012) and children (e.g., Flobbe, Verbrugge, Hendriks, & Krämer, 2008). However, whereas most of these studies made important contributions, their immediate relevance to Centipede research is limited, because most presented research participants with a large variety of strategic games only few of which actually satisfied this review's inclusion criteria. Because it was impossible to tease out the data derived from pure Centipede games, these studies have been excluded from the review.

1.2.1.2: Definition of Centipede payoff function

Both constant-sum and increasing-sum Centipede games were included in this review (no experiments with decreasing-sum games have appeared), provided that their payoff functions satisfied certain defining properties. Using the expression $x(t)$ for the payoff x to Player A at terminal node t (where "terminal node" refers to the game's end point that is reached when either player chooses STOP at a decision node), and $y(t)$ for the payoff y to Player B at terminal node t, the defining properties for Centipede payoff functions were as follows:

1. At every odd-numbered terminal node, $x(t) \geq y(t)$, and at every even-numbered terminal node, $y(t) \geq x(t)$. This means that a player who defects invariably receives a payoff at least as great as the co-player's.
2. At every odd-numbered terminal node, $x(t) > x(t + 1)$ and at every even-numbered terminal node, $y(t) > y(t + 1)$. A player invariably receives a strictly larger payoff by defecting than by cooperating if the co-player defects at the following node.
3. At every odd-numbered terminal node, $x(t) < x(t + 2)$, and at every even-numbered terminal node, $y(t) < y(t + 2)$. A player invariably receives a strictly smaller payoff by defecting immediately than by cooperating and then defecting (if possible) at the next available opportunity.

4. For Centipede games with zero payoffs to both or all players in the last terminal node, if the game has *k* terminal nodes, then properties 1–3 apply up to the (*k* – 1)th terminal node only.

Some experimental Centipede games included unorthodox features, notably decisions made simultaneously (Cox & James, 2012) and games with continuous time replacing discrete decision nodes, in which players could defect whenever they wished (Murphy, Rapoport, & Parco, 2006). These features, which will be discussed more fully in the Results section, were formalised for the purpose of this review by integrating and displaying them within the decision trees of standard Centipede games. For example, the STOP moves made in games without discrete decision nodes, where participants received payoffs associated with their respective stop-times, were retrospectively divided up to correspond to a distinct node structure and allow comparison with other experiments.

1.2.1.3: Independent and dependent variables

Most published and unpublished experiments have investigated the effects of one or more independent variables on behaviour in Centipede games. For the purpose of this review, these independent variables were categorised under three main headings. Using a classification adapted from Vinacke (1969), these three sections contain narrative reviews of the effects of *game variables*, *situational variables*, and *individual difference variables*. Game variables are features of the particular Centipede games used in the experiments, including variations in payoff function, monetary incentives associated with the payoffs, information available to players about co-players' payoffs, decision space (the options from which players choose their moves), number of players (two-player or multi-player), and game length (number of decision nodes and number of rounds of play). Situational variables are aspects of the social or experimental environment in which the games are played, including individual versus group decision making, ingroup and outgroup interactions, effects of extraneously introduced extreme players, and so on. Individual difference variables are variations among the subjects or players, including differences in cognitive ability, other-regarding preferences, and personality traits.

To facilitate comparison across experiments, three main indices of cooperation (dependent variables) were recorded for each treatment condition in the experiments reviewed. Scores were provided for these indices regardless of the study's elicitation method (i.e., direct response method or strategy method). Because the scores are not completely comparable, each treatment condition using (a variation of) the strategy method was marked with an asterisk.

First, to quantify adherence to the subgame-perfect Nash equilibrium solution, the percentage of games terminating in the subgame-perfect equilibrium outcome was recorded (in the vast majority of cases, these were games ending at the first terminal node). For games played using the strategy method, percentages of STOP moves at Node 1 by participants in the role of Player A were calculated.

Second, to assess the prevalence of altruism, the percentage of games reaching the last terminal node (the game's natural end) were recorded. It should be noted, however, that for games played using the direct response method the percentage of games reaching the final terminal node can never be a precise measure of altruism and is likely to underestimate its prevalence within a given sample. The reasons are that, for this elicitation method, the statistic can measure altruism only in participants assigned the role of Player B (or Player C in the three-player version of the game), because only this player can ever get the chance to make the final, altruistic move. Furthermore, many games involving an altruistic participant in the role of Player B could be stopped by less cooperative co-players long before the end, in which case any altruistic intentions of Player B would go unnoticed. With regard to studies using the strategy method, the total percentage of players (Players A and B) choosing GO at their final decision node was calculated.

Third, to provide a measure of average cooperation levels, mean exit node in each treatment condition was calculated. Because experimental games varied in length, this mean was divided by the total number of terminal nodes, to provide an index of *standardised mean exit points* ranging from 0 to 1.

1.2.2: Results

The results of this review are manifold. Whereas an effort was made to provide a quantitative summary of measures associated with the reviewed studies in Section 1.2.2.1, Sections 1.2.2.2−1.2.2.5 contain narrative reviews of the effects of task variables, situational variables, and individual difference variables on behaviour in published and unpublished studies.

1.2.2.1: Summary measures

The summary measures were calculated for all studies published in peer-reviewed journals or books, provided that sufficient data were available for analysis (either through publication or direct contact with the respective authors). Figure 1.3 shows the percentages of games ending at the first and last decision nodes. Findings closest to the game-theoretic equilibrium solution were reported by Cox and James (2012) in a study of a 10-move linear Take-it-or-leave-it Centipede game with an unorthodox move structure (simultaneous moves under time pressure). Next closest to the game-theoretic solution was a study of expert and grandmaster chess players using a six-move exponential Centipede game (Palacios-Huerta & Volij, 2009), and experiments using 6-move and 10-move constant-sum Centipede games (Fey, McKelvey, & Palfrey, 1996). The vast majority of experiments show large deviations from the game-theoretic solution. In some treatment conditions, not a single game outcome conformed to the game-theoretic prediction.

Furthermore, many experiments provide evidence for substantial proportions of altruists. The high percentages of altruists in Gerber and Wichardt's (2010) study (up to 56%) in eight-move linear Centipede games are easily explained by "welfare-enhancing instruments" used in the experiment—options to buy insurance against termination by the co-player or to pay a small price in return for offering the co-player a bonus for not terminating the game. Bornstein et al.'s (2004) Condition 1, using a six-move linear Centipede game, also yielded a very high percentage of altruistic moves (16.67%). However, it is important to note that the total number of games included in this condition was comparatively small, so that 16.67% translates into only three games with altruistic terminations. It is noteworthy that studies using the strategy method (e.g., Baghestanian & Frey, 2014; Le Coq et al., 2015; Nagel & Tang, 1998) were marked by very high percentages of altruistic moves. This can be explained by the more complete and accurate results yielded by the strategy method, which reflect both players' levels of altruism and are independent of the co-players' choices.

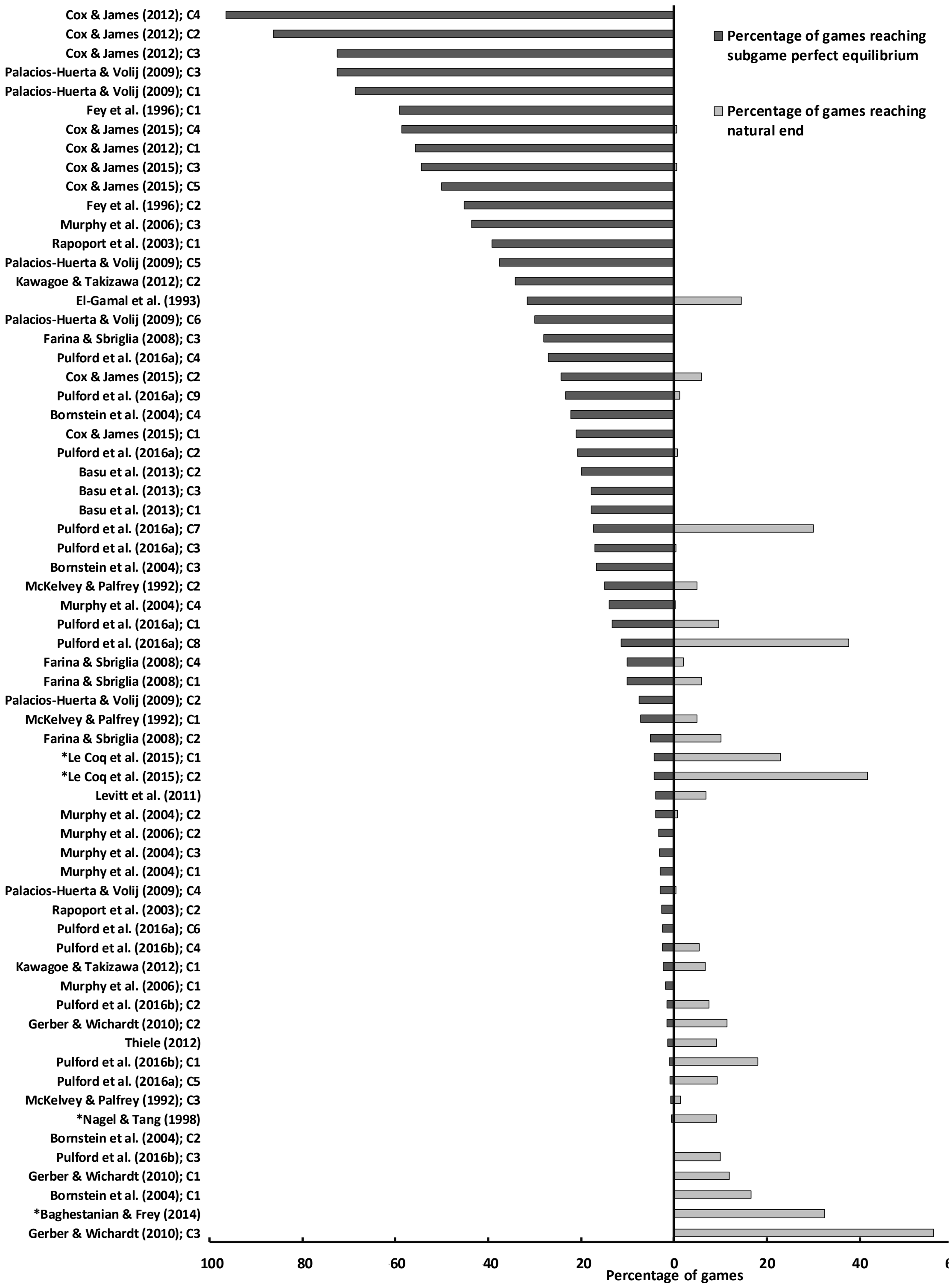


Figure 1.3. Game percentages ending at first and last terminal nodes across 72 treatment conditions (“condition” abbreviated “C”). All games played using (a variation of) the strategy method are marked with an asterisk.

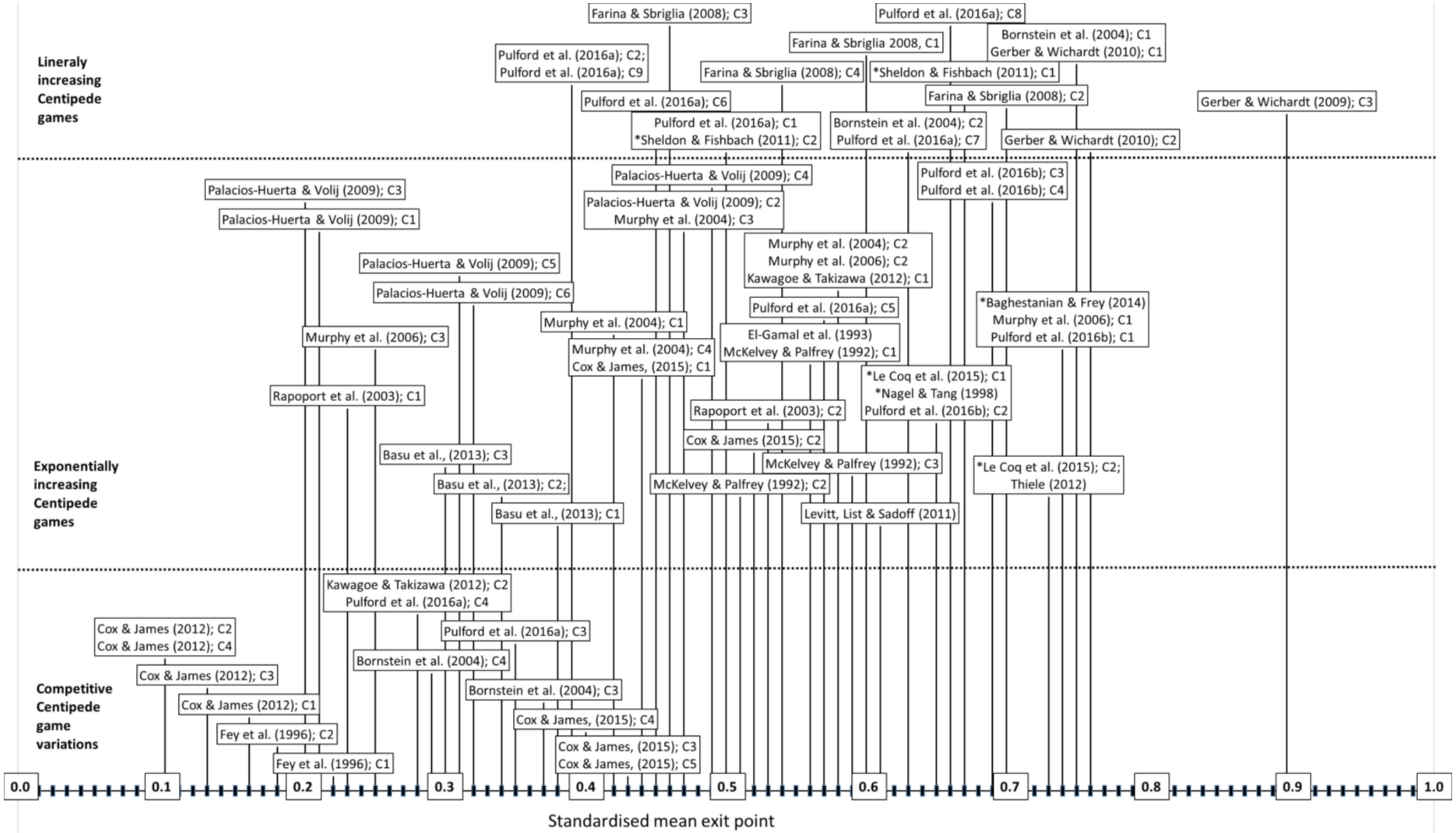


Figure 1.4. Standardised mean exit points across 72 treatment conditions (“condition” abbreviated “C”), classified by payoff function types. All conditions played using (a variation of) the strategy method are marked with an asterisk

Figure 1.4 provides an overview of the distribution of standardised mean exit points across different experiments and treatment conditions. In this figure, treatment conditions are classified according to payoff function (linear, exponential, or competitive variations including constant-sum and Take-it-or-leave-it payoff functions). It is immediately obvious that a high proportion of experiments have focused on exponential Centipede games. On average, competitive games seem to elicit the lowest proportions of GO moves and linear games the highest. The rank order of standardised mean exit points presented in Figure 1.4 correlates highly with the ranking of results both according to percentages reaching only the first terminal node: $r_s\,(67) = –.812$, $p < .001$, and according to percentages reaching the last terminal node: $r_s\,(67) = .649$, $p < .001$.

1.2.2.2: Task variables

The experiments under review used Centipede games that vary considerably in their payoff functions. Several other aspects of the task presented to the participants also differed between experiments and between treatment conditions within experiments. The following paragraphs will review the effects of these variables on the dependent variables that were identified above, and summarise the key findings.

Payoff function

With regards to the payoff function, the following aspects were more closely examined: Constant-sum versus increasing-sum games, Take-it-or-leave-it payoff function, risk cost and payoff asymmetry, and focal points.

Constant-sum and increasing-sum games. From a theoretical point of view, the most important factor differentiating Centipede game payoff functions is the distinction between constant-sum, on the one hand and increasing-sum, whether linear or exponential, on the other. Linear or exponential decreasing-sum payoff functions are theoretically possible, but no experiments investigating them have been reported. The reason why this distinction is so important is that, according to basic principles of game theory, two-player constant-sum games are *strictly competitive*, and this implies that there is no scope for mutually beneficial cooperation and no social gain from GO moves: players can only struggle for shares of a fixed pot, one player's gain invariably being equal to the other's loss. Because GO moves are frequently interpreted as cooperative, and cooperation is obviously an important motive for choosing GO, one should expect earlier defection in constant-sum than other Centipede games.

A different reason for the importance of distinguishing between increasing-sum and constant-sum games was provided by Pulford, Colman, Lawrence, and Krockow (2017). These authors pointed out the potential applicability of fuzzy-trace theory (Reyna & Brainerd, 1991, 1995), which suggests the formation of mental *gist representations* when one is presented with an abstract decision context. To simplify their choice process and avoid storing detailed payoff information, players in the Centipede game may generate gist representations to guide their decisions. Such representations are likely to associate STOP moves with the certainty of small payoffs and GO moves with the possibility of larger payoffs, thus tempting players to choose GO repeatedly in the game. This gist seems highly compelling in increasing-sum Centipede games, where the payoffs associated with early exit nodes are appreciably smaller than those associated with later exit nodes. In constant-sum games, on the other hand, the potential gains to be reached by choosing GO tend to be comparatively small, thus decreasing the temptation to choose GO and increasing defection rates.

Only a small number of experiments have investigated constant-sum Centipede games. Fey, McKelvey, and Palfrey (1996) reported that decision making in their six-move constant-sum game was closer to the game-theoretic solution than in previous studies using increasing-sum games. The relative frequency of defection at the first decision node of their game was .59—much higher than the relative frequency of .01 in McKelvey and Palfrey's (1992) six-move exponentially increasing game. Relative frequencies of defection increased with every decision node, and 45 participants out of 176 chose STOP at every opportunity. Kawagoe and Takizawa (2012) confirmed the results of Fey et al. in a direct replication and comparison of the original two games.

The effect of constant-sum versus non-constant-sum payoff functions reported by Fey et al. (1996) and Kawagoe and Takizawa (2012) may be confounded with incentive effects. Fey et al. used very low stakes with a maximum individual payoff of $2.92. In McKelvey and Palfrey's (1992) game, on the other hand, it was possible to win up to $25.60 in a single game. Payoff function was thus confounded with stake size, and this raises the possibility that the different response patterns in games with different payoff functions may have been caused by the smaller incentive to choose GO in the constant-sum game in both experiments.

Bornstein, Kugler, and Ziegelmeyer (2004) solved this methodological problem by controlling for stake size in their comparison of constant-sum and linear Centipede games, and even with this additional control they found a significant difference between the two payoff functions. Not a single six-move constant-sum game reached the last three terminal nodes, compared to an overwhelming 88% in the increasing-sum condition. Pulford, Colman, Lawrence, and Krockow (2017) compared eight-move constant-sum Centipede games with different versions of linearly increasing Centipede games—all carefully controlled for stake size—and found similar differences to those reported by Bornstein at al., with constant-sum games eliciting significantly less cooperation than increasing-sum versions. These findings were further corroborated by two as-yet unpublished experimental comparisons of linearly increasing and constant-sum Centipede games with ten moves and three moves, respectively (Atiker, Neilson, & Price, 2011; Wang, 2015). Taken together, the results suggest that constant-sum and increasing-sum Centipede games provide significantly different contexts for decision making, despite their identical equilibrium solutions.

Take-it-or-leave-it payoff function. Another class of payoff functions that induces highly competitive behaviour includes those in which a player who defects invariably receives the entire accumulated payoff, leaving nothing for the co-player. Only four experimental studies have investigated such Take-it-or-leave-it Centipede games (Cox & James, 2012; Cox & James, 2015; Huck & Jehiel, 2004; McIntosh, Shogren, & Moravec, 2009). Cox and James reported one of the lowest levels of cooperation ever found. This must be due, at least in part, to their highly competitive Take-it-or-leave-it payoff function, but it is difficult to draw clear conclusions from their study on account of various confounding factors. An unorthodox presentation format required some players to move simultaneously, and although others moved sequentially, their moves were timed, and a failure to move within each 10-second window caused the move to pass on to the co-player, in effect treating non-responses as cooperative GO moves and imposing considerable psychological pressure on players to move quickly. At least some—perhaps many—of the defections in this experiment may represent panic moves, rather than carefully considered decisions to defect.

Extending their previous experiment, Cox and James (2015) conducted another complex Centipede study that included one of McKelvey and Palfrey’s (1992) original Centipede games together with four other games conditions that differed in stake size, payoffs to non-takers (Take-it-or-leave-it game versus standard Centipede game), time pressure imposed, and presentation format (clock versus tree format). Again, Take-it-or-leave-it payoff functions led to earlier defection in the game.

Another relevant study in the context of Take-it-or-leave it Centipede games is McIntosh, Shogren, and Moravec's (2009) investigation of competitive Centipede tournaments. Across two experiments, participants completed five Centipede games using the strategy method. Because the strategy method requires players to specify in advance how they would act in every situation that could arise in the game, it is possible for a researcher to match any two strategies in a virtual game to determine what the outcome of the game would be. In this experiment, each participant's strategy was matched with every other participant's strategy twice, so that player roles could be reversed the second time around. All games had identical payoff trees but different rules on how to convert payoff points received in the game into actual cash earnings. Most conversion rules were based on linear functions: the total number of payoff points earned in the experiment was multiplied by a fixed rate of exchange. However, both experiments also included one competitive treatment condition each in which the subjects' strategies were entered into tournaments, and monetary rewards were determined based on relative ranking schemes.

In the tournament of Experiment 1, the strategies were ranked according to the total number of payoff points earned. In the tournament of Experiment 2, "tallies" were awarded to the "winner" of each game, essentially turning the original Centipede game into a constant-sum, Take-it-or-leave-it game. The participant with the highest number of tallies overall, received the highest financial reward. In Experiment 1, only 11.9% of tournament games ended at the first decision node, and no significant differences were found between the tournament treatment condition and the treatments using other (less competitive) conversion rules. After adding the tallies in Experiment 2, the tournament treatment yielded an exit percentage of 38% at Node 1 that differed significantly from the four treatments with less competitive monetary conversion rules. These results indicate that the binary Take-it-or-leave-it incentive structure significantly decreases cooperation levels. However, they do not allow for any inferences about the effects of those Take-it-or-leave-it functions characterised by increasing sums.

Risk cost and payoff asymmetry. Horng and Chou (2012) examined another aspect of the payoff function, namely the *risk cost* associated with each GO move. Risk cost is the loss of payoff resulting from a GO move in the event that the co-player defects at the immediately following decision node. In the high risk cost treatment condition, each cooperative GO move led to a decrease of the prospective personal payoff of 90%; in the medium risk cost condition, the decrease was 50%; and in the low risk cost condition, the decrease was 20%. The results showed significant differences between these three conditions, with the high risk cost condition yielding earlier defection than the other two. An interaction was found between risk cost and overall stake size, a larger effect of risk cost occurring in games with high stakes than in games with low stakes.

High risk cost, as defined by Horng and Chou (2012), is almost invariably associated with payoff asymmetry between players. When the cost of a GO move to a player is increased, the co-player’s share of the pot has to be increased proportionately to maintain the payoff function. Murphy et al. (2006) manipulated payoff asymmetries at the terminal nodes in exponential Centipede games presented in a format as unorthodox as Cox and James’s (2012) design, characterised by simultaneous moves, non-discrete decision nodes and a large number of players. They reported that larger differences between payoffs induced more competitive play and led to significantly earlier defection. Pulford et al. (2017) compared three types of eight-move linear Centipede games of varying payoff symmetry. In the standard version, the payoff difference between players remained constant throughout the game. In the other two versions, the differences either decreased or increased with every decision node that was passed. The results showed highest cooperation levels in the decreasing-difference game, probably due, at least in part, to inequality aversion, because cooperation in this game had the effect of reducing inequalities between players’ payoffs. Similarly, Maniadis (2008) manipulated the payoffs at the final terminal node of their exponential Centipede games, and found that lower payoff inequalities significantly increased cooperation compared to their control condition.

Focal points. The standard Centipede game with its payoff function following a regular and logical mathematical pattern lacks useful focal points as delineated by Schelling (1960). If any terminal node is made more salient (or focal) by breaking the previous payoff pattern, this should focus the players’ attention on the anomalous node, improve predictions about the likely decisions at the node in question, and subsequently enhance BI reasoning. An unpublished study by Atiker, Neilson, and Price (2011) directly manipulated payoff functions to introduce either early or late focal points to their ten-move Centipede games. Both types of focal points increased the frequency of Nash equilibrium play, and the early focal points (at Nodes 3 and 4) had a particularly large effect. Using the strategy method, these researchers found 34.7% of players in role A to choose defection at Node 1 as opposed to 4% in their standard Centipede condition. The focal point theory also extends to findings regarding the influence of zero payoffs at the game's final end (e.g., Rapoport et al., 2003). It is possible that equal payoffs of zero at the ultimate terminal node appear salient to the players, because they break the pattern of the rest of the payoff function. Consequently, players may be better able to predict decision-making at the penultimate node, which in turn could have the effect of kick-starting BI reasoning. This interpretation, however, requires further support by a controlled comparison of games with and without zero payoff values at the final exit point.

Incentives

A number of investigations have shown that financial incentives tend to reduce the variance in decision makers' behaviour and more generally bring decisions closer to the normative prescriptions of decision theory and game theory, especially for decisions of intermediate difficulty (Camerer & Hogarth, 1999; Hertwig & Ortmann 2001). Several studies have manipulated stake size to investigate the effects of financial incentives on decision making in Centipede games. McKelvey and Palfrey (1992) included a high-payoff treatment condition in their experiment in which payoffs were quadrupled relative to the control condition. Overall, however, their stakes were not very large—in the high-payoff condition, the maximum individual payoff was $75.00, and the average actually received was only $41.50. Rapoport et al. (2003) used much higher incentives in a nine-move exponential Centipede game, with a maximum individual payoff of $2,560 dangling from the Centipede game's front leg (this was a game with zero payoffs in the last terminal node). Compared to their lower-stakes treatment condition, the high-stakes condition yielded significantly lower levels of cooperation. Over 60 rounds of the game, as many as 39% of high-stakes games ended at the first decision node, and only 17% continued beyond the third. An unpublished paper by Nachbar (2014) reported an experiment with high stakes, as in Rapoport et al.'s study. In a fifteen-move Centipede game, Nachbar also found a high proportion of defections at the first decision node.

These high-stakes games were all multi-player Centipede games (three and five players respectively) with an unusually high payoff asymmetry between players. Rapoport et al.'s (2003) high-stakes condition had a payoff ratio of 10:1:1 (the defecting player received $10 whereas the "losers" received $1 each) at every terminal node, compared to 4:1 in the two-player high-payoff game used by McKelvey and Palfrey (1992). Furthermore, every GO move in the high-stakes condition was associated with high risk cost—an 80% decrease in personal payoff at the next terminal node—and, because it was a three-player game, every player had to wait for two co-players to move before being able to move again, adding to the risk of cooperation. In the light of Horng and Chou's (2012) later findings of the effects of risk cost on decision making in the Centipede game, this suggests that Rapoport et al.'s study may be confounded. Whereas high stakes undoubtedly encouraged early defection, it is impossible to disentangle the relative effects of stake size and risk cost, both of which were exceptionally high in the high-stakes condition. Further research by Farina and Sbriglia (2008a, 2008b) corroborated the findings on the importance of stake size. Comparing Centipede games with two different, moderately high stake sizes and moderate risk costs, the authors reported lower cooperation levels in the game condition with higher stakes.

Incomplete information

The vast majority of experimental Centipede research has focused on games with complete information. The first study to introduce an element of incomplete payoff information was reported by Cox and James (2012). In their experiment, the initial payoffs at the first terminal node were randomly drawn from a uniform distribution from 0.01 to 10.00. Both players were informed about their own draw as well as the general rule governing payoff increases from node to node, but each player was ignorant of the co-player's initial payoff. Unfortunately, Cox and James did not include a control group with complete information, hence the magnitude of the effect of incomplete information on Centipede play is unknown.

Furthermore, no research to date has examined the influences of incomplete information with regards to the rules of the Centipede game. With risk and uncertainty being common factors in real-life decision making, the manipulation of knowledge for example pertaining to the game length and termination rules could be particularly fruitful (Jiborn & Rabinowicz, 2003).

Decision space

In order to overcome the limitations of the alternating decision structure of the Centipede game, Murphy et al. (2006) introduced a version without discrete decision nodes. In the standard Centipede game, the inequality of payoffs between the two players at any terminal node leads to an inherent asymmetry between player roles. Consequently, in games with even numbers of moves, Player A has better payoff prospects and—depending on the payoff function—this advantage can be substantial. An iterated *real-time trust game* (RTTG) introduced by Murphy et al. involved multiple players (either three or seven in their experiment), who decided when to stop a game within a continuous time frame of 45 seconds. No player was assigned any particular role, and consequently any player could exit at any time. With time elapsing, the total payoff to all players increased in line with the payoff function approximating an exponential Centipede game. The player stopping the game (the "winner") received the lion's share of the payoff associated with the stop time, and all other players (the "losers") received equal but smaller payoffs. If no player decided to STOP before the natural end, then all participants received zero payoffs (this is equivalent to zero payoffs in the final terminal node of a conventional Centipede game).

The RTTG resembles a Centipede game because of its payoff function, but it lacks the discrete sequential structure that, in standard Centipede games, enables players to signal trust and cooperation by actively choosing GO moves rather than by doing nothing. This turns the RTTG into a highly competitive game, especially with many players and high payoff ratios (much greater payoffs to winners than losers). Experimental results showed that, under these extreme conditions, cooperation dropped rapidly towards the game-theoretic subgame-perfect equilibrium solution, and the experimenters even decided to abort one testing session prematurely because of "clear signs of irritation in some of the participants" (Murphy et al., 2006, p. 158).

A similar procedure was used by Cox and James (2012) with Centipede games presented either in the classic game tree format or in a "clock format". The clock format translated the traditional game tree of a 10-move Take-it-or-leave-it Centipede game into a 10-second time frame, with each tick of a clock indicating the next move. As in the RTTG of Murphy et al. (2006), only STOP moves required any action by the players, non-action functioning as GO, and payoffs dropped to zero if no player terminated the game within the given time frame. The payoff function followed the usual pattern of a Take-it-or-leave-it Centipede game (with zero payoffs at the end), the player stopping the game receiving the entire payoff pot and the co-player nothing. The authors compared decision making across four treatment conditions, pairing clock Centipede games and standard tree Centipede games with either simultaneous moves or sequential moves. Results showed that participants presented with a game in tree format defected later than those given the clock format, and that games ended later in sequential-move games than in simultaneous move games. Regardless of the initial levels of cooperation, players across all game conditions showed high learning rates and converged to equilibrium play after several repeated rounds. In the condition combining simultaneous move structure and clock format, near-perfect equilibrium play was reached after only three rounds.

These results stand out from the relatively high levels of cooperation and mixed learning effects found in experiments with orthodox Centipede games. It is difficult to pinpoint the precise reason for this, because Cox and James (2012) used a complex experimental design incorporating several unusual features at once, including incomplete payoff information, a Take-it-or-leave-it payoff function, zero payoffs for all if no player defected, and clock timing. Furthermore, follow-up research by the same authors (Cox & James, 2015) investigating four-move Centipede games produced contradictory results. In contrast with their first study, game versions with time pressure and clock format did not yield lower cooperation levels than the control condition. Additional research with carefully manipulated control conditions is necessary to clarify the previous, contradictory results.

Number of players

The Centipede game was originally envisaged as a two-player game (Rosenthal, 1981), and the majority of experimental studies, starting with McKelvey and Palfrey (1992), have used two-player games. A small number have investigated multi-player Centipede games. In the most common multi-player version, three players take turns deciding between the usual STOP and GO moves in an exponential game with nine decision nodes. A player who defects receives a larger payoff than the co-players, who typically receive the same smaller payoff as each other, and at the final terminal node all three receive zero payoffs. This three-player version, first studied by Parco, Rapoport, and Stein (2002) and Rapoport et al. (2003), yielded very different results from previous Centipede studies, but only when combined with very high stakes. The low-stakes version elicited remarkably similar behaviour to McKelvey and Palfrey’s

(1992) six-move, two-player game. Only 2.5% of the low-stakes three-player games were in line with the equilibrium solution (compared to 0.7% in the two-player game) and both games produced the same noticeable decision pattern, with relative frequencies of STOP moves increasing from one decision node to another.

In an unpublished study using five-player, high-stakes Centipede games, Nachbar (2014) reported high defection rates at the first decision node (0.363) but found less evidence for learning across game rounds and a higher number of consistent cooperators than in Rapoport et al.'s (2003) high-stakes three-player experiment. Murphy et al.'s (2006) experiment using a continuous-move version of the Centipede game was the only study directly investigating the effects of player numbers. The results showed that increasing the number of players from three to seven led to significantly earlier defection. Future research should continue to investigate the effects of player numbers on decision making, particularly the differences between standard two-player games and multi-player versions. Any direct comparison will need to control for payoff function variations (including risk cost and payoff asymmetry) and game length.

Game length

Any Centipede game, irrespective of its payoff function, can be extended indefinitely by adding decision nodes and associated terminal nodes according to the appropriate payoff function rule. Game length appears to be a seriously under-researched independent variable. Experimental Centipede games have all been comparatively short, with numbers of decision nodes ranging from 3 to 12. Furthermore, the longest game used in a published experiment—Nagel and Tang's (1998) 12-node Centipede version—was presented in normal form, thus avoiding any sequential interaction between players. Nachbar's (2014) unpublished study reported results from a game with 15 decision nodes, but this was a five-player game, and 15 decision nodes could be considered the minimum length for a player group of that size, because no player can make more than three moves. Only McKelvey and Palfrey (1992) and Fey et al. (1996) have compared behaviour in games of different lengths directly, and the differences that they examined were small: four versus six decision nodes (McKelvey & Palfrey) and six versus ten decision nodes (Fey et al.).

A retrospective analysis of variance of McKelvey and Palfrey's (1992) data set reveals a significant difference between the mean exit proportions of their high-stake four-move game (*M* = .51; *SD* = .12) and their low-stake six-move game (*M* = . 61; *SD* = .11), $F(2, 65) = 4.11$, $p < .05$, partial $\eta^2 = .11$, indicating medium effect size, whereas their low-stake four-move and low-stake six-move games did not differ significantly. Hence, although there was evidence for differences between games of different lengths in McKelvey and Palfrey's study, it is difficult to disentangle the respective effects of game length and stake size. Further research needs to be done to arrive at a better understanding of the effects of game length.

Number of rounds

Increasing experience with a game can have an important impact on decision making (Ponti, 2000). Some studies of the Centipede game have varied the numbers of repetitions or rounds of the game, ranging from one (Bornstein et al., 2004; Levitt, List, & Sadoff, 2011; Palacios-Huerta & Volij, 2009) to many rounds. Most experiments with multiple rounds have revealed small learning effects: McKelvey and Palfrey (1992), Fey et al. (1996), and Pulford, Colman, Lawrence, and Krockow (2017) all reported slightly earlier defection in later than earlier rounds of the game. Thiele (2012) found decreasing cooperation over three rounds of Centipede games played with the same co-player. However, when the co-player was changed on the fourth round, cooperation spiked upward once more before decreasing again over the following game repetitions with the second co-player, suggesting that repeated games with the same co-player maybe treated by players as a supergame (one large game consisting of several iterations of the basic Centipede game), thus evoking different learning patterns.

Nagel and Tang (1998) investigated learning patterns over 100 rounds of a Centipede game and found the emergence of some inflexible strategies that were not usually in line with the game-theoretic solution. It is unwise to generalise these findings, because Nagel and Tang presented the game to the players in reduced normal form, as an abstract payoff matrix rather than a game tree, and participants merely indicated their preferred stopping nodes. This had the effect of turning an essentially dynamic, sequential-move game into a one-shot simultaneous-move game. Furthermore, the highly complex payoff matrix may have been poorly understood by some participants.

Rapoport et al. (2003), using a conventionally presented three-player exponential Centipede game, found convergence towards the subgame-perfect equilibrium after 60 rounds of play, but this effect occurred only in their extremely high-stakes experiment and not in their lower-stakes experiment. The previously reviewed studies of continuous-move and simultaneous-move games (Cox & James, 2012; Murphy et al., 2006) also reported evidence for learning across the number of game rounds, with rapid convergence towards subgame-perfect equilibrium play irrespective of initial cooperation levels. An investigation by Huck and Jehiel (2004) of Take-it-or-leave-it games, in which players were provided with varying amounts of information about their co-players' previous decisions suggested that the availability of accurate information about the co-player's choices in the most recent game rounds of the experiment encouraged early defection.

Summary of game variables

Taken together, the results on game variables suggest that payoff function variations and incentives affect behaviour significantly, but more research is required to understand the separate and joint effects of these variables. Players are highly sensitive to variations in payoff functions: they exhibit higher levels of cooperation in symmetric, low risk cost payoff structures that provide opportunities for social gains. There is some evidence that high stake sizes lead to earlier defection in three-person, high risk cost Centipede games, but more research is needed to investigate the effects of incentives in standard two-player games when effects of other game variables are controlled. It seems reasonable to infer from the existing evidence that high stakes, high risk costs, and payoff asymmetry are likely to accelerate learning effects and convergence towards subgame-perfect equilibrium play over repeated rounds of the game, but additional research is necessary before these effects are firmly established.

Particular variables of interest are focal points of zero at the final exit node, and Take-it-or-leave-it payoff functions. Previous research suggests that both may lead to earlier defection in the game but no studies to date have investigated the effects with a controlled experimental design. Furthermore, two potentially important factors—incomplete information and game length (number of decision nodes)—have received very little attention to date, and should be examined in future investigations. This would also increase real-life applicability of empirical Centipede research given that relationships often include a high number of reciprocal interactions with potential outcomes not always fully known to the respective individuals.

1.2.2.3: Situational variables

Situational variables are aspects of the social or experimental environment in which the task is performed that may influence players' behaviour. Six main factors studied in this area will be reviewed: individual versus group decision making; ingroup and outgroup interactions; effects of extreme players; interpersonal control; public information about co-players' previous choices; and wealth differences.

Individual versus group decision making

A substantial body of evidence has accumulated in support of the *interindividual–intergroup discontinuity effect*, according to which interactions between individuals tend to be more cooperative than interactions between groups, and this is usually attributed to greater fear and greed in intergroup relative to interindividual interactions (Wildschut et al., 2003).

Bornstein et al. (2004) compared decision making by individual and group players in six-move constant-sum and linear increasing Centipede games. In the group condition, three participants conferred before making a joint decision at each decision node. In addition to the quantitative assessment of exit nodes, the group discussions were recorded for additional qualitative analysis. The main finding was that group players defected significantly earlier than individuals in both types of games. In the linear Centipede game, none of the three groups reaching the final decision node chose the cooperative GO option, whereas in the individual condition, three out of four players who reached that point decided altruistically to cooperate. Bornstein et al. offered several explanations for these findings, one of which was that groups appeared to be less prosocial than individuals. This inference was backed up by the taped discussions, in which a single competitive individual could persuade the group to defect more easily than a cooperative individual could persuade the group to cooperate. Based on these findings, the authors suggested that group players may resemble the rational agents assumed by classical game theory more closely than individuals do. An alternative explanation could be that due to ingroup–outgroup biases, group players may feel more strongly about the payoffs of fellow ingroup members. With the aim of maximising ingroup payoffs and beating the outgroup, they might defect earlier than in the individual player condition. The following subsection includes a more detailed discussion of ingroup–outgroup biases.

Important decisions in everyday life are increasingly often made not by individuals but by groups, and in some cases—two teams of lawyers making alternating proposals in an effort to negotiate a legal settlement, two boards of directors of commercial companies making alternating suggestions about a potential arrangement of mutual benefit, a trade union and an employers' executive committee taking turns suggesting an acceptable settlement to an industrial dispute, and so on—reciprocal turn-taking of the Centipede type appears relevant. The potential value of further studies of group decision making in Centipede games therefore seems high. Furthermore, as Bornstein et al. (2004) used a one-shot Centipede game, replications using repeated games may provide interesting insights into individual versus group learning processes.

Ingroup and outgroup interactions

Le Coq, Tremewan, and Wagner (2015) compared six-move exponential Centipede games played between individual members of the same social group (ingroup interactions) and members of different social groups (outgroup interactions). The study was theoretically grounded in a large body of research suggesting that perceptions of group identity can produce favourable attitudes towards ingroup members and dismissive attitudes towards outgroup members (for an overview, see Postmes & Branscombe, 2010), thereby presumably affecting behaviour and decision making in relevant social contexts. In line with previous research, the authors hypothesised that ingroup interactions would produce higher levels of mutual cooperation, but they were surprised to find no significant difference: outgroup decisions were more cooperative, although the difference was not statistically significant. Le Coq, et al. suggested that participants may have perceived their fellow ingroup members to be more similar, and this assumption of ingroup similarity could have led to a higher certainty about their co-players' likely exit nodes. The outgroup condition, on the other hand, provided fewer social clues about the co-players' probable strategies, and players in that condition may consequently have engaged in more exploratory play to test for the outgroup members' willingness to cooperate at different stages of the game, leading (possibly) to slightly increased levels of cooperation.

These findings should be treated with caution. The investigators used Selten's (1967) strategy method, an experimental procedure that eliminates the sequential interaction between players that is inherent in the standard procedure. Players were merely asked to indicate whether they would choose STOP or GO at each decision node if the opportunity were to arise. To determine the participants' respective payoffs, the strategy vectors of two randomly selected players were pitted against each other. This method obviously fails to capture the dynamic essence of the Centipede game.

Effects of extreme players

Murphy, Rapoport, and Parco (2004) studied the influence of extreme player types on overall cooperation levels within groups of players. By adding zero, three, or six computer players with programmed strategies (either unconditional cooperators or unconditional defectors) to their testing sessions of 21, 18, or 15 human players, they investigated whether the sample composition could affect the general patterns of decision making over 90 rounds of a three-player, nine-move exponential Centipede game. The results showed that the addition of unconditionally cooperative programmed co-players increased the cooperation of the human players significantly, leading to later (human) defection than was observed in a control group without programmed co-players. In contrast, the inclusion of unconditionally defecting co-players had no significant effect on the behaviour of human players. The authors suggested that this could be explained by the existence of "hard-core cooperators" who showed very high levels of cooperation independent of their co-players' choices, and that other less inflexible players seemed willing, nonetheless, to ignore the highly non-cooperative behaviour of a few of their co-players, presumably attributing it to greed, stupidity, or malice. The authors concluded that natural predispositions to cooperation have an important influence on decision making in the Centipede game that cannot be reversed by the competitive play of a minority of co-players. These findings corroborate McKelvey and Palfrey's (1992) identification of diehard altruistic player types and offer important insights into group dynamics within a given testing session. They also highlight the importance of large sample sizes in order to overcome potentially distorting effects of a few highly cooperative players.

Interpersonal control

Previous research suggested that the level of interpersonal control in combination with the perceived "barrier to success" might have an influence on decision making in the Centipede game. Sheldon and Fishbach (2011) studied decisions of participants in the role of Player A—arguably the role with higher interpersonal control in the Centipede game, because it empowers the first—and in certain cases the only—decision. The authors manipulated the perceived barrier to success in the game by asking participants to think about risk in the task (strong barrier to success) or about security in the task (weak barrier to success). The human Player As were subsequently paired with computer players and completed one Centipede game each. Findings showed that participants in whom expectations of strong barriers to success had been induced cooperated significantly more frequently than those with the opposite induction. The authors suggested that participants in the strong barrier condition increased their cooperation to counteract the anticipated difficulties in the task and the temptation to defect. They further argued that this was possible only because of their induced perception of control vis-à-vis their co-players.

Public information about co-players' previous choices

In a study of a three-move exponential Centipede game, El-Gamal, McKelvey, and Palfrey (1993) found support for the importance of players' past experience in the game. Their sequential econometric model suggested that participants learn about the population within a given testing session and adapt their play on the basis of previous experience. These results were extended by three as-yet unpublished studies manipulating the amount of information available to players about their co-players' history of decision making (Gamba & Regner, 2015; Huck & Jehiel, 2004; Maniadis, 2008).

In a complex experiment using a nine-move Take-it-or-leave-it game, Huck and Jehiel (2004) found that participants used both their own past experience and public information—if available—to inform their decisions. The use of public information was particularly influential in conditions in which players were provided with detailed statistics (relative frequencies of GO choices at specific decision nodes, aggregated over the most recent games), and this tended to lead to a continuous decrease in cooperation across 50 rounds of play. Because this study used a competitive Take-it-or-leave-it game, it would be imprudent to generalise the findings to other types of Centipede games. However, the experiment does provide evidence for the influence of players' reputations on their co-players' decision making.

In a related study conducted as part of an unpublished PhD thesis, Maniadis (2008) investigated the effects of varying amounts of aggregate information about the previous game outcomes (no information, full information and partial information about other player group only) on decision making in two different Centipede games. In line with Huck and Jehiel's (2004) results, information about previous play decreased cooperation levels. Interestingly, Gamba and Regner (2015) obtained slightly different results in a similar study. The authors manipulated the type of information about the co-player's behaviour (personal information about own game outcome only versus public information about all game outcomes from previous round) while comparing results across different elicitation methods in the games (direct response method versus strategy method).

Gamba and Regner (2015) also measured *social value orientation* (SVO), a psychological concept introduced by Messick and McClintock (1968) denoting a person's preference about how to allocate a divisible resource such as money between self and another person. In Gamba and Regner's experiment, SVO was assessed using a combination of questionnaire data from an SVO scale and behavioural data from a simple trust game. The data from the two-move sequential trust game, characterized by a choice dilemma between selfish and cooperative strategies similar to the Centipede game, was used to determine a threshold for categorising the continuous scores derived from the SVO questionnaire. Subjects were subsequently categorized as either *proselfs* (people who are motivated solely or predominantly to maximize their own payoffs) or *prosocials* (people who are motivated to maximize not only their own payoffs but also the payoffs of the co-player).

The authors reported that proselfs cooperated more frequently in games with public information (particularly when combined with the strategy method) compared to games with personal information only. This was explained by the fact that the additional information about choices of all players of opposite participant role (rather than just of the own co-player) led them to adapt their initially non-cooperative strategies in order to increase their own payoffs. These findings suggest that individual differences could play an important role when it comes to information processing of co-players' previous choices, with proselfs being more flexible in their strategies than prosocials. Overall, additional public information led to an increase in cooperation, rather than a decrease as reported by Huck and Jehiel (2004) and by Maniadis (2004)—this could be attributed to the linearly increasing payoff function of the Centipede game used in their study, where cooperation involves greater risk than in the games with exponentially increasing payoff functions that were used in earlier studies. For a more detailed discussion on risk-cost associated with different types of payoff functions, refer back to the section on Game Variables.

Using a slightly different approach to providing information about the co-player, Farina and Sbriglia (2008a; 2008b) investigated the effects of knowledge about the co-players' strategic profile in a trust game on decision making in the Centipede game. Participants completed a two-stage trust game using the strategy method and then played two Centipede games. Before engaging in the Centipede game, the players were informed about their co-players' choices in the trust game, identifying them as selfish, altruistic, or reciprocating individuals. Again, information about choices in the trust game decreased cooperation in the Centipede game. The authors attributed this to very early game exits by homogenous pairings of selfish individuals.

Whereas the above studies suggested that public information about a player's history in games with random player matching led to a decrease in cooperation, Pulford, Colman, Lawrence, and Krockow (2017) found the opposite effect for fixed player matching (repeated games played with the same co-player) over 20 rounds of eight-move linear Centipede games. The authors reported significantly higher levels of cooperation with fixed matching compared to their random matching control conditions. These findings were interpreted to indicate the effect of reputation-management in the service of reciprocity across repeated games with the same co-player.

Wealth differences

It seems reasonable to expect different levels of income and overall wealth among research participants to influence their behaviour in any incentivised experiment. Furthermore, the knowledge of the co-player's wealth and likely attitudes towards the incentives may also have an impact on behaviour. In a six-move exponential Centipede game, Basu, Mitra, and Gupta (2013) investigated whether public information about the co-player's wealth (categorised as low, middle, or high income) would have an impact on decision making over five rounds of play. Using a within-subjects design, they manipulated the pairings of their participants: players were paired randomly in one treatment condition, with co-players from the same income group in a second, and with co-players from a different income group in a third condition. In the latter two conditions, participants were informed about their co-players' respective income group before the start of the game. Comparing patterns of decision making for the different treatment conditions, Basu et al. reported that the number of defecting moves differed significantly across the three treatment conditions.

Although the report is not entirely clear, it appears that the highest level of cooperation occurred when players were randomly paired without information about the co-player's income group, and the lowest level when they were paired with co-players from a different income group. The authors interpreted this to indicate that wealth information had a significant impact on decision making in the game.

The design and data analysis of the experiment reported by Basu et al. (2013) suffers from several shortcomings, including a small sample size and possible order effects (all participants completed the treatment conditions in the same sequential order). The within-subjects design that was used may not be ideally suited to the study of experimental games. Carryover effects are likely to occur, and because the outcome of any one game depends partly on the co-player's decisions, the comparison of a player's scores across conditions is problematic. Also, it is questionable whether effects of wealth information on decision making can be attributed to financial or economic factors per se. Rather, knowledge of a co-player's income group is likely to contribute to social identity effects by eliciting either ingroup or outgroup attitudes and behaviour, as suggested by Le Coq et al. (2015). This explanation could be particularly powerful in countries such as India in which different income levels are associated with different social groups or castes. Basu et al.'s participants were all recruited from Jadavpur University in Kolkata, India. Future research could build on Basu et al.'s highly suggestive study by extending it and introducing better experimental control in a between-subjects design with a larger number of players and, perhaps, questionnaire measures of relevant socio-cultural attitudes.

Summary of situational variables

Although the empirical base of these findings is relatively small, a number of situational variables have been found to affect reciprocal cooperation in repeated interactions. Group decision makers appear to exhibit lower levels of cooperation than individual players in Centipede games. This could be due to decreased levels of prosociality in groups or to ingroup–outgroup biases. The presence of a minority of highly cooperative and altruistic players in repeated rounds of a Centipede game encourages cooperation in the rest of the player sample present at the same testing session, and this has important implications for experimental methodology, including the sizes of testing sessions and matching algorithms. Additional factors, such as social identity and players' perceived wealth levels may also influence decision making in Centipede games but these require further investigation.

1.2.2.4: Individual difference variables

In the context of this review, individual difference variables are more or less stable psychological or behavioural differences between players (Vinacke 1969). Only a small number of individual differences have been systematically investigated in relation to reciprocal cooperation in Centipede games, which will be reviewed below.

Cognitive ability

Much discussion about the Centipede game has focused on the reasoning abilities involved in inferring the game-theoretic solution. The deliberate and self-conscious application of BI requires stepwise reasoning and high concentration on the task (Camerer & Fehr, 2006; Colman, 2003; Dulleck & Oechssler, 1997), and this may pose a considerable challenge to many research participants (typically, undergraduate students). Gerber and Wichardt (2010) therefore designed an experiment to test the iterative reasoning abilities of student participants over ten rounds of an eight-move linear Centipede game. The researchers introduced two treatment conditions, offering players one of two different tools designed to delay game termination and increase cooperation. In the first condition, participants could decide whether to buy insurance that would top up their payoffs in the event of a co-players' defection. In the second condition, players could offer their co-players bonus payments, paid for out of their own payoffs, as a reward for not defecting. The researchers argued that both tools ought to be chosen by rational players, according to game-theoretic analysis, but that the insurance tool requires stepwise reasoning to assess its benefits, taking into account its signalling value (buying insurance signals to co-players that one no longer fears defection) whereas the bonus tool was easier to comprehend. This difference was reflected in the results: the bonus option was chosen frequently (in 154 instances out of 200) and the insurance tool comparatively rarely (in 53 instances out of 200). The researchers interpreted their results as "consistent with subjects using only a limited degree of iterated reasoning" (p. 135), but the evidence seems rather indirect.

Palacios-Huerta and Volij (2009) conducted a study to test for a direct effect of BI reasoning skills on decision making in a one-shot, six-move exponential Centipede game. They sampled a group of expert chess players, including internationally renowned chess grandmasters, who were assumed to be accustomed to using iterative reasoning in chess games. The study, which used a high-stakes version of McKelvey and Palfrey's (1992) six-move exponential Centipede game, consisted of a field experiment and follow-up laboratory sessions, investigating interactions between chess players and undergraduate students. Among chess experts, 73% of all field Centipedes conformed to the game-theoretic solution and stopped at the first decision node. Furthermore, whenever Player A was a grandmaster, 100% of games stopped at the first decision node. In comparison, McKelvey and Palfrey's low-stakes six-move game ended at the first node in less than 1% of all cases. Interestingly, the pattern of early defection was not replicated when chess players were matched with students of presumably lesser cognitive ability in the laboratory; the percentage of games stopping at the first decision node was halved. Taken together, these findings suggest a strong connection between iterative reasoning ability and decision making in the Centipede game. Furthermore, the fact that chess players behaved more cooperatively when paired with students, whose rationality they presumably doubted, lends support to the theoretical prediction that common knowledge of rationality is a key prerequisite for equilibrium play.

These results on the importance of common knowledge of rationality are called into question by an as-yet unpublished study of Wang (2015), who assessed their participants' predictions of co-players' strategies and examined whether the participants' choices represented the best reply to their co-player's anticipated exit move. The results indicated substantial differences between actual choices and best reply as based on the players' own beliefs. This suggests that the beliefs about the co-player (including common knowledge of rationality) may not be the crucial factor informing decision making. However, it is also important to note that Wang assessed the participants' beliefs after they had already completed the game component of the experiment. It is possible that at the time of decision making they did not actually engage in careful considerations about their co-players' likely strategies, and this could explain the divergence between actual game choices and theoretically best replies.

Overall, Palacios-Huerta and Volij's (2009) results from their experiment on chess players are among the closest to the subgame-perfect equilibrium ever reported (see Figures 3 and 4), and their findings with chess grandmasters in the role of Player A showed 100% subgame-perfect play. Levitt et al. (2011) attempted to replicate these findings using the same one-shot, six-move exponential Centipede game and a comparable sample of chess players, including grandmasters. Additionally, their participants completed two rounds of the Race to 100 game, a game that also requires iterated reasoning but whose constant-sum, winner-take-all payoff function precludes any social gains and provides no reason for cooperating. In the Race to 100 game, two players take turns choosing whole numbers from a pre-defined set, for example {1, 2, …, 9}, aiming to arrive at a sum of 100, with the player who chooses the last number winning the race. This game can be viewed as a more direct measure of BI reasoning skills than an increasing-sum Centipede game, where other-regarding preferences (a concern for the other player's payoff or for the team payoff) could affect decision making.

Levitt et al. (2011) failed to replicate the findings of Palacios-Huerta and Volij (2009). Their chess players were as cooperative as a typical student sample, with only 3.9% of games stopping at the first decision node. Also, contrary to the earlier experiment, not a single chess grandmaster in the role of Player A opted for immediate defection. The chess players solved the BI problem frequently in the Race to 100 game, but none of those who showed perfect BI reasoning in Race to 100 defected at the first opportunity in the Centipede game. These findings indicate that advanced cognitive abilities and BI reasoning skills may not be the decisive determinants of decision making in Centipede games.

In an as-yet unpublished study, Baghestanian and Frey (2014) used a similar approach to determine the importance of cognitive abilities on decision making in the Centipede game. They sampled professional players of the complex strategic board game "Go" and compared their choices across four different games: normal-form Centipede game, Traveller's dilemma, Kreps game, and Matching Pennies game, the first two of which are characterised by inefficient equilibrium solutions. They further measured strategic reasoning skills by assessing the participants' Go Elo scores (numerical ratings of the relative skills of players in competitive games, originally chess) and analytic reasoning skills with the help of Frederick's (2005) cognitive reflection test (CRT). Participants were found to deviate from the Nash equilibria in Centipede games and Traveller's dilemmas but not in the other two, suggesting that those deviations were unlikely to have been caused by a lack of cognitive ability. However, decision making in those two games correlated with the two different reasoning measures, with higher Elo scores related to lower cooperation levels and higher CRT scores related to higher cooperation levels. These findings suggest that different types of reasoning may affect decision making in the Centipede game. Given that the findings of Levitt et al. (2011) appear to contradict those of Palacios-Huerta and Volij (2009), and in view of the inconclusive findings of Baghestanian and Frey (2014), additional experiments are called for.

Other-regarding preferences

Numerous studies across several areas of research in experimental games have indicated that human decision makers are not concerned solely with their own payoffs but appear also to be motivated by other-regarding preferences. McKelvey and Palfrey (1992) reported that 8% of their sample were altruists, who cooperated at every opportunity, and similar proportions have been observed in subsequent research (e.g., Rapoport et al., 2003; Murphy et al., 2004). Experiments manipulating payoff structure and comparing Centipede games with and without social gains have found significantly higher cooperation rates in the former (e.g., Bornstein et al., 2004; Fey et al., 1996; Kawagoe & Takizawa, 2008; Levitt et al., 2011). One factor, well documented across a range of experimental games and in other areas of psychology that can help to explain this finding is inequality aversion (Fehr & Schmidt, 1999; Hatfield, Walster, & Berscheid, 1978). Perhaps even more important are collective rationality and prosocial preferences, which appear to play important roles in Centipede games. A substantial proportion of players seem to be driven by the motivation to increase the joint payoff of the player pair. Colman, Pulford, and Rose (2008a, 2008b) and Colman, Pulford, and Lawrence (2014) have provided strong experimental evidence for the importance of other-regarding preferences, especially collective rationality, in other types of games.

To clarify different underlying motivations in experimental games, including the Centipede game, the psychological concept of social value orientation (SVO) is useful and interesting. Viewed as an individual difference trait, SVO categorises decision makers according to their predominant preferences regarding the distribution of (financial) resources between themselves and at least one other person (e.g., Balliet, Parks, & Joireman, 2009; Balliet & Van Lange, 2013). Questionnaire surveys of trait SVOs in a number of countries have found that approximately 57% of people are predominantly cooperative, motivated to maximise the joint or collective payoff of the player pair or group; 27% are individualistic, motivated to maximise their own individual payoffs; and 16% are competitive, motivated to maximise the difference between their own and their co-players' payoffs (Au & Kwong, 2004). The *prosocial* orientation is an umbrella term combining cooperative, altruistic (motivated to maximise the payoffs of their co-players), and equality-seeking (motivated to minimise the difference in payoffs between themselves and their co-players) motives. Alternatively, SVO can also be interpreted as a state variable, influenced by situational factors and therefore experimentally manipulable, and this was the form in which the concept was originally introduced (Messick & McClintock, 1968).

In two experiments using an eight-legged exponential Centipede game, Pulford, Krockow, Colman, and Lawrence (2016) used framing instructions designed to induce different state SVOs in their players. They compared four different treatment conditions: cooperative, competitive, individualistic, and a neutral control condition, the manipulation consisting of small “reminders” inserted into the written instructions. In the cooperative condition, the reminder was, “Please remember: Your decisions and those of the other person will determine how many points you both earn”, in the competitive condition, it was, “Please remember: Your decisions and those of the other person will determine who wins”, in the individualistic condition, it was, “Please remember: Your decisions and those of the other participant will determine how much money you receive for yourself”, and in the neutral condition, no reminder was given. This manipulation yielded significant effects, with the cooperative condition producing higher levels of cooperation than the competitive condition, clearly distinguishable from the play of participants in whom an individualistic motivation was explicitly induced, and players who were given no explicit motivational induction exhibited largely competitive play. Trait SVO, measured with a standard questionnaire, affected cooperation differently depending on the state SVO that had been experimentally induced. In particular, players with competitive trait SVO did not defect significantly more frequently than other players in neutrally framed Centipede games, because neutral framing tended to elicit competitive rather than individualistic play.

Personality traits

Atiker’s (2012) doctoral dissertation investigated the influence of personality traits on play in the Centipede game. Participants completed a personality questionnaire (the International Personality Item Pool) and then engaged in 12 different Centipede games (drawn from of a pool of 17 Centipede games with different payoff functions). A significant correlation was found between the personality variable “performance motivation” and the choice at Node 1, indicating that highly motivated individuals adhered to the game-theoretic solution more frequently than others. High self-esteem and intellectuality also yielded a more frequent use of BI reasoning and, thus, lower cooperation levels. Risk-takers and assertive personalities, on the other hand, were shown to cooperate longer than others.

Summary of individual differences

Individual differences have received far too little attention from experimental researchers studying reciprocal cooperation in Centipede games. The few studies that have appeared suggest that individual differences may have important effects. Research on Centipede play by expert Chess and Go players has yielded strikingly inconsistent findings, but the apparently well controlled experiment reported by Levitt et al. (2011) suggests that even chess grandmasters, who have an ability to perform BI reasoning when analysing chess positions, and who used this ability in Race to 100 games were either unable or unwilling to follow its dictates in the Centipede game. Gerber and Wichardt (2010) showed that many ordinary participants (not chess experts) have difficulty applying iterative reasoning and comprehending its logic in the context of the Centipede game, and this suggests that limited cognitive ability may account, at least in part, for recurrent deviations from the game-theoretical solution. But the possibility remains that expert chess players who deviate from BI do so not because they fail to understand its logic but because they believe that they can do better by cooperating.

The study of other-regarding preferences in general and trait SVO in particular has important implications for understanding individual differences in Centipede play. The experiments of Pulford, Krockow, Colman, and Lawrence (2016) show that state SVO, manipulated by framing the task in different ways, can have significant effects on levels of cooperation in Centipede games, and that neutral framing tends to elicit competitive rather than individualistic play. These findings suggest that the standard assumption in experimental games that players are individualistically motivated may be questionable, which in turn has important implications for experimental gaming research. Initial research on personality traits links performance motivation to equilibrium play but so far no published research has appeared on this topic. Furthermore, no studies to date have investigated the importance of different types (and levels) of trust on cooperation in the game, nor has any research compared choices of players with different cultural backgrounds.

1.2.3: Discussion

This review included research from 25 publications of empirical Centipede studies and several unpublished articles. It compared experimental designs and quantitative results across the different studies with a particular focus on cooperative choices in the game. Overall, the research reviewed in this chapter shows that human decision makers do not follow the game-theoretic prescription of defecting at the earliest opportunity in the Centipede game. They tend to do so only under extreme conditions—three or more players, very high stakes, very costly GO moves, high risk costs or payoff asymmetry, and time pressure, all or at least most of these factors operating together. Findings from the vast majority of experiments lacking these extreme conditions have reported rampant cooperation. Typical findings are that few players defect at the very first decision node. Most make a few cooperative moves at least, so that exponential Centipede games typically end at a decision node between a quarter and two-thirds of the way to the last decision node; and in most experiments, close to 10% of players cooperate altruistically even at the final decision node.

Among the various factors that have been found to increase or decrease levels of cooperation, the most well established include the following. Constant-sum payoff functions, which are intrinsically competitive, result in much earlier defection, whereas linear payoff functions generally encourage more cooperative moves and later defection. More generally, high risk cost—the proportion of payoff lost as a consequence of cooperating if the co-player defects immediately after—and high payoff asymmetry lead to earlier defection, and increasing the number of players may also lead to earlier defection, but this needs further investigation. Repeating the game many times tends to result in small learning effects in the direction of earlier defection, although these effects were found to depend on the particular game design employed, with high-stakes multi-player games generating steeper learning curves. Group decision makers tend to defect earlier than individuals. There is no unambiguous evidence that high cognitive ability leads to earlier defection, but SVO may have an effect, with prosocial players making more cooperative moves than others.

Despite the increasing interest in the Centipede game, many aspects are still under-researched. In a game, where BI reasoning dictates unconditional defection, the findings of rampant cooperation still remain to be fully understood and many research gaps need to be addressed.

Since the game's introduction by Rosenthal in 1981, only quantitative experiments have been conducted to make inferences about cooperation in the Centipede game. This approach, while yielding mostly precise quantitative data, ignored the richness of motives which are likely to drive human decision making (e.g., Ericcson, 1998), and made it difficult to fully interpret participant data.

Furthermore, intentional and unintentional variations across experimental designs resulted in a lack of control and made it difficult to draw conclusions on the effects of individual variables. In particular, Take-it-or-Leave-it payoff functions (e.g. Cox & James, 2012) or those with zero payoffs at the final exit point (e.g., Rapoport et al., 2003) were never investigated in isolation, and their ostensible influences on behaviour were likely to be confounded. Consequently, it is impossible to generalise the findings to decision contexts of the standard Centipede design with linearly or exponentially increasing payoffs and non-zero payoff ends.

Most research also focused on Centipede games of very short length (e.g. McKelvey & Palfrey, 1992) which may not accurately reflect actual decision situations in real life. In most choice contexts, individuals can expect to have frequent encounters (e.g. due to physical proximity created by close home addresses or common work places), thus offering many opportunities for reciprocity without a finite horizon of the interaction (Jiborn & Rabinowicz, 2013).

Finally, very few individual difference variables have been examined to date. In particular, the role of cultural background has been completely ignored in the Centipede literature so far. The vast majority of experimental research on the game has been conducted in Europe and the US, and not a single cross-cultural study has been published to date. Other factors that deserve additional attention are trust, risk-taking and SVO (e.g., Pulford, Krockow, Colman, & Lawrence).

1.3: Conclusions and thesis outline

This chapter provided an introduction to the topic of this thesis, presented the Centipede game, and provided detailed results from a systematic literature review covering all relevant empirical studies undertaken to date.

At the beginning of this chapter, a comprehensive understanding of cooperation was identified as a key research topic of continued, cross-disciplinary importance (May, 2006). In this context, the Centipede game (Rosenthal, 1981) was shown to provide a useful research paradigm for investigating cooperation and reciprocity in repeated interactions with a variety of payoff functions. As demonstrated by the literature review, an increasing amount of empirical research on Centipede-type decision sequences has been conducted with over 30 published an unpublished studies to date. However, this chapter also identified a number of research gaps and experimental shortcomings which hindered the development of a better understanding of factors enhancing cooperation in human relationships. These included narrow investigations of decision making with purely quantitative approaches, confounding variables because of the large diversity in research designs, lack of real-life applicability due to short games, and neglect of individual differences and cultural factors and their effects on cooperation.

The aim of this thesis is to address these research gaps across four chapters and six empirical studies. Chapter 2 reports the qualitative findings of Study 1, thereby providing an introduction to the wealth of motives and reasoning levels in Centipede-type interactions as evidenced by verbal protocols. Chapter 3 addresses the shortcoming of uncontrolled variations in previous experimental designs. It presents the findings of Study 2 which included a controlled comparison of games with different payoff functions, focusing on games with zero payoff values at the final exit node and on Take-it-or-leave-it variations of the Centipede game. Chapter 4 discusses the results of Studies 3 and 4, two related experiments on games of varying lengths and termination rules aimed to increase real-life applicability of the game. Chapter 5 centres on individual difference variables and national culture. The findings of Studies 5 and 6 on cross-cultural differences between Japanese and British/European participants are evaluated while taking into account individual differences in SVO, risk-taking and trust. Finally, Chapter 6 provides a general discussion of all six studies conducted as part of this thesis, and draws overall conclusions of the findings presented.

Chapter 2: Qualitative Analysis of Cooperation in Centipede Games

This chapter provides details of Study 1 which examines decision making in the Centipede game with an innovative, qualitative methodology rarely used to study experimental games; verbal protocol analysis. In particular, it is investigated whether reasoning skills or other-regarding motivations play a larger role in determining cooperation levels of the participants. The explorative data thus provide new insights on the Centipede game by producing much richer information on the thought processes underlying decision making.

2.1: Background

Previous research on the Centipede game has been dominated by quantitative studies. Based on the data obtained, various econometric models have been derived, but although these may provide more-or-less accurate predictions of decision making, their explanatory power is limited. McKelvey and Palfrey’s (1992) initial model of their Centipede data, for example, contained a parameter to account for individuals who never defect in the game. The authors speculated that such players may be altruistic, but this is an empirical assumption that is open to experimental testing. Hard-core cooperators could, for example, be driven by an action bias (enjoying the mere interaction and offering the other player a chance to participate); they may be acting in accordance with implicit demand characteristics; or their cooperative moves may be determined by misunderstandings of the instructions or the payoffs.

Existing models cannot capture the multitude of explanations underlying decision making in the Centipede game, nor can they reveal motives that the researchers have not anticipated, and to advance our understanding of motives for cooperation in this game, analysis of qualitative data derived from vocal records of participants’ reasoning processes during the game provides a promising avenue of investigation.

As outlined in the literature review provided by Chapter 1, different explanations have been suggested for the pervasive deviations from the game-theoretic solution. Generally, these explanations can be divided into two strands, focusing either on insufficient cognitive ability to perform BI reasoning, or on other-regarding motives that might interfere with rational (but selfish) decision making. The following sections outline the most prominent and influential theory associated with each of these strands, with Section 2.1.1 introducing the concept of Theory of Mind, and Section 2.1.2 discussing social value orientation (SVO). Finally, Section 2.1.3 discusses the foundations of qualitative methodology, with a particular focus on verbal protocol analysis.

2.1.1: Theory of Mind

Theory of Mind (ToM) is a psychological theory describing the cognitive processes involved in perspective-taking to infer another person's knowledge, beliefs, and intentions. Whereas the bulk of research on ToM has been conducted by developmental psychologists examining children's awareness of other people's mental states, it has more recently been applied to strategic games in order to investigate the sophistication of reasoning levels by human decision makers (Doshi, Qu, Goodie, & Young, 2012; Goodie, Doshi, & Young, 2012; Hedden & Zhang, 2002; Zhang, Hedden, & Chia, 2012). According to ToM, the players' predictions about their co-players' preferences and strategies in the game influence their own choices. Accurate assumptions about the other person's future moves make it possible to identify best replies that maximise personal payoffs. In the Centipede game, the best reply to a co-player's strategy of stopping at Node x_n is invariably to exit at the immediately preceding Node x_{n-1} (Droste, Kosfeld, & Voorneveld, 2003). ToM categorises decision makers according to the number of steps of recursive perspective-taking they can perform, and these are referred to as levels of rationality (e.g., Goodie, Doshi, & Young, 2012), with 0th-level rationality assigned to individuals who make decisions based on their personal preferences without consideration of their fellow decision makers' likely moves. In the Centipede game, a Player A with 0th-level rationality is likely to identify the highest possible personal outcome (i.e., £25.50 at Exit Node 7) and aim for that outcome without taking into account Player B's likely STOP move at Node 6. The next higher level of reasoning, 1st-level rationality, refers to individuals who act to maximise their personal payoffs on the assumption that their co-players are 0th-level reasoners. A Player A with 1st-level reasoning would be able to predict Player B's exit move at the penultimate node, and would consequently choose to exit the game at the preceding Node 5. The next higher level of reasoning, 2nd-level rationality, applies to individuals attributing 1st- and 0th-level rationality to the co-players, and so forth. With every additional level of rationality, the individual is able to perform one more step of iterated reasoning. To achieve the perfect BI outcome in a 6-node version of the Centipede game, Player A would thus require 3rd-level rationality.

Early experiments assessing the frequencies of different reasoning types used 3 × 3 matrix games and the "Guess the Average Number" game. Results showed that most players initially exhibited 1st- or 2nd-level reasoning and improved their performance slightly with experience (Nagel, 1995; Stahl & Wilson, 1995). In the context of the Centipede game, several investigators have proposed econometric models based on the closely related economic counterparts of ToM; Cognitive Hierarchy Theory and Level- *k* reasoning (e.g., Camerer, Ho, & Chong, 2004; Ho & Su, 2011; Kawagoe & Takizawa, 2012). More recent research (e.g., Colman, Pulford, & Lawrence, 2014; Hedden & Zhang, 2002) has confirmed that 1st-level reasoning is most common, followed by 2nd-level reasoning.

A study by Palacios-Huerta and Volij (2009) found convergence towards the game-theoretic solution in a sample of expert chess players, who were assumed to have very high levels of iterated reasoning ability. However, cooperation levels among the chess players increased when they were paired with university students of supposedly lesser strategic reasoning ability. Taken together, these findings indicate that recursive reasoning skills could have significant effects on decision making in the Centipede game. However, they also underline the importance of common knowledge of rationality. Advanced reasoning is unlikely to result in the BI outcome unless coupled with the firm belief in the co-player's equally advanced cognitive abilities and the absence of irrational motives.

Nevertheless, none of these studies directly assessed reasoning ability or explored alternative motives for move choices in the game. Also, the findings by Palacios-Huerta and Volij (2009) were challenged by a replication in which chess grandmasters made very similar decisions in the Centipede game to student samples (Levitt, List, & Sadoff, 2011). Finally, the Centipede game, whose mixed-motive payoff function allows for social gains to the player pair, may elicit a wider range of motives than the previously studied Guess the Average Number game with its strictly competitive (zero-sum) payoff function, in which there is no scope for social gains and hence no incentive to cooperate.

2.1.2: Social value orientation

Many different other-regarding motives could potentially explain cooperation in the Centipede game. The most frequently suggested include altruistic and team-orientated payoff preferences. Those and related preferences regarding the distribution of monetary resources between oneself and others are conveniently interpreted within the psychological framework of *social value orientation* or *SVO* (Messick &, McClintock, 1968; McClintock, 1972) which was briefly introduced in Chapter 1. The concept initially included only cooperative, individualistic, and competitive orientations, but it was later extended to cover altruistic and equality-seeking preferences as well (Kelley & Thibaut, 1978; Van Lange, 1999). In the context of two-player experimental games, individuals with different orientations can be characterised as follows: Cooperative players seek to maximise the combined payoffs of the player pair; individualistic players seek to maximise their personal payoffs; competitive players seek to maximise the difference between their personal payoffs and their co-players' payoffs; altruistic players seek to maximise their co-players' payoffs; and equality-seeking players aim for an even split of the payoffs between themselves and their co-players.

SVO has been shown to affect levels of cooperation in experimental games (see Balliet, Parks, & Joireman, 2009, for a review), and a recent study by Pulford, Krockow, Colman and Lawrence (2015) found that both state SVO (induced by task framing instructions) and trait SVO (assessed by a questionnaire measure) significantly affected decision making in the Centipede game. Across two experiments, Pulford et al. showed that cooperative and individualistic state SVO led to significantly later exit moves (higher levels of cooperation) than a competitive state SVO. The influence of trait SVO depended on the state SVO that had been experimentally induced. So far, however, no research has investigated the effects of equality-seeking or altruistic SVO, the latter of which has frequently been suggested as an explanation of cooperation at the game's final decision node (e.g., McKelvey & Palfrey, 1992).

2.1.3: Verbal protocol analysis

The generation of data from verbalisations of thoughts and feelings can yield a wealth of information on human cognitive and emotional processes.
Concurrent verbalisation during task performance (rather than retrospective verbalisation after task completion) is likely to produce the best results in the context of experimental games, because the verbal records created during the task cannot be degraded by forgetting or hindsight biases. This method was previously criticised for its possible interference with task performance, but its influence on cognitive processes was demonstrated to be non-significant across several studies, provided that instructions to think aloud were kept general rather than targeted to yield specific contents such as explanations or reasons for behaviour (see Ericsson & Simon, 1993, for a review). The

only reliable influence of concurrent verbalisations was shown to be an increase of the time taken to complete a task.

2.2: Study 1

This study adopted an exploratory approach towards the investigation of decision making in the Centipede game. Using verbal protocols, strategic reasoning levels, social motivations (including SVO), and other motives for choices in the game were investigated. Additional attention was paid to the participants' processing of the task instructions and experimental cues that could suggest methodological improvements for future experiments.

2.2.1: Method

This method section includes details of the study's participants (Section 2.2.1.1), the design (Section 2.2.1.2), materials (Section 2.2.1.3), procedure (Section 2.2.1.4), and data analysis (Section 2.2.1.5).

2.2.1.1: Participants

The sample comprised 12 students and members of staff from the University of Leicester (six males and six females) with a mean age of 26.33 years (*SD* = 6.59). They were incentivised with a £5.00 show-up fee and additional remuneration according to their payoffs in one round chosen randomly from the ten completed during the testing session. The mean remuneration per participant was £12.08, including the show-up fee.

2.2.1.2: Design

Six testing sessions were conducted with one pair of players in each. The computer randomly assigned the participants to the role of either Player A or Player B, and they stayed within that role for the duration of the testing session. In their pairs, they played ten rounds of the exponentially increasing Centipede game displayed in Figure 2.1 while verbalising their thoughts.

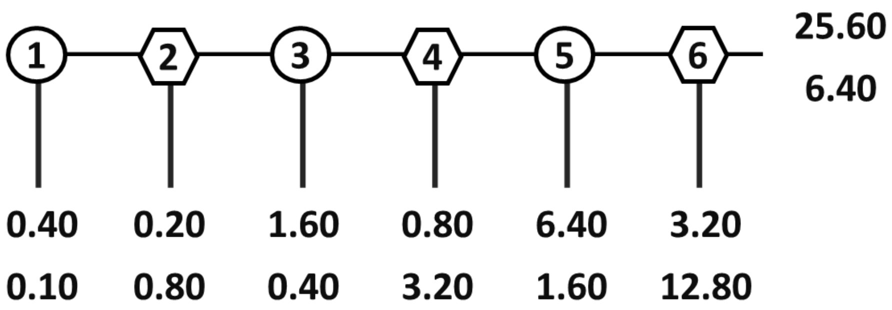


Figure 2.1. Exponentially increasing Centipede game adapted from McKelvey and Palfrey (1992).

2.2.1.3: Materials

The study was conducted in two laboratories located in different buildings to ensure complete anonymity of the two participants interacting with one another. Each laboratory contained a computer with internet access, a digital voice recorder, and a video camera placed behind the participant. The video camera was used to back up the voice recording and to match the verbalisation with the display on the computer screen. For the interaction between the two participants, a custom-made, web-based game application was used that included several detailed instructions slides and a colour-coded, animated display of the Centipede game. Comprehensive screenshots of the web application are presented in Appendix B. All following studies reported in this thesis (apart from Study 5) used close variations of this web applications, only adapted to match the particular games used in the respective experiments.

2.2.1.4: Procedure

Testing sessions lasted between 30 and 45 minutes. The two participants in each session were met in front of different buildings by two different experimenters and shown to the respective laboratories. Participants were informed about the study procedure and made aware of the use of voice recorders and cameras. To practise their verbalisation skills, they were given a well-known logic puzzle—a four-disk, electronic version of the Tower of Hanoi—and they were asked to try to solve it while thinking aloud.

Following this training, participants received detailed on-screen instructions about the rules and payoff structure of the Centipede game, presented to them as a “decision-making task” (words such as “game”, “player” and “cooperation” were avoided to minimise priming effects). The voice recorders and cameras were then switched on, and the participants interacted over ten rounds of the Centipede game while verbalising their thoughts. The exact instructions, based on Ericsson and Simon (1998), were:

> Please remember to talk aloud for the whole duration of the decision sequence, just like you did in the previous training session. Verbalise everything that passes through your head whilst reaching a decision in the task. If you need to read something on the computer screen, please read aloud. Do not try to explain anything to anyone else. Pretend there is no one here but yourself.

Whenever participants stopped speaking, the experimenter prompted them as follows: “Please keep talking” or “Please verbalise your thoughts”.

2.2.1.5: Data analysis

For all games completed, the exit nodes, ranging between 1 and 7, were recorded. Additionally, all verbal data were transcribed and analysed using NVivo Qualitative Data Analysis Software, Version 10 (2012). For each participant, a separate data file containing the verbal records was uploaded as a coding source in NVivo. Verbal statements were classified in a hierarchical network of “parent” and “child” coding nodes, with each coding node representing a different statement category and serving to collect references for that particular category. Whereas the initial network was theory-driven and centred on the two thematic pillars of depth of strategic reasoning and social motivation, it was adapted, refined, and extended though a bottom-up coding process. In its final form, the data also included coding nodes for study concerns (e.g., doubts about the reality of payoffs), the type of talk recorded (e.g., purely descriptive talk versus detailed deliberation about the game), and significant quotes. Finally, in order to investigate the salience of specific strategic reasoning levels and motives at specific decision nodes in the game, a contextual category was created containing coding nodes for the moves “GO”; “GO at first node”; “GO at last node”; “STOP” and “STOP at first node”. A display of the most relevant coding categories—reasoning level and other-regarding motives—including both parent and child coding nodes with example statements is displayed in Table 2.1.

Table 2.1

Hierarchical Coding Node Structure for "Levels of Reasoning" and "Motives" Including Example Statements, Number of Coding Sources, and Number of Individual Coding References

	Number of sources (participants)	**Number of coding references**
Levels of reasoning		
0th level	4	16
P6: "OK . . . sooo. I'm gonna press GO again. I don't know a reason why not to again. If the other participant said he can continue then I might as well choose GO."		
1st level	8	14
P3: "OK, and now I'll STOP at the fourth decision because Participant A . . . he's more likely to STOP at the fifth decision . . . so . . . yeah, I'll STOP at the fourth decision."		
2nd level	3	9
P11: "So . . . I might think about stopping at 1.60 actually. Because if I were in the other room, I'd be thinking that the other person will be stopping at 6.40."		
BI reasoning	1	4
P2: "If I keep stopping at 6, and they're gonna . . . Yeah, it's probably gonna escalate and they're gonna want to STOP then at 5 and yeah, then all the way back."		
Motives		
SVO Individualistic	10	33
P3: "Yes, and I STOP here. . . . Yeah, 'cause I won't ever do the last GO because, um . . . I have no benefit from it. So . . . I think I'm always gonna keep with this 6th decision."		

SVO Cooperative	7	24
P5: "I'm gonna go for GO and then we can both make some good money."		
SVO Equality-seeking	5	19
P1: "They've been so nice to me. Yeah . . . they've been so nice to be over the . . . over whole the study, soo. . . . It's only . . . it's only fair that they get some of the payoffs as well."		
Take the best	6	18
P1: "Yeah, they pressed GO and obviously I press GO as well 'cause I want the maximum pay-out which is at the end."		
Frustration	4	17
P10: "Seventh one and I'm still Participant A. They still keep stopping. Arghh!"		
Probing	5	15
P10: "I like to just see in this one how long I can keep the other person going for it as well. . . . The decision they'll make in this one will be interesting to see what I think they're gonna do for the next ten."		
Learning	5	14
P8: "Umm so he's gone and now it's my turn. Um ohh it's a tricky one. I think last time I let him go and then he stopped so I'm going to STOP this one here now."		
Habitual strategy	7	13
P5: "Oh, OK, it's the same sequence as last time. So it's about getting as far . . . as far as I can. Hopefully . . . it looks like he might do the same thing. We just try to get to the end."		

Spite *P11: "Although [Laughter], were it me, and I knew that the person in the other room was basically stopping me from getting quite a lot, I'd be tempted to just . . . mess it up for them and click a really low value [Laughter] . . ."*	6	13
SVO Competitive *P11: "So now I'm just gonna try and mess with their heads a little bit. I'll STOP at 1.60. Which I know that gets me less potentially but it's still more than they would have got… of the total if that makes sense."*	3	13
Reciprocity/retaliation *P8: "So it's my turn. Oh I have to STOP it here because I had a few GOs and he does it all the time so . . . ok."*	7	12
Activity bias *P4: "I want to see if we can take it to the end. Purely for fun, I think. Regardless of the money that's at the bottom."*	6	12
Avoid the worst *P2: "And I don't think they'd be happy with 3.20 really when 25.60 is just around the corner."*	6	11
Kindness *P1: "If I do the kind thing and GO on then that person will STOP. They will completely ignore my kind deed of not stopping here whereas I will get a much, much higher proportion of. . ."*	4	11
Hope *P10: "I'm hoping if I keep trying . . . yeah . . . I'm hoping that if I keep trying then they won't. Ahh yeah, they keep stopping"*	5	10
Loss aversion *P6: "Really tempted to press STOP to see what would change umm but that would mean that I would probably lose and I'm not sure I wanna lose, yet."*	3	8

Curiosity	4	7
P7: "And again, if they click GO, then I will click GO again to see what they do on the next sequence . . . cause I'm a bit curious like that."		
SVO Altruistic	3	7
P5: "And I'm gonna GO again as well. So, it's looking good for both of us. Obviously a bit better for him than for me."		
Risk	4	6
P3: "And ugh, I think I'm going to STOP again because the difference here is, um, higher and this is, um, at the end. This is a more, um, risk to take so I'm going to STOP at this 6th decision."		
Temptation	4	6
P6: "Really tempted to press STOP to see what would change umm but that would mean that I would probably lose and I'm not sure I wanna lose, yet."		
Completing the game	3	6
P10: "Umm I'm gonna keep going. My aim is to try and get all the way to the end just to feel like I've finished it."		
Generosity	3	6
P2: "Well, if they STOP at 5 now, that's sort of like a rude move really cause I've been letting them get 25.60 all those times but we'll see how generous they're feeling really."		
Gambling	4	5
P4: "Actually, I wanna do third time lucky. I wanna see if this person will take, will GO to the end third time around. And if they don't, I'm just gonna STOP it at number 5 next time. . . . It's like gambling, this!"		

Minimum payoff goal	4	4
P11: "So there's a potential that they're gonna STOP at 4. At 3.20 and that would leave me with 80p but I don't think they will. I don't think 3.20 is enough."		
Compromise	3	4
P4: "I think if the next person clicks GO, I will click GO at 3 because financially, I'd come slightly better off. Although not as better off as if we went to question 5."		
Guilt	2	4
P4: "So now I have to be generous, I feel. Click GO again. And then . . . I would feel bad if I stopped at 3 again."		
Greed	1	3
P12: "So they STOP at 5. Oh, all right! They probably think I'm greedy as well! Oh yeah, oh, alright, OK."		
Coordination	2	2
P1: "Well to me this looks like a . . . well, not like a puzzle but like a task that requires unspoken coordination from both the players for maximum payoff."		
Trust	2	2
P9: "I can choose to GO or STOP, um, I'm going to GO . . . Hopefully . . . come on . . . yes! Ummm . . . How much do I trust A? . . . Come on, come on."		

2.2.2: Results

The results comprise both quantitative results generated by the game exit points of the players (see Section 2.2.2.1), and qualitative results obtained from the participants' verbalisations (see Section 2.2.2.2).

2.2.2.1: Quantitative results

The quantitative results are displayed in Table 2.2. The mean exit node across 60 rounds of the Centipede game was 5.12 (*SD* = 1.78). Only a single game was exited at the first decision node, and 18 games (30%) reached their natural end without any defecting move. The observed patterns of quantitative game results for each player pair fell into one of three categories:

Table 2.2

Exit Nodes across Ten Rounds (R1–R10) of the Centipede Game for Six Pairs of Participants

		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Number of STOP moves
Pair 1	P01; A	7	7	7	7	7	7	7	7	6	6	0
	P02; B											2
Pair 2	P03; B	3	4	5	6	6	6	5	5	4	3	5
	P04; A											5
Pair 3	P05; B	7	7	7	7	7	7	7	7	7	7	0
	P06; A											0
Pair 4	P07; A	4	3	2	3	2	2	2	1	2	2	3
	P08; B											7
Pair 5	P09; B	6	4	5	6	6	2	4	6	6	6	9
	P10; A											1
Pair 6	P11; A	5	3	5	5	5	5	5	5	5	5	10
	P12; B											0

Perfect cooperation

The games completed by Pairs 1 and 3 showed almost perfect cooperation across all ten rounds of the game. Pair 1 deviated slightly from this pattern on the 9th and 10th rounds, stopping at Node 6 instead of Node 7, but the overall level of cooperation was almost fully cooperative.

Head-to-head

The games by Pairs 2 and 4 were characterised by fairly even numbers of STOP moves by the two players. For these two pairs, the ratios of STOP moves by Player A compared to Player B were 5:5 and 3:7 respectively. None of the games reached its natural end, and one of Pair 4's games was exited at the first decision node.

Dominant defector

The interactions by Pairs 5 and 6 showed a marked dominance by one player—in Pair 5, it was Player B, in Pair 6, Player A. The dominant players accounted for at least 90% of the exit moves across ten rounds, but their exit points varied; Pair 5 exited at decision nodes ranging between 2 and 6; Pair 6 exited at Node 5 in nine out of ten games.

2.2.2.1: Qualitative results

The number of verbal statements associated with each coding node are displayed in Table 2.1, and participant profiles, providing overviews of all motives and reasoning levels at the participant level, are shown in Table 2.3 with graphical illustrations displayed in Figures 2.2-2.7. Despite the verbalisation training, both quantity and quality of the verbalisations varied considerably from one participant to another. Participant 11 produced the most data (almost 1,500 words), and Participant 9 produced the least (less than 200 words).

Table 2.3

Number of Coding References per Reasoning Level and Motive for Each Participant

Participant number	01	02	03	04	05	06	07	08	09	10	11	12
0th-level reasoning			**2**			**2**	**9**	**3**				
1st-level reasoning	**3**	**1**	**1**	**1**				**1**		**1**	**5**	
2nd-level reasoning		**1**						**4**			**4**	
BI reasoning		**4**										
Activity bias			**1**	**2**			**3**	**2**		**3**		**1**
Avoid the worst	**1**	**3**		**2**			**1**		**1**		**3**	
Completing the game				**1**	**1**					**4**		
Compromise		**2**		**1**							**1**	
Coordination	**1**							**1**				
Curiosity						**1**	**3**	**2**		**1**		
Frustration							**1**	**4**		**5**		**7**
Gambling	**1**			**1**					**2**		**1**	
Generosity		**3**		**2**								**1**
Greed												**3**
Guilt				**3**				**1**				
Habitual strategy	**1**		**1**	**1**	**7**	**1**					**1**	
Hope	**2**				**3**		**1**		**1**	**3**		
Kindness	**9**	**1**		**1**						**1**		
Learning			**1**			**1**		**6**		**3**	**3**	
Loss aversion						**1**	**3**	**4**				
Minimum payoff		**1**			**1**						**1**	**1**
Probing				**3**			**4**			**2**	**2**	**4**
Reciprocity/retaliation	**4**	**1**		**3**		**1**	**1**	**1**		**1**		
Risk		**1**	**2**					**1**	**1**		**2**	
Spite	**1**	**1**					**1**			**2**	**5**	**2**
SVO Altruistic	**3**	**2**			**2**							
SVO Competitive				**4**							**8**	**1**
SVO Cooperative	**3**	**3**		**2**	**3**			**1**		**7**		**5**
SVO Equality-seeking	**6**	**4**		**5**		**1**						**3**
SVO Individualistic	**2**	**6**	**1**	**2**	**1**	**2**	**2**	**6**			**9**	**2**
Take the best	**2**	**1**			**2**		**1**			**1**	**11**	
Temptation	**2**					**1**		**2**			**1**	
Trust					**1**				**1**			

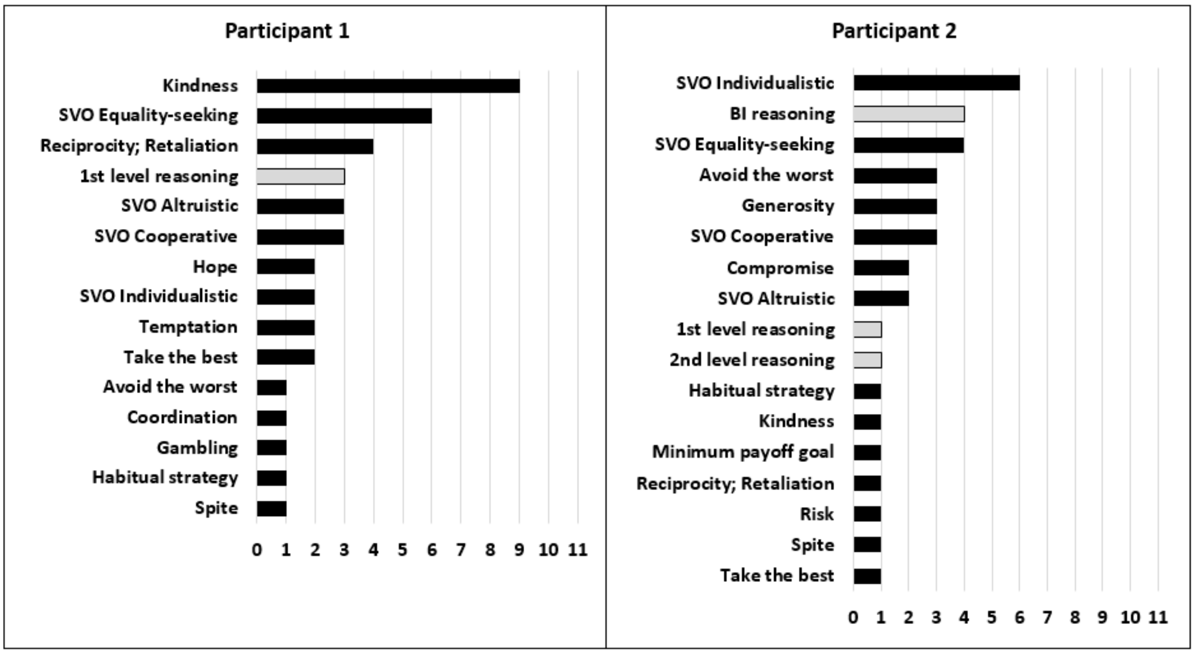


Figure 2.2. Number of coding references for Pair 1's levels of reasoning (grey bars) and motives (black bars).

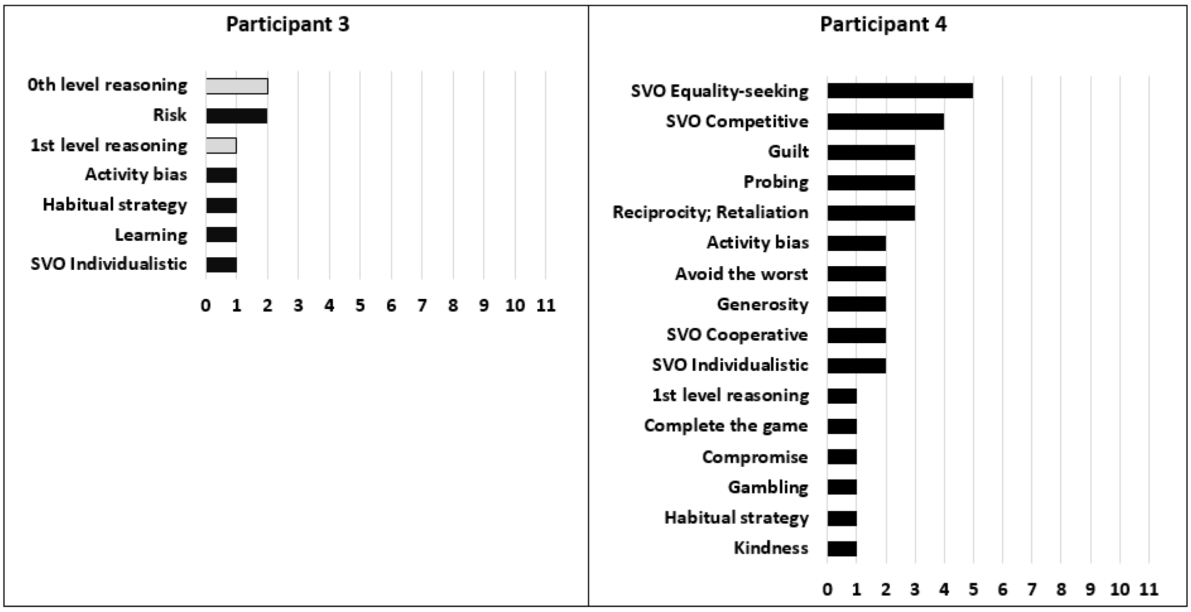


Figure 2.3. Number of coding references for Pair 2's levels of reasoning (grey bars) and motives (black bars).

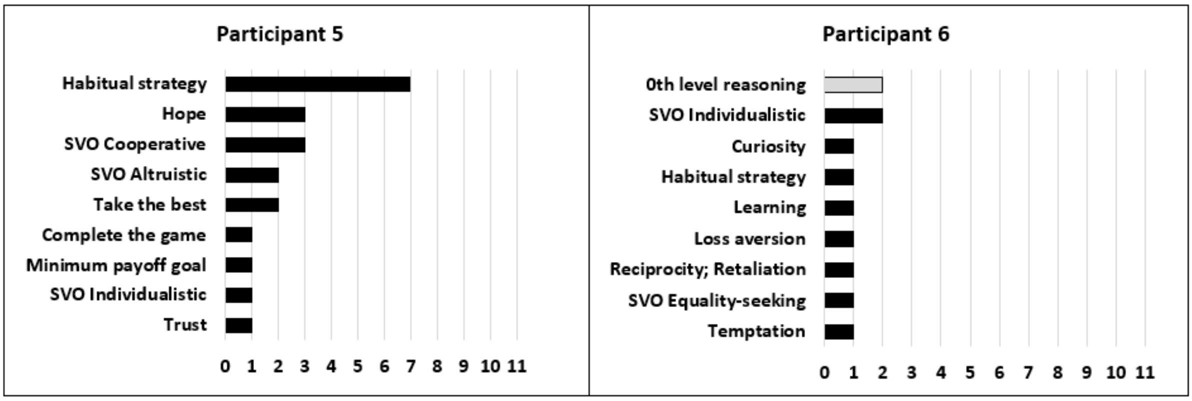


Figure 2.4. Number of coding references for Pair 3's levels of reasoning (grey bar) and motives (black bars).

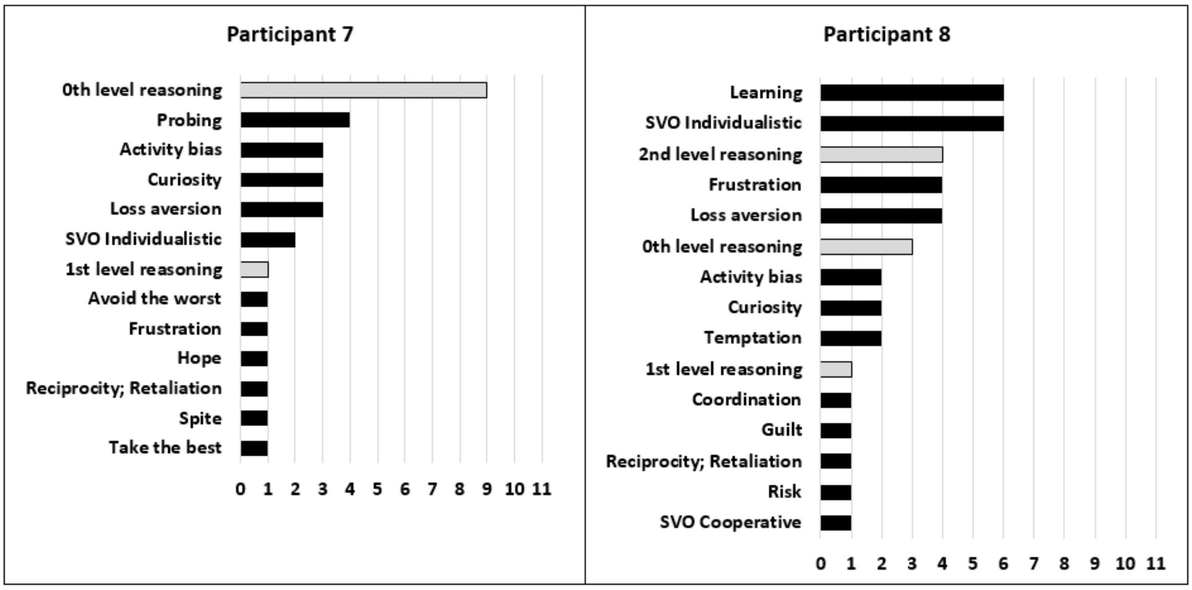


Figure 2.5. Number of coding references for Pair 4's levels of reasoning (grey bars) and motives (black bars).

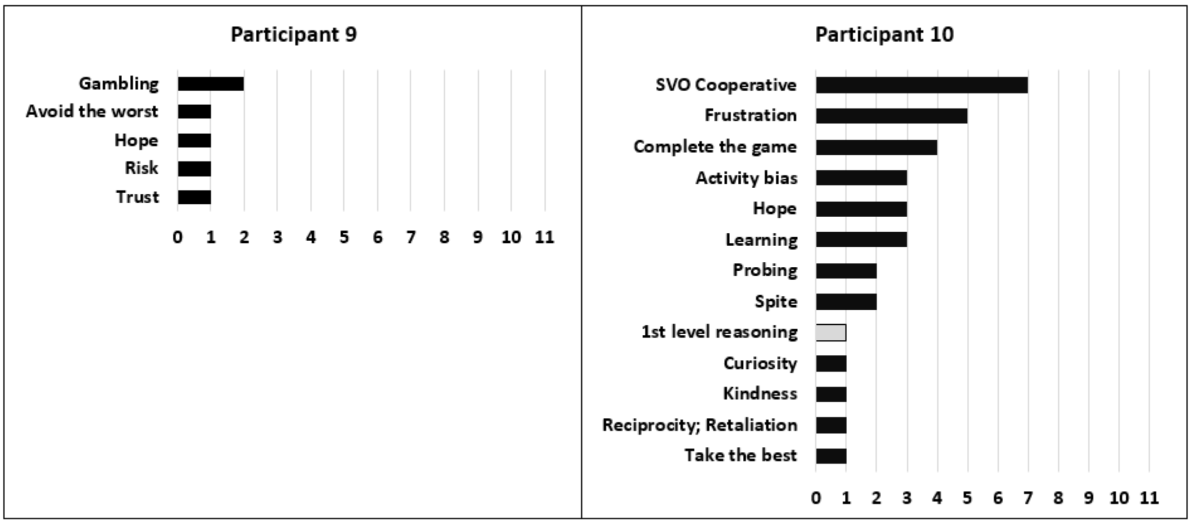


Figure 2.6. Number of coding references for Pair 5's levels of reasoning (grey bar) and motives (black bars).

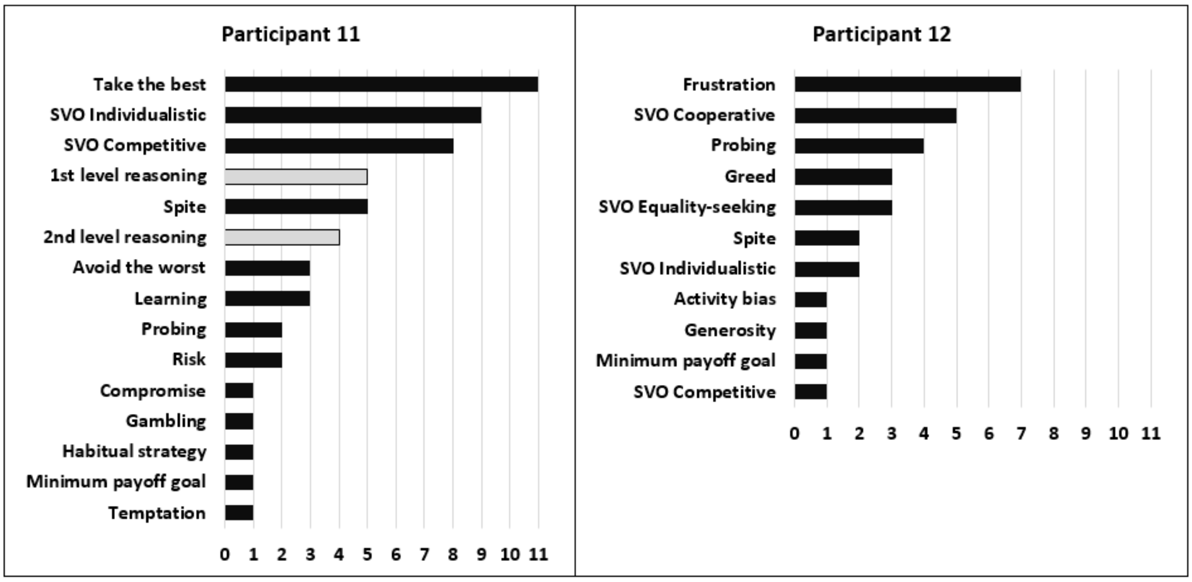


Figure 2.7. Number of coding references for Pair 6's levels of reasoning (grey bars) and motives (black bars).

The verbalisations also differed in type of content, ranging from categories requiring lower levels of processing such as "reading off screen" or "descriptive talk" to more profound categories such as "deliberation about the game" or "reflection about other player". In two cases (Participants 3 and 9), the majority of talk was purely descriptive. All other participants, however, spent the majority of their time engaging in analyses of the game or the co-player's behaviour.

In addition to the overall quantity and quality of the verbalisations, their contents were analysed against the background of three different themes.

Levels of reasoning

The verbal records yielded evidence for all four possible levels of reasoning in the 6-node Centipede game (0th, 1st, 2nd, and full BI reasoning). Table 1 shows that the majority of participants used some iterated reasoning, with eight participants demonstrating a minimum of 1st-level reasoning on at least one occasion during the testing session. Two (Participants 8 and 11) showed some 2nd-level reasoning; Participant 11, for example, reasoned as follows:

> So . . . I might think about stopping at 1.60, actually. Because if I were in the other room, I'd be thinking that the other person will be stopping at 6.40 . . . umm . . . But then again, there's 25.60 at the end . . . Soo . . . I'll click GO.

Furthermore, one player (Participant 2) demonstrated full BI reasoning for the super game consisting of the 10 repetitions of the game:

> If I keep stopping at 6, and they're gonna. . . . Yeah, it's probably gonna escalate and they're gonna want to STOP then at 5 and yeah, then all the way back. It's probably better to go for 6.40 now, even though that's less than 12.80 [Player B's potential maximum payoff] because, um, at least that way, um, it should go quite smoothly perhaps. 'Cause if I try and STOP and get my 12.80, then they'll realise that's what I'm doing, and they'll get back to their 6.40 probably.

Interestingly, however, higher-level reasoning did not lead to earlier defection as predicted by classical game theory. As evident from the example, Participant 11, despite considering an exit move at Node 3 that would have rendered a personal payoff of £1.60, was too tempted by the £25.60 dangling from the Centipede's final leg to defect. Similarly, Participant 2 decided to go all the way to the game's natural end with a personal payoff of £6.40 rather than defecting at Node 6, which would have yielded this player's maximum of £12.80, in order to prevent the game from unravelling.

Motives

Across the 12 participants, no fewer than 32 distinguishable motives for decisions were identified (see Table 1). This most important finding is the surprisingly large variety of different motives affecting play in the game. Five of the motives correspond to standard SVO categories. The individualistic SVO was by far the most common, with 33 coding references across 10 different participants. For example, Participant 3 in role of Player B said: “Yes, and I STOP here. . . . Yeah, ‘cause I won’t ever do the last GO because, um . . . I have no benefit from it. So . . . I think I’m always gonna keep with this 6th decision.” The second most frequent SVO was the cooperative orientation with 24 coding references across seven participants. For example, Participant 5 said:

> Do you know what, I’m just gonna, um, go for it, just carry on cause I figure out I do alright for many of these now. And he does all right for. . . . So I think he’s . . . ohh! . . . Do you know what, I’m gonna . . . I’m gonna go for GO and then we can both make some good money.

This was followed by the equality-seeking orientation with 19 coding references across five participants. For example, Participant 1 said: “They’ve been so nice to me. Yeah . . . they’ve been so nice to be over the . . . over whole the study, soo . . . It’s only . . . it’s only fair that they get some of the payoffs as well.”

Following in frequency was the competitive SVO with 13 coding references across three participants. For example, Participant 11 said:

> So if I was them, I would probably STOP at 3.20 next because they know I wanna GO for 6.40 again. So now I’m just gonna try and mess with their heads a little bit. I’ll STOP at 1.60. Which I know that gets me less potentially but it’s still more than they would have got . . . of the total . . . if that makes sense.

Least frequent was the altruistic SVO with seven coding references across three participants. Participant 5 said: “And I’m gonna GO again. And . . . I think he’s gonna GO again . . . ah yeah . . . . And I’m gonna GO again as well. So, it’s looking good for both of us. Obviously a bit better for him than for me.”

Importantly, however, not a single participant was characterised by one orientation only. Instead, a range of value orientations and additional motives informed choices in the game, with up to 16 different motives identified for a single participant (see Figures 2–7). These included (in descending order of coding frequency): “Take the best” (going for the highest payoff possible in the game); “Frustration”; “Probing”; (testing the other player’s behaviour) and “Learning from previous experience”.

To investigate motives and specific key moves in the game (“GO”; “GO at first node”; “GO at last node”; “STOP”; and “STOP at first node”), the coding references for the motivations and the different moves were cross-tabulated with the help of a NVivo Matrix Coding Query (see Table 2.4).

Table 2.4

Results of NVivo Matrix Coding Query: Frequencies of Coding References of Motives across Five Specific Decision Nodes in the Game

	GO	GO at first node	GO at last node	STOP	STOP at first node
Activity bias	4	6	1	1	0
Avoid the worst	3	1	0	3	0
Completing the game	4	0	4	1	0
Compromise	1	0	0	2	0
Coordination	1	0	0	0	0
Curiosity	3	2	0	1	0
Frustration	8	0	1	9	2
Gambling	3	0	0	2	0
Generosity	4	0	1	1	0
Greed	1	0	0	3	0
Guilt	2	0	0	2	0
Habitual strategy	7	0	5	0	0
Hope	6	2	2	1	0
Kindness	4	0	3	4	0
Learning	3	0	1	10	0
Loss aversion	1	0	0	7	0
Minimum payoff	2	0	1	0	0
Probing	10	1	0	2	0
Reciprocity/retaliation	1	0	0	5	1
Risk	5	0	0	2	0
Spite	1	0	0	8	1
SVO Altruistic	3	0	4	0	0
SVO Competitive	0	0	0	8	1
SVO Cooperative	14	2	7	0	0
SVO Equality-seeking	6	0	1	5	0
SVO Individualistic	8	0	2	21	0
Take the best	11	1	2	7	0
Temptation	2	0	0	6	0
Trust	2	0	1	0	0

The motive most frequently associated with a general GO move (at any decision node) was the cooperative SVO (14 coding references). This was closely followed by "Take the best" (11 coding references) and "Probing" (10 coding references). The latter refers to the aim of assessing the co-player's behaviour and predicting future moves on that basis. Participant 10, for example, said:

> Now they've chosen to GO as well. Umm, I'm gonna keep going. I like to just see in this one how long I can keep the other person going for it as well. . . .The decision they'll make in this one will be interesting to see what I think they're gonna do for the next ten.

GO moves at the first decision node are of particular theoretical importance, because orthodox game theory predicts an immediate STOP move at Node 1. In the data, the most commonly motive linked to an initial GO move was activity bias. For example, Participant 10 said: "OK, OK . . . so the first one is blue so it's my turn. I choose to GO or STOP. Umm I keep going, umm, 'cause this is the first one, so I might as well GO and see what happens."

The most frequent motive associated with a GO move at the last decision node leading to the natural end of the game was the cooperative SVO. Additional motives associated with cooperation at the last decision node were the altruistic SVO and a wish to complete the game. Participant 10 said: "Umm, I'm gonna keep going. My aim is to try and get all the way to the end just to feel like I've finished it but I think the other person is gonna keep stopping at what benefits them."

A general STOP move (at any decision node) was most frequently associated with an individualistic SVO. For example, Participant 8 commented: "I'm gonna STOP here, umm, so that if this round is chosen to pay me, then I'll probably be paid, umm, a good amount." Another coding category commonly linked with STOP was the learning from previous experience in the game; For example, Participant 8 said:

> Oh, so he's decided to oh . . . 'The decision sequence has been ended' . . . so he decided to STOP now. Ugh, maybe I should have just stopped there. But it's fine, like, umm, I've actually lost 40p but it's, it's OK. I can just be careful next time.

A STOP move at the first decision node occurred only once across 60 games, and was linked to frustration, retaliation, and spite on the part of both players. Participant 7 explained the immediate exit move as follows: “So because they keep pressing STOP, I’m going to press STOP on the first go”; and Participant 8’s reaction was: “Oh he stopped it right at the first go! [Laughter] I’m getting angry now!”

With the help of another Matrix Coding Query, motives were cross-tabulated with reasoning levels to investigate shared coding references and thus explore the relationship between levels of reasoning and motives (see Table 2.5). A strong association between 0th-level reasoning and the following motives became evident: “activity bias”, “curiosity”, “probing”, and “loss aversion”, indicating that low-level reasoners typically used loss-sensitive trial-and-error strategies. For example, Participant 3 said: “I decide to GO . . . and the Participant A chose to GO . . . and ugh OK. I think I’m going to STOP. . . . So that there’s more action [laughter].” Participant 7 said: “And again, if they click GO, then I will click GO again to see what they do on the next sequence . . . ’cause I’m a bit curious like that.”

Table 2.5

Results of NVivo Matrix Coding Query: Frequencies of Coding References of Motives across Four Levels of Reasoning in the Game

	0th-level	1st-level	2nd-level	BI reasoning
Activity bias	5	0	0	0
Avoid the worst	1	1	0	1
Completing the game	0	0	0	0
Compromise	0	1	0	1
Coordination	0	0	0	0
Curiosity	5	0	0	0
Frustration	1	0	0	0
Gambling	0	0	1	0
Generosity	0	0	0	0
Greed	0	0	0	0
Guilt	0	0	1	0
Habitual strategy	0	0	0	0
Hope	0	0	0	0
Kindness	0	1	0	0
Learning	1	2	1	0
Loss aversion	4	1	0	0
Minimum payoff	0	0	0	0
Probing	4	1	1	0
Reciprocity/retaliation	1	0	0	0
Risk	0	1	0	0
Spite	0	1	2	0
SVO Altruistic	0	0	0	1
SVO Competitive	0	2	1	0
SVO Cooperative	0	0	0	0
SVO Equality-seeking	0	0	0	0
SVO Individualistic	2	6	3	3
Take the best	1	4	1	0
Temptation	0	2	0	0
Trust	0	0	0	0

Study concerns

The last coding category is a collection of verbalisations regarding various aspects of the research design and task variables that could prove useful in refining existing experimental methods and procedures. Example statements are provided in Table 2.6.

Table 2.6.

Hierarchical coding node structure for "Study concerns" including example statements, number of coding sources, and number of individual coding references

Study concerns	**Number of sources (participants)**	**Number of coding references**
Timing clues *P5: "Ooh he's taking a bit longer to decide this time . . . umm . . . interesting . . . Not sure why he's delaying it. Was a bit worried there, wondering what he was up to . . . But he seems to have gotten back on to track."*	8	24
Misunderstanding instructions *P2: "So the reason I did that was because I imagine that these scores are gonna switch over and I'll be able to win the 25.60 at some point and perhaps if I let them win £25 now, in the future they'll let me GO."*	5	10
Comparing player roles *P11: "And it's actually quite useful being Participant A because I get to make the first decision, which kind of gives me a bit more power because I could just STOP it now and still have more money than they do."*	3	3
Doubts about co-player being real person *P12: "What? Did you see, this is starting to make me think that the other person is not real. Who takes five . . . um five seconds to decide if they want 40p? Instead of maybe, don't know, 1.60?"*	1	3

Doubts about payoff information	1	3
P6: "So, anyway, still going. He's still going, too. So in order for him to still be going and knowing that he's being paid less money, then that means that he's probably seeing the same thing like me or something . . . I don't know. Wouldn't make any sense."		
Identity of other player	1	2
P12: "At this point, I'm starting to be a bit mad. Umm . . . I don't know why. They might be a woman. Might be. But I don't associate women with such greediness."		

Most participants showed excellent understanding of the Centipede game's rules and payoff structure following the detailed task instructions, even though some participants seemed to expect a change in player roles from one game to another in spite of having been instructed otherwise. The majority of participants appeared to have accepted the task instructions received by the experimenter. Only two participants, whose co-players behaved in ways quite contrary to their expectations, began to challenge the information that they had been given.

Interestingly, eight participants (with a total of 24 individual coding references) interpreted the co-player's response latency as an important signal about the co-player's intentions. Participant 5, for example, commented:

> Ooh, he's taking a bit longer to decide this time . . . umm . . . interesting. . . . Not sure why he's delaying it. Was a bit worried there, wondering what he was up to. . . . But he seems to have gotten back on to track.

Participant 12 even manipulated his own response times to confuse his co-player: "Let's take five seconds to think. Actually, I'm not going to think. I'm just going to wait here for five seconds to make them think that I'm thinking. And then . . . see what happens."

2.3: Discussion

Cooperation levels in the present study were marginally higher than levels reported in previous studies using the same version of the Centipede game. The quantitative results show a mean exit node of 5.12, as compared to 4.27 (McKelvey &Palfrey, 1992) and 4.00 (Kawagoe & Takizawa, 2012). This could be explained by the use of fixed participant pairing for all ten rounds of the game rather than random re-matching after each round. In a direct comparison of fixed pairing versus random re-pairing in Centipede games, Pulford, Colman, Lawrence, and Krockow (2015) found higher cooperativeness in the fixed-pairing condition, and this was explained in terms of direct reciprocity and trust-building across rounds.

The results of the verbal protocol analysis provide strong support for the existence of different levels of rationality as well as different types of SVOs among the participants. In accordance with previous research (e.g., Nagel, 1995), the majority of participants used 1st-level reasoning when trying to derive an optimal strategy. Furthermore, there was evidence for five different types of SVO motivating the participants' moves, with individualistic concerns being the most common, followed by cooperative, equality-seeking, competitive, and altruistic orientations. These findings are in line with previous results by Au and Kwong (2004), who assessed the occurrence of the three main SVOs across different countries and found that 57% of people were motivated predominantly by prosocial concerns (including cooperative, equality-seeking and altruistic), 27% by individualistic, and 16% by competitive orientations.

However, despite the qualitative support for the theoretical concepts, the verbal records showed that almost all participants engaged in multiple levels of reasoning and were influenced by several different SVOs, depending on the situation and their previous experience in the game. Furthermore, the data provided evidence for a wealth of additional motives for choice that mingled and interacted to determine an individual's moves. To illustrate the variety of factors and their complex interplay when making decisions in the Centipede game, the comparison of the verbal records generated by two player pairs with ostensibly similar strategies (as shown by almost identical game outcomes) is instructive.

The quantitative results for the games completed by Pair 1 and Pair 3 were very similar. Both pairs demonstrated high levels of cooperation across rounds (apart from Rounds 9 and 10 completed by Pair 1), generally reaching the game's natural end.

Given these similar quantitative results, one might expect similar motives or reasoning levels to have influenced the respective players' choices. In fact, the pairs were radically different. The players of Pair 1 were among the most sophisticated decision makers in the present study. Both used iterated reasoning to choose moves in the game, and Player B (Participant 2) was the only participant to have demonstrated perfect BI reasoning in the study:

> So yeah, I'm basically halving what I can get at the end because I feel that if I stopped at 6, they'd realise that's what I was doing and then perhaps STOP at 5 and then . . . and you know . . . and I guess the way this is set up means that it would then, you know, cascade backwards almost.

Despite successfully identifying the subgame-perfect Nash equilibrium, Player B chose to cooperate and compromise, even choosing an altruistic GO move at the final decision node, in an attempt to prevent the game unravelling and yielding a minimal BI payoff. Player B further considered a premature STOP move by Player A unlikely due to the game's negligible payoffs at early exit nodes:

> See, I don't think there's gonna be any decision making here, really, 'cause we want to GO. It's gonna be at 4 or 5 that the decision will be made, really. I don't know why they would want to STOP at 3.

Only on Rounds 9 and 10 did Player B decide to maximise his personal payoff and STOP at the last decision node, because the opportunities for Player A to retaliate were minimal at this point. Player B explained: "So I think I'll STOP at 6 on the 10th go. So then I'll have a 10% chance of getting the 12.80 but there's no point of doing it before that because they might STOP at 5."

Pair 1's Player A initially chose to cooperate out of a recognition of the need for teamwork in order to get to the high payoffs towards the end of the game, all the while hoping the other person would play along:

> Um, kind of tempted to carry on . . . kind of tempted to carry on because I'll get half and they'll get a massive bonus. So I'll see . . . I'll be nice to them and we'll see what happens. We'll see how they react.

As Player B kept cooperating at the final decision node, Player A was struck by his kind nature, expressed a high level of gratitude, and increasingly reported unease at the accruing payoff inequality between the two players. Consequently, Player A appeared almost relieved that Player B finally opted to counteract the payoff imbalance and stopped earlier for rounds 9 and 10: “Ahhh yes, “chose to STOP”. There you go! I do not blame you. I don’t blame you! I have been . . . I have been . . . It’s only fair!”

Looking at the verbalisations by Pair 3 of this study, neither player demonstrated any form of iterated reasoning. Player A (Participant 6) was particularly myopic in choosing a strategy in the game:

> OK . . . sooo. I’m gonna press GO again. I don’t know a reason why not to again. If the other participant said he can continue then I might as well choose GO. OK, I’m waiting. . . . He said GO again. So, umm, I’m gonna continue, too.

Player B (Participant 5), instead of engaging in recursive reasoning on the other player’s likely aims and choices, merely hoped for reciprocal cooperation:

> I can see the only way that I’m gonna make . . . umm . . . the best way for me to make some money is to get all the way to the end umm the further up I can go umm. . . . So I’m gonna GO on this one I think and hope for the best.

The decision to cooperate at the final decision node was driven by a highly prosocial (cooperative and altruistic) SVO and the wish to complete the game. Furthermore, after the first round of the game, Player B continued with his initial strategy and made all following decisions comparatively quickly and with little additional deliberation.

Player A, on the other hand, initially chose to cooperate based on mere curiosity. Following a few rounds of the game, however, she became increasingly perturbed by the identical payoffs and her repeated personal gains, consequently starting to question the set-up of the study: “Umm. I’m really sorry to have second thoughts about this. . . . I don’t know. . . . It doesn’t seem right for me to be winning all the time. Winning in the sense of making more money than him.” The individualistically orientated Player A continued to choose GO because it seemed to be rewarding, but was deeply perplexed about Player B’s reason for continually choosing GO.

This detailed comparison of two player pairs with very similar quantitative results reveals the variety of cognitive processes and considerations underlying any one strategy, powerfully showcasing how identical moves can be interpreted in drastically different ways. This qualitative study showed that no one move was associated with a particular level of rationality or a motive. There was no evidence that sophisticated recursive reasoning skills led to the equilibrium outcome of immediate defection in the Centipede game. In fact, those participants with higher-level reasoning skills—and in particular the one participant with full BI reasoning—cooperated more consistently than participants of lesser strategic depth who frequently opted for haphazard trial-and-error strategies. These qualitative results therefore call into question previous empirical findings on BI play by expert Chess players with supposedly advanced levels of reasoning (Palacios-Huerta & Volij, 2009). Furthermore, despite lending support to the existence of different types of rationality as assumed by ToM, the findings challenge these types' predictive power in the context of the Centipede game.

When examining the effects of different motives, a closer look at the context of the move is necessary to detect patterns in the verbal data. A mere activity bias appeared to be the most frequent motive for cooperation at the first decision node. Many participants considered the initial GO move an obvious, almost non-debatable choice. Furthermore, early GO moves were generally linked to a general pursuit of high numbers, because most participants considered the payoffs at the first few terminal nodes insubstantial. This finding lends support to previous research demonstrating the importance of stake size in Centipede games (Rapoport, et al., 2003). Motives such as prosocial value orientations usually became important only towards the end of the game and, alongside a wish to complete the game, seemed to have a particularly strong influence on the decision at the final decision node.

Similarly, whereas there were many motives for general STOP moves in the game, with a majority related to individualistic concerns about personal risks and losses, there was a strong link between immediate defection at Node 1 and spite, frustration, and retaliation. The game-theoretic outcome was therefore interpreted as a particularly competitive move.

With regard to the research design and materials, the verbalisations demonstrated that the instructions on the game's rules were well understood and generally believed by all participants. However, details (e.g., regarding the assignment of player roles) were occasionally overlooked and could be made more prominent in future instruction slides.

An important aspect of the design—shared with most published Centipede experiments—was the flexibility of permitted response times that allowed for indefinite delays, potentially carrying non-verbal timing signals. The qualitative data revealed that human decision makers attach meaning to pauses made by their co-players and that they also sometimes deliberately use delays as covert signals of their own intentions or emotions, such as discontent. Future studies should therefore control such means of communication and impose standardised response times in order to circumvent covert signalling between participants.

2.4: Conclusions

This chapter presented Study 1, which provided exploratory, qualitative data of the decision-making processes involved in Centipede-type decision scenarios. Overall, the chapter demonstrates the potential merits of qualitative analyses for behavioural game theory. Study 1 showed that all participants produced intelligible verbalisations that provided powerful evidence for a complex interplay of large numbers of different reasoning levels and motives. The range of motives was much larger than could ever be accounted for by econometric models, and the qualitative data provide evidence for previously neglected motives, such as activity bias. The findings also point to the need for design improvements, such as the control of permitted response latencies. Future research should apply qualitative methods to a wider range of experimental games, with a focus on other mixed-motive games in which motives for choices are likely to be complex.

Chapter 3: Competitive Centipede Games

Following the explorative qualitative study presented in Chapter 2 which highlighted the vast range of reasoning levels and motives in the Centipede game, this chapter presents the quantitative findings of Study 2 which sets out to overcome the limited generalisability of previous research findings due to variations in experimental designs. Centipede games with different, competitive payoff functions are compared and tested for the relative influences of zero-end payoff structures and take-it-or-leave-it structures. The results shed light on the surprising effects of seemingly small manipulations of the games' payoff functions.

3.1: Background

Reciprocal, Centipede-type interactions characterised by a repeated pattern of give-and-take can take on many forms in human relationships. The following example should not be taken too literally but rather be considered as an archetype of a wide range social relationships: Two neighbours with adjacent properties take turns, once a week, tending to an apple tree growing on the border which separates their gardens. With each week of cultivation, the number of apples on the tree increases, and existing apples ripen, thus improving the prospective value of the harvest. This process continues as long as both neighbours continue to cooperate, and it terminates as soon as one of them defects by harvesting the crop. In this case, the defector secures a larger share of fruit, leaving a comparatively small share to the other person. If neither neighbour chooses to defect, then the process comes to a natural end once the fruit have reached full ripeness. In this second case, the individual whose turn it is at the time takes the larger share. The same basic strategic structure is present in a very wide variety of human interactions, including interpersonal relationships characterised by repeated, alternating opportunities for reciprocal acts of cooperation, economic and business relationships with recurrent opportunities for turn-taking assistance or favours, and political interactions with sequential opportunities for the exchange of support in voting assemblies, for example.

In the apple harvesting example, even small variations of the collaborative reciprocal relationship could turn it into a new, much more competitive interaction. One such variation could be the introduction of a deadline by which the crop had to be harvested in order to prevent the fruit from rotting and leaving both neighbours with nothing. Such a deadline would make defection—at some point during the interaction—virtually inevitable. Hence, in contrast to the decision *whether* to defect, in this scenario individuals would have to decide *when* to defect. Another variation could be to increase the inequality in crop distribution between the two neighbours, in the most extreme case allocating the total crop to the defector. By increasing differences in relative gains, the roles of "winner" and "loser" become more pronounced and every cooperative action becomes more risky.

The harvest decision context and its two competitive variations can all be modelled with variations of the Centipede game (see Figure 3.1). The standard, exponential game version is depicted under (a). At a workshop in Haifa organised by the Israeli economist Joseph Greenberg in 1988, Robert Aumann presented a competitive game version belonging to the type shown under (b), in which both players are faced with zero payoffs at the end of the interaction if neither chooses to defect. These games shall be called type *Zero-end* Centipede games. The competitive version shown under (c), in which a player who defects takes the entire payoff pot that has accumulated up to that point, leaving nothing to the co-player, was introduced by Reny (1992), who named games of this type *Take-it-or-leave-it* Centipede games (Huck and Jehiel, 2004, called them *Take-or-pass* games). Finally, a game version combining both competitive features—Zero-end and Take-it-or-leave it payoff function—is displayed under (d).

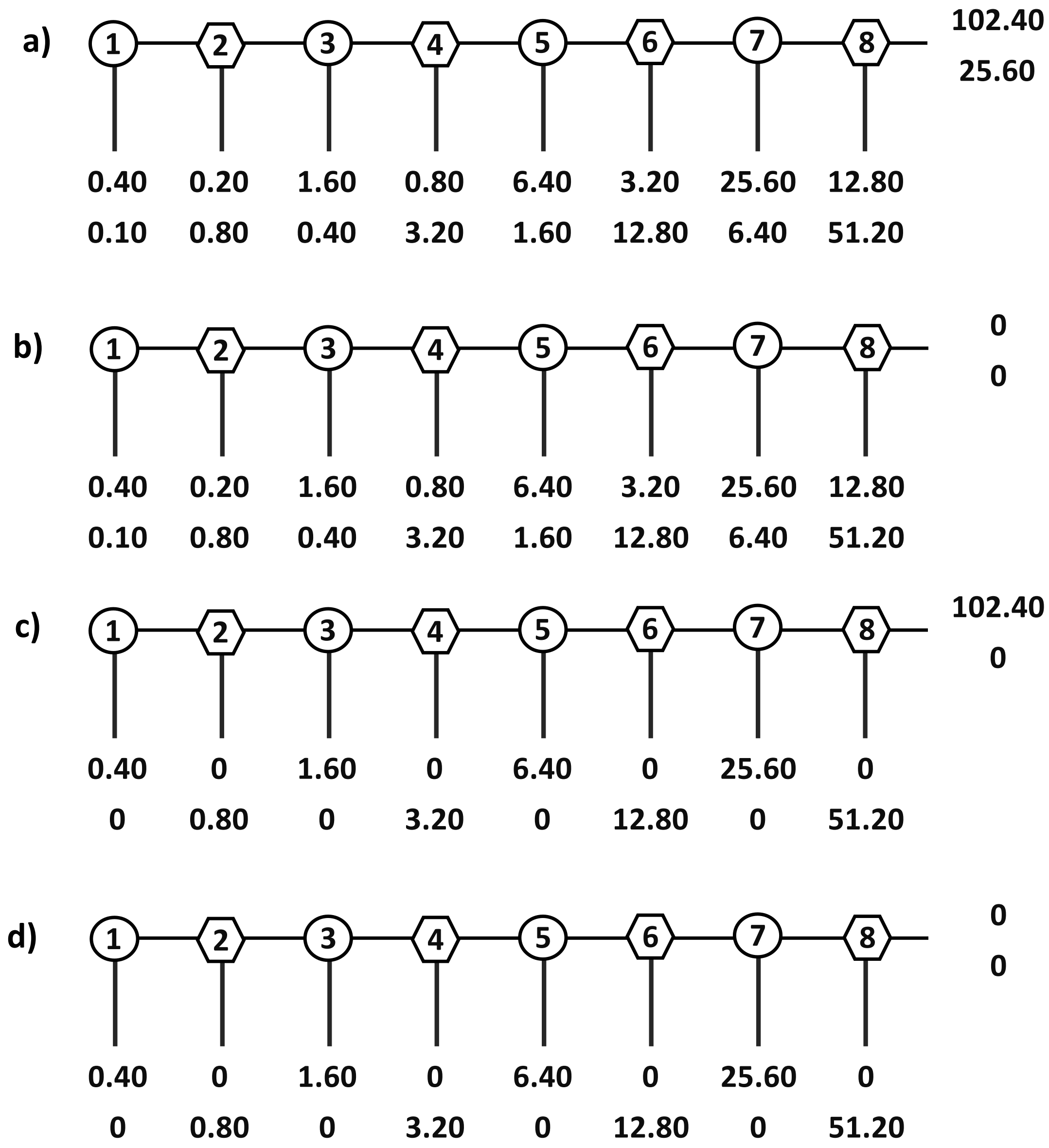


Figure 3.1. Four treatment conditions: (a) exponential Centipede game with positive payoffs at terminal exit node; (b) Exponential Zero-end Centipede game; (c) Take-it-or-leave-it Centipede game with positive payoffs at terminal exit node; (d) Take-it-or-leave-it plus Zero-end Centipede game.

The subgame-perfect Nash equilibrium solution of the Centipede game—in all its variations—is an immediate STOP move by Player A at Node 1, and this is proved with the well-known BI argument described in Chapter 1.

Despite a growing body of empirical research on Centipede games, comparatively little research has focused on more competitive versions of the Centipede game (Figure 3.1, (b) and (c)). Parco, Rapoport, and Stein (2002) first introduced a nine-node Centipede game with three players, high payoff differences between players, and zero payoffs at the final exit node. This game was subsequently used in a number of experiments (Murphy, Rapoport, & Parco, 2004; 2006; Rapoport, Stein, Parco, & Nicholas, 2003). In a study of a high-stakes version of the game, Rapoport, et al. (2003), found very low levels of cooperation (almost 40% of their games ended at Node 1) and strong learning effects with decreasing cooperation across 60 repeated rounds of the game. This experiment elicited a different pattern of decisions from what is typically observed in standard Centipede games, but it remains unclear to which aspects of the design these differences can be attributed. The zero payoffs at the end are likely to have played an important role, but the number of players and the high payoff inequality may also have had large effects. Another confounding factor that could explain the strong learning effects reported in multi-player Zero-end Centipede games is the comparatively small pool of players taking part in the reported experiments, especially taking into account the high number of players per game and the numerous game repetitions (60–90 rounds). Even with anonymous random re-pairing after each round, players in these studies must have been aware of the high likelihood of repeated pairings with the same co-players, which could have elicited elements of super game thinking and behavioural adaptations based on experience from previous rounds.

Three studies—two of which as yet unpublished—used Take-it-or-leave-it Centipede games with even greater payoff inequality than the games used by Rapoport and his colleagues (Huck & Jehiel, 2004; Cox & James, 2012). In a complex research design investigating decision making in Take-it-or-leave-it Centipede games with partially unknown payoff functions, continuous *versus* discrete moves, and simultaneous *versus* sequential move order, Cox and James reported the lowest cooperation levels ever reported in any type of Centipede game. In their version of the game with continuous and simultaneous moves, more than 95% of all games ended at the first decision node. However, as in the case of the multi-player Zero-end games discussed above, it is difficult to pinpoint which of their design aspects—continuous moves, partial payoff information, Zero-end payoffs, or Take-it-or-leave-it payoff function—were the decisive factors yielding these remarkable results. In a follow-up study (Cox & James, 2015), the same authors compared four-node Exponential Centipede games with two Take-it-or-leave-it game variations—one under time pressure and one without—and found that the high payoff difference of the Take-it-or-leave-it games decreased cooperation whereas time pressure did not affect the choices in the game.

Nevertheless, due to the shortness of the games used in this experiment, overall stake sizes remained small (maximum of $6.40) which is likely to have influenced decision making. Given the lack of conclusive results from previous studies on competitive Centipede games, a controlled comparison of a standard Centipede game with versions characterised by zero payoff ends and/or high player inequality is needed to disentangle the respective influences of these different game variations.

3.2: Study 2

In order to resolve the ambiguities outlined above, the Study 2 compared an eight-node version of McKelvey and Palfrey's (1992) original Exponential Centipede game with three competitive variations: an Exponential Zero-end version, a Take-it-or-leave-it version, and a game combining both competitive features. Based on game-theoretic predictions, if the standard common knowledge assumption of game theory applies, then all games should elicit the same decision patterns, since they share the subgame-perfect Nash equilibrium in which Player A defects at the first decision node. Nevertheless, the previous studies reviewed above indicate that certain game features may have important psychological effects on human decision makers, leading to strikingly different choices in games with only slightly different payoff functions. Drawing on this research, it was proposed that the standard Exponential Centipede game with positive payoffs at the terminal exit node would yield significantly higher levels of cooperation than Zero-end and Take-it-or-leave-it games. It was further hypothesised that the game version combining both competitive features—Zero-end and Take-it-or-leave-it payoff function—would yield even lower levels of cooperation than games with just one of these competitive features.

3.2.1: Method

This method section provides details of the study's participants (Section 3.2.1.1), the design (Section 3.2.1.2), materials (Section 3.2.1.3), and procedure (Section 3.2.1.4).

3.2.1.1: Participants

The sample consisted of 82 undergraduate psychology students from the University of Leicester—17 males and 65 females—with a mean age of 19.78 years (*SD* = 3.29), all of whom received course credits for participation. Additionally, all participants were entered into a lottery, and one person per testing session had his or her payoff from a randomly selected game completed during the experiment converted to a cash payment in pounds sterling. There is evidence for the validity of this random lottery incentive system (Bolle, 1990; Cubitt, Starmer, & Sugden, 1998). The mean cash remuneration of the four participants selected was £5.60.

3.2.1.2: Design

The participants were randomly assigned to one of four treatment conditions varying in their game designs: (a) Exponential Centipede game; (b) Exponential Zero-end Centipede game; (c) Take-it-or-leave-it Centipede game; and (d) Take-it-or-leave-it plus Zero-end Centipede game (see Figure 3.1). The dependent variable was the mean exit node of all games completed during one round of the game. Large values indicated late exit moves and thus high levels of cooperation, whereas small values indicated early exit moves and low levels of cooperation.

3.2.1.3: Materials

The study was conducted in a large computer laboratory. Each participant was seated at a computer—separated by at least one free seat from the next person—and interacted in the Centipede game through a custom-made, web-based game application that included several detailed instruction slides and a color-coded, animated display of the relevant Centipede game.

3.2.1.4: Procedure

Testing took place in groups of 18 to 22 participants with each session lasting between 30 and 45 minutes. The participants were told not to communicate with each other, and the experimenter ensured that participants focused attention on their own computer screens. After filling in the consent form, participants were presented with the game instructions and encouraged to ask questions about the rules and procedure. They were then randomly assigned to a player role (Player A or B), and they remained in the same role for the duration of the testing session. Each participant completed 20 rounds of one of the four Centipede games, with random and anonymous pairings for each round. They received real-time feedback on their co-players' moves, the outcome of each game, and the number of rounds completed. Following the last round, one participant was randomly drawn from the group for remuneration on a randomly selected game played during the session.

3.2.2: Results

Out of 820 games played in total, 18 (2.2%) ended at the first exit node and 21 (2.6%) continued until the final exit node (Node 9). Figure 3.2 shows the proportions of games ending at each exit node per treatment condition. The modal exit node for Conditions 1 and 3 (both characterised by positive payoffs at the terminal node) was Node 6. The modal exit node for Conditions 2 and 4 (Zero-end games) was Node 5. Only 2% of all games in Condition 4 (Take-it-or-leave-it plus Zero-end game) and not a single game in Condition 2 (Exponential Zero-end game) continued beyond Node 7. Furthermore, Condition 2 yielded a very high percentage of games terminating in the first third of the game tree: Over 24% of games ended at one of the first three decision nodes, whereas in the other three conditions, this percentage did not exceed 4.5%.

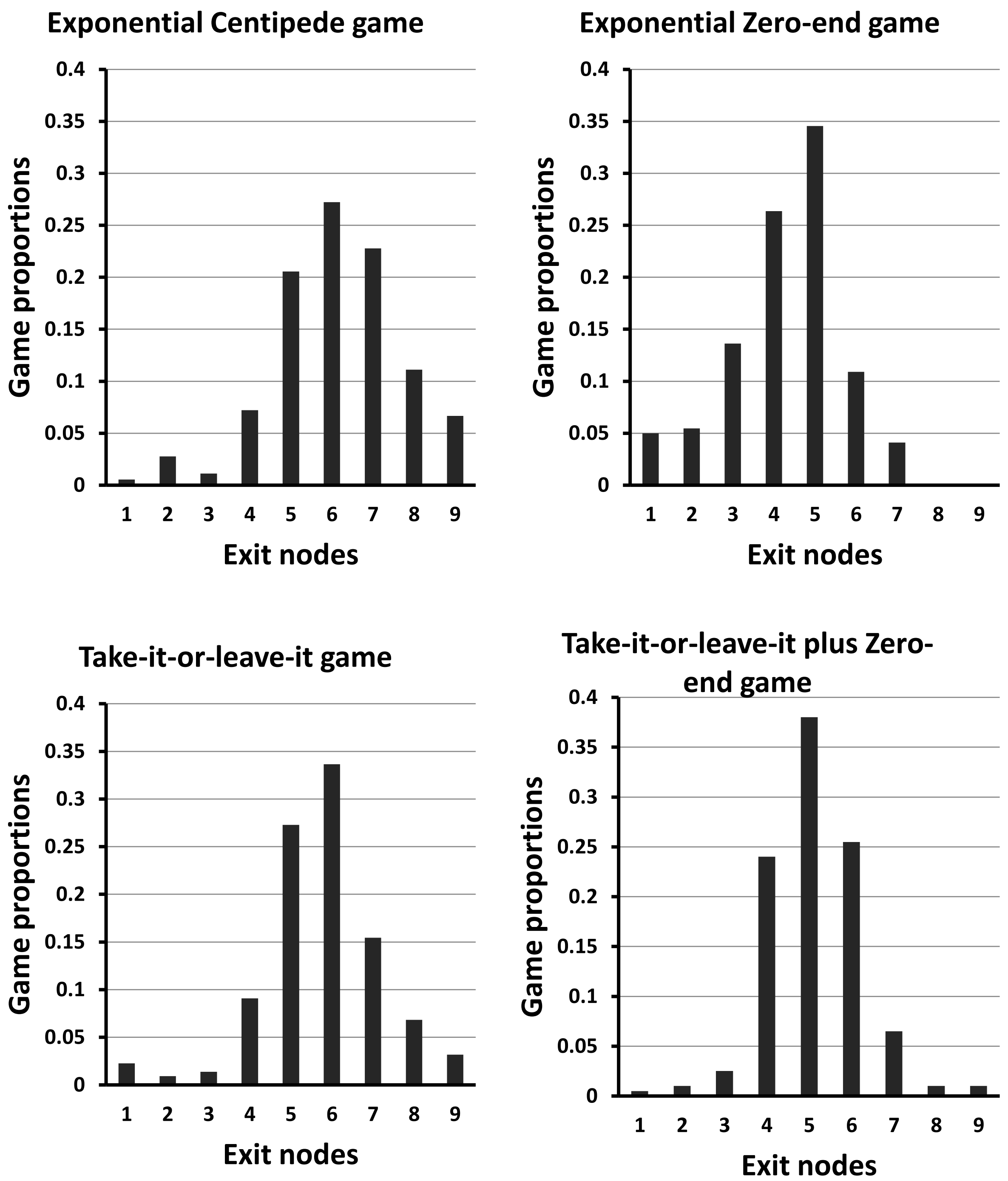


Figure 3.2. Proportion of games ending at each exit node for the four game conditions.

The time series for the different games do not show any discernible trends of either increasing or decreasing cooperation with greater experience in the game.

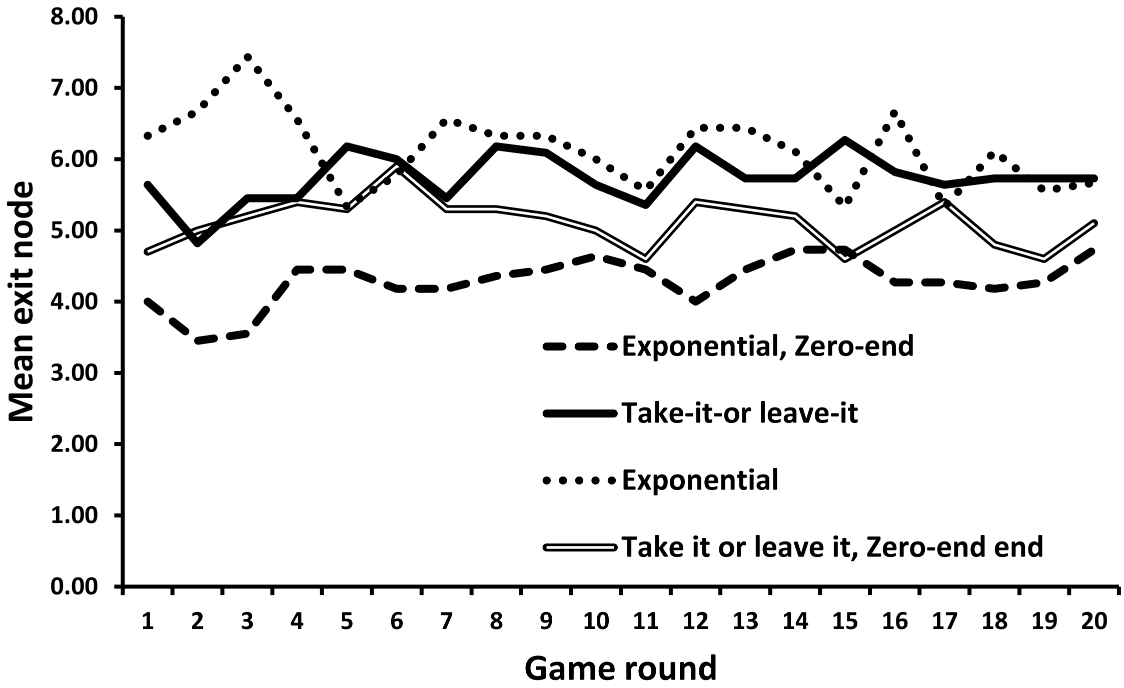


Figure 3.3. Mean exit nodes per game round across the four treatment conditions.

The experimental manipulation had a significant effect on the mean exit points, $F(3, 76) = 77.272$, $p < 0.001$, $\eta_p^2 = 0.75$ (medium effect size). Post-hoc comparison indicated significant differences between all four treatment conditions (Tukey HSD tests yielded $p < 0.02$ in all cases). The Exponential game with positive payoffs at the end produced the highest cooperation levels ($M = 6.13$; $SD = 0.56$). This was followed by the Take-it-or-leave-it Centipede game with positive payoffs at the end ($M = 5.74$; $SD = 0.35$) and the Take-it-or-leave-it plus Zero-end game ($M = 5.12$; $SD = 0.33$). The Exponential Zero-end Centipede game yielded the lowest levels of cooperation ($M = 4.29$; $SD = 0.35$).

There were no significant gender differences. Across treatment conditions, the mean exit nodes were 5.19 (male) and 5.33 (female), $t(80) = 0.467$, $p = 0.64$ (two-tailed), and for each of the four treatment conditions separately, the mean difference was very small, with $p > 0.25$.

3.3: Discussion

Following the largely explorative research reported in Chapter 1, this chapter reported quantitative findings from Study 2 which set out to investigate how particular, competitive features of the payoff function can influence decision making in repeated reciprocal interactions modelled by the Centipede game. Overall, the results confirmed previous findings of low defection percentages at the first decision node and an absence of any marked learning effects across games rounds (McKelvey & Palfrey, 1992; Nagel & Tang, 1998). The results further support the first hypothesis that modifications of the game's payoff function elicit significant changes in the participants' decision patterns, even though the game-theoretic solution is identical in all game variations. As predicted, Zero-end Centipede games and those characterised by a Take-it-or-leave-it payoff functions were shown to elicit significantly lower levels of cooperation compared to the standard Exponential Centipede game.

In the Zero-end game, this finding can be attributed to the deterrent psychological effect of a zero payoff at the terminal exit node. In this version, players are forced to defect at some point during the game in order to avoid a payoff of zero at the game's natural end. This finding is in line with previous research by Rapoport et al. (2003) and Murphy et al. (2004, 2006), who reported play in their three-player, Zero-end Centipede game to be much more competitive than in standard Centipede games with positive values at the natural end, but those previous studies did not allow the separate effects of game variations to be compared.

In the Take-it-or-Leave it game, lower cooperation levels can be explained by the extreme player inequality and the higher risk involved in choosing a cooperative GO move; if the co-player terminates the game at the immediately following decision node, then the payoff to the player who previously cooperated is zero. The findings on the Take-it-or-leave-it game link in with previous research that found very low cooperation levels using a game of a similar winner-takes-all payoff function (Cox & James, 2012, 2015), although, once again, the research design made it impossible to pinpoint the factor(s) that caused the low levels of cooperation.

Contrary to the predictions of the second hypothesis, the game design combining both competitive features—Take-it-or-leave-it payoff structure and Zero-end—was not the one to yield the lowest cooperation levels overall. Whereas participants in this condition exited significantly earlier than in the standard Exponential game and the Take-it-or-leave-it game with positive payoffs at the natural end, the game condition eliciting the earliest exit moves was the Exponential Centipede game with Zero-end payoff structure. When comparing the numbers of games terminating at each exit node across treatment conditions, the Exponential Zero-end game stood out as the condition with the most STOP moves in the first third of the game tree, leading to the lowest mean exit node of all four game variations.

Following considerations could explain why the Exponential Zero-end game yielded lower levels of cooperation than the Take-it-or-leave-it plus Zero-end version. The payoff function of the Take-it-or-leave-it plus Zero-end version is heavily dominated by zeroes (the losing player never receives anything), and one consequence of this is that the zero payoffs at the end has less salience than in the Exponential Zero-end version, where these are the only zeros. Consequently, the deterrent psychological effect of the zero payoffs at the end may be comparatively smaller than in the version characterised by the typical Exponential payoff function.

A second possibility, not necessarily negating the first, is that fairness-seeking or inequality-averse individuals may perceive the equal payoffs of zero to both players as a desirable goal in a Centipede game with Take-it-or-leave-it plus Zero-end payoff function, because the payoffs at all other exit nodes create extreme inequality between the two players—a lot more so than in the standard Exponential Centipede game. Indeed, two of the participants with the role of Player B in Condition 4 opted for GO at the final decision node, thus choosing equal payoffs of zero at Exit node 9 over a personal payoff of 51.20 with the co-player receiving nothing at Exit node 8. These decisions must either be errors arising from bounded rationality or manifestations of inequality aversion in the form of a strong drive to achieve a fair outcome for both individuals.

Fey, McKelvey, and Palfrey (1992) and Kawagoe and Takizawa (2012) studied choices in constant-sum Centipede games with high payoff differences, increasingly unequal from one decision node to the next, and they found more frequent defection at the first decision node than was found in this experiment. In game-theoretic terms, any two-player constant-sum game is strictly competitive, and an implication of this is that it is impossible for both players to benefit from cooperation, as there is no social gain from cooperation. In the experiment’s non-constant-sum Centipede games, by contrast, the payoff pot increases and both players can hope to benefit from reciprocal cooperation, hence it is hardly surprising that less defection was observed at the first decision node.

3.5: Conclusions

Taken together, the findings presented in this chapter shed further light on the different and often subtle aspects of reciprocal interactions that may influence the extent of cooperation and teamwork exhibited by human decision makers. The increase of inequality between two individuals in an interpersonal relationship was shown to reduce overall cooperation significantly. Furthermore, the introduction of undesirable final payoffs as a consequence of unconditional or automatic cooperation was shown to have an even stronger effect on reducing cooperation. Surprisingly, however, coupling these two deterrent factors did not reinforce their respective effects but appeared to form a novel decision-making context that elicited slightly higher cooperation levels than expected. The results of this study therefore demonstrate the need for carefully controlled experimental designs when investigating decision making and cooperation. Variations in the game's payoff structure can elicit significant behavioural changes, and the interplay of these factors can have unexpectedly complex effects.

Chapter 4: Centipede Games with Varying Lengths and Termination Rules

This chapter presents the findings of Studies 3 and 4 which aim to increase real-life applicability of the Centipede game by introducing longer decision sequences with different termination rules. Whereas Study 3 mainly manipulates game length and the players' knowledge thereof, Study 4 investigates the effects of random game termination through a computer player ("Nature"), which introduces a new level of risk beyond the players' control.

4.1: Background

Consider again the following example situation first described in Chapter 1: Two neighbouring couples alternate helping each other with the baby-sitting. Neither of the couples particularly enjoys looking after the other family's badly behaved children, and there is always the possibility that one couple could decide to end the relationship without further reciprocation. Nevertheless, in the long run, both couples benefit from the connection. Crucially, the couples are ignorant of the maximum number of evenings they could baby-sit (the interaction's end is unknown) but due to situational factors such as geographic proximity, the relationship is likely to endure. In fact, the interaction is likely to be indefinite, that is, lacking a predetermined length. Instead, there may be an element of chance involved (existence of a player "Nature") when it comes to the duration of their interaction. Whereas the baby-sitting agreement may not have a fixed end, it could terminate abruptly due to, for example, a sudden move of house or an accident.

Whereas the example's basic structure of repeated reciprocal cooperation can easily be modelled by a linearly increasing Centipede game, standard payoff functions and termination rules may be insufficient to investigate long relationships with, for example, unknown or indefinite ends.

As reviewed in Chapter 1, only finite and relatively short Centipede games have been studied so far. The longest Centipede game ever used in an experiment was Nachbar's (2014) 15-node game. However, given that this study was based on a five-player design (as opposed to the standard two-player design), the length of the interaction still seemed very limited, with each player facing a maximum of only three choices each. These short games may not reflect real-life interactions adequately, which are usually characterised by a higher and often unknown number of iterations as illustrated above (Jiborn & Rabinowicz, 2013).

Also, even though the Centipede games of two-player experiments varied considerably in length (between three and twelve decision nodes), only two studies compared games of different lengths directly. Fey et al. (1996) reported earlier exit moves in shorter Centipede games, but differences were comparatively small. Furthermore, their study used highly competitive constant-sum games whose results may not be applicable to games with increasing-sum payoff functions. McKelvey and Palfrey (1992), who compared four-move and six-move exponential games, also reported evidence for earlier defection in shorter games. A retrospective analysis of variance of McKelvey and Palfrey's data set reveals a significant difference between the standardised mean exit points of their high-stake four-move game (*M* = .51; *SD* = .12) and their low-stake six-move game (*M* = . 61; *SD* = .11), ($F(2, 65) = 4.11$, $p < .05$, η_p^2 = .11, indicating medium effect size). However, given that their low-stake four-move and low-stake six-move games did not differ significantly, it is difficult to disentangle the respective effects of game length and stake size. Hence, further research needs to be done to arrive at a better understanding of the effects of game length.

Finally, no research to date has investigated Centipede games with different termination rules such as unknown ends or random game termination, even though they could provide highly informative insights into decision-making situations marked by uncertainty or risk. A helpful point of reference could be the literature on the iterated or repeated Prisoner's Dilemma game (RPDG). The RPDG comprises a series of identical one-shot Prisoner's Dilemma games, all completed with the same co-player. This yields a repeated interaction resembling that created by the Centipede game, despite lacking the following unique features of the game. In the RPDG, the decision to defect does not terminate the entire interaction. Retaliation through strategies such as Tit for Tat is therefore possible. Furthermore, in the standard RPDG, decisions are made simultaneously by both players, thus lacking the sequential, reciprocal move structure of the Centipede game. Finally, the payoffs of the RPDG remain constant throughout the decision sequence and therefore cannot model the same variety of dynamic incentive structures as the Centipede game.

Despite these differences, research on the RPDG, which frequently used long and indefinitely repeated decision sequences (e.g., Rapoport & Chammah, 1965), could provide interesting information on the importance of game length and termination rules. A particularly useful study is Normann and Wallace's (2012) comparison of RPDGs with different termination rules. Whereas the authors did not find significant differences between their conditions, this fact could be attributed to a flawed design; the conditions were too similar (e.g., all games—even those with random termination rules—were programmed to continue for at least 22 iterations). Furthermore, the participants only played a single RPDG, preventing learning across games and increasing the possibility of reasoning mistakes.

4.1.2: Chapter aims

Against the background of flawed and very limited research regarding the influence of game length and termination rules on decision making in repeated interactions, there is an important need for investigation of these factors in the Centipede game. To gauge the impact of the game length, Study 3 in Section 4.2 contrasts decision making in 8-node and 20-node Centipede games. It further manipulates the player’s knowledge of the game’s natural end, comparing full knowledge of the game’s end with the uncertainty of an unknown end, and the risk of a randomly determined end. Study 4 presented in Section 4.3 follows up on the initial findings by improving specific features of the previous experimental design, and by further exploring the effects of different rules for random termination. Taken together, this chapter aims to provide a more comprehensive account of decision making in repeated interactions characterised by incomplete information, and to thereby model the uncertain and risky conditions of real-life choice contexts more closely. Overall findings are discussed and evaluated in Sections 4.4 and 4.5.

4.2: Study 3

This study provided an initial investigation of the effects of game length and termination rule on cooperation in the Centipede game. To this end, it borrowed aspects of Normann and Wallace’s (2012) research design which was developed to compare different types of RPDGs. The original experiment compared four treatment conditions with different termination rules. The first condition included a finite 22-move game with known end, and served as control. Introducing an element of uncertainty, the second condition informed participants about an interaction of at least 22 moves, while concealing the exact length of 28 moves. The last two treatment conditions consisted of games which continued at random (with 1/6 and 5/6 probability respectively) once the participants had completed the minimum number of 22 moves.

With a view to targeting the specific research gaps identified above, the previous design was adapted for the purpose of the present Centipede game study. In order to investigate the effects of game length, this experiment included two game conditions with known lengths. Condition 1 used a game of standard length (eight moves), while Condition 2 introduced a longer decision sequence of 20 moves. Condition 3 of this study employed a game of fixed but unknown length. However, rather than specifying a minimum number of decision nodes to participants as seen in Normann and Wallace (2012), very neutral game instructions were used in order to avoid confounding anchoring effects. Finally, only one condition of random termination was included in this experiment. Again, as opposed to the RPDG study, this experiment used games without a fixed minimum length. As in the original study, however, the games could continue indefinitely provided that the computer and both participants repeatedly chose GO.

4.2.1: Method

This method section outlines details of the study's participants (Section 4.2.1.1), the design (Section 4.2.1.2), materials (Section 4.2.1.3), and procedure (Section 4.2.1.4).

4.2.1.1: Participants

The sample consisted of 72 undergraduate psychology students from the University of Leicester—14 males and 58 females—with a mean age of 19.4 years (*SD* = 1.53). Participants could choose between receiving course credits (EPR) and a £4.00 show-up fee for participation. Additionally, all participants were entered into a lottery, and one person per testing session had his or her payoff from a randomly selected game converted to a cash payment in pounds sterling. The mean cash remuneration of the four participants selected was £15.25.

4.2.1.2: Design

The participants were randomly assigned to one of four treatment conditions varying in the lengths and termination rules of their respective games (see Figure 4.1): (a) Finite 8-node Centipede game; (b) Finite 20-node Centipede game; (c) Finite 20-node Centipede game with end unknown to participants; and (d) Indefinitely extended Centipede game with a random STOP probability of 1/6 after every move.

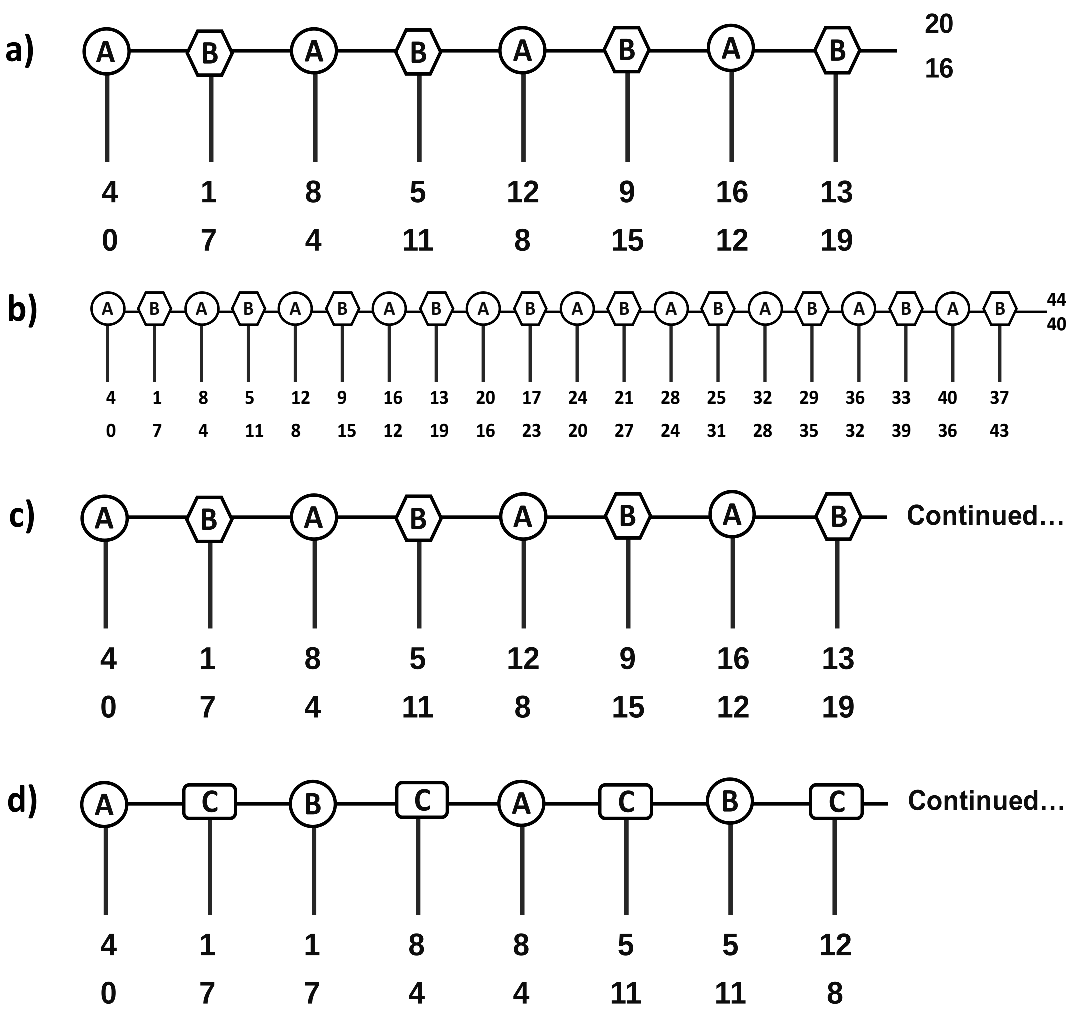


Figure 4.1. Four treatment conditions: (a) Finite 8-node game; (b) Finite 20-node game; (c) Finite 20-node game with end unknown to participants; (d) Indefinitely extended game with random termination of the computer "C" (probability = 1/6).

Three dependent variables were calculated; the proportion of games terminated at Node 1, the proportion of games terminated at the natural end, and the standardised mean exit points of all games completed. The last variable was derived by dividing the mean exit point by the game length (i.e., number of exit nodes). Calculating this standardised cooperation measure was necessary to enable the comparison of games with different lengths.

Each of the three variables provides a slightly different measure of cooperation, with the first indicating the proportion of games adhering to the subgame-perfect Nash equilibrium solution, the second giving an estimate of pure altruism, and the third measuring overall cooperation levels across all decision nodes. The last two variables could only be calculated for Conditions 1-3 because they used games of a finite length.

4.2.1.3: Materials

The study was conducted in a large computer laboratory. Each participant was seated at a computer and interacted in the Centipede game through a custom-made, web-based game application that included several detailed instruction slides and a colour-coded, animated display of the relevant Centipede game. Whereas for Conditions 1 and 2, the full game was displayed on the participant screens, the participants of Conditions 3 and 4 only saw game excerpts of 8 nodes at a time since their games involved unknown or random ends.

4.2.1.4: Procedure

Testing took place in four groups of 18 participants with each session lasting between 30 and 40 minutes. Two experimenters ensured that participants focused only on their own computer screens and did not talk or otherwise communicate with anybody else. After filling in the consent forms, participants received written task instructions on their computers which they could read in their own time. Afterwards, they had the opportunity to ask questions about the rules and procedure. Then, the computer assigned them to a player role (Player A or B), which they remained in for the whole duration of the testing session. The participants did not know the identity of their co-players and they were randomly re-paired after each game round completed. The web application provided them with real-time feedback on their co-players' moves, the outcome of each game, and the number of rounds completed. In the first three testing sessions (corresponding to Conditions 1-3), each participant completed 20 rounds of their respective Centipede games. The fourth testing session (Condition 4; indefinitely extended games with random termination), encountered problems with the computer software, resulting in some missing data after round 14 which increased over the last few rounds. The participants completed an average of 17.22 game rounds, with every participant finishing at least 14 rounds. Instead of the planned 180 games, data from only 155 games could be obtained in Condition 4, but this is still sufficient for the analyses. At the end of each testing session, one participant was randomly drawn from the group for remuneration on a randomly selected game played during the session. Furthermore, those participants incentivised with a show-up fee rather than course credit were paid £4 each.

4.2.2: Results

The proportion of games ending at each exit point for the four game conditions is displayed in Figure 4.2. For Condition 4 (indefinitely extended Centipede games with random termination), all even-numbered exit points mark games ended by the computer and are therefore highlighted. Notably, whereas Condition 1 (finite 8-node Centipede game) yielded a typical near bell-shaped distribution with a central peak at Exit points 4-6, the distributions of the other conditions were markedly different. Condition 2 (finite 20-node game) yielded a negatively skewed distribution, with its mode at the game's latest possible exit point of 21. The distribution of Condition 3 (finite 20-node game with unknown end) shared this mode of 21, but additionally featured a smaller peak of STOP moves at Exit points 6 and 7. Finally, the distribution of Condition 4 was positively skewed, with a modal exit point of only 3 (when ignoring the games terminated by the computer).

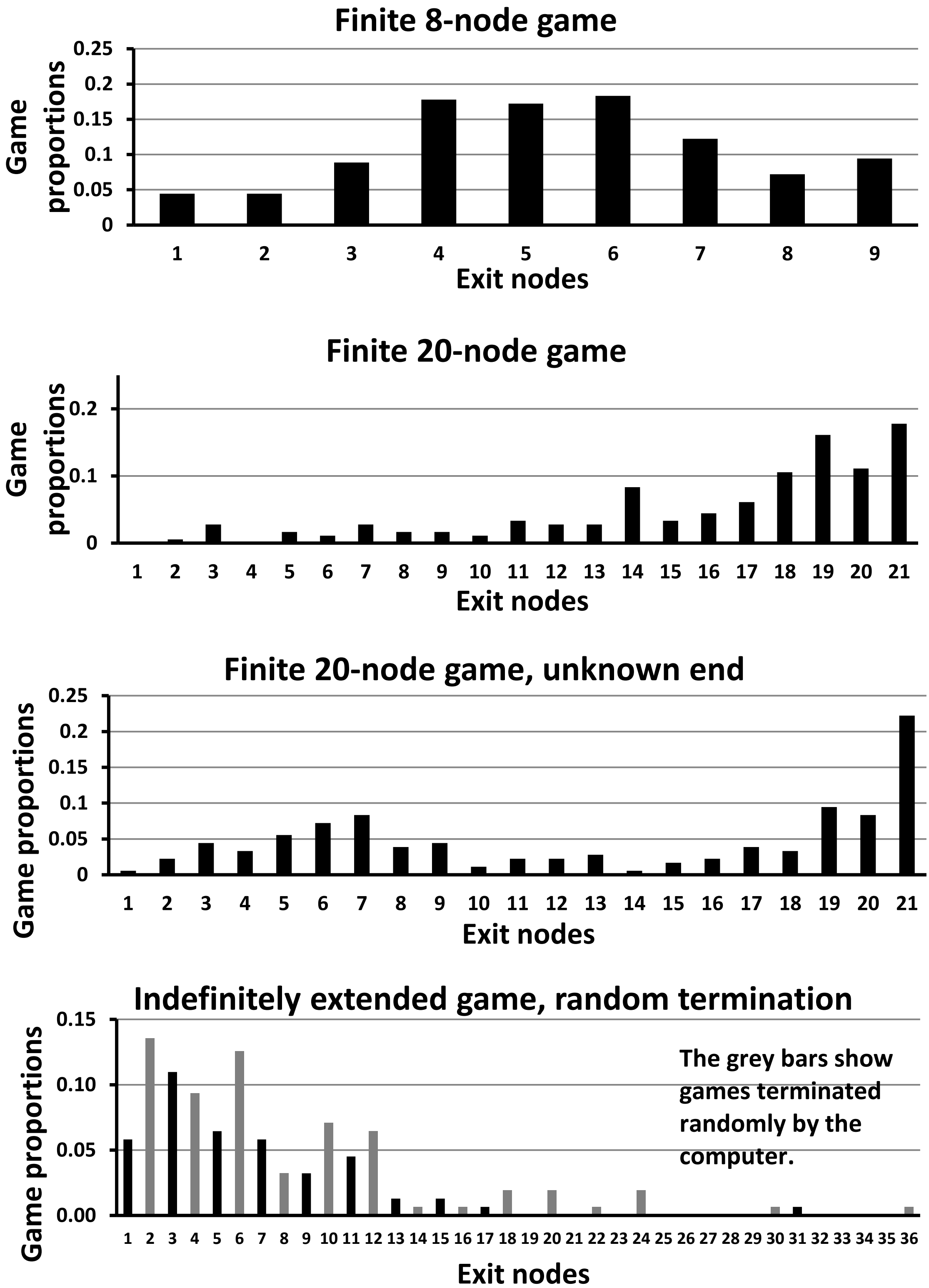


Figure 4.2. Game proportions across exit nodes for the four game conditions

Out of 695 Centipede games completed across all four conditions, only 18 (2.59%) were terminated at the subgame-perfect equilibrium. A one-way ANOVA compared the four treatment conditions and found a significant effect on the mean percentage of games per participant that stopped at the first node, $F(3, 71) = 11.070$, $p <$ .001, $\eta_p^2 = 0.33$, see Figure 4.3. Post-hoc comparison showed significant differences between Condition 4 (random termination) and all other treatment conditions (Tukey HSD tests yielded $p < .001$ for Conditions 2 and 3 and $p < 0.05$ for Condition 1). The indefinitely repeated game Centipede with random computer termination yielded the highest percentage of games in line with equilibrium play ($M = 5.78$; $SD = 5.20$), followed by the finite 8-node game ($M = 2.44$; $SD = 3.82$), the finite 20-node game with unknown end ($M = 0.56$; $SD = 1.62$), and lastly the finite 20-node game where only a single game stopped at the first node.

Out of 540 Centipede games with a finite number of exit nodes, 89 games (16.48%) ended at the natural end—Node 9 in case of the 8-node game and Node 21 in case of the two 20-node games. Another one-way ANOVA compared the three respective treatment conditions, and found a non-significant effect on the mean percentage of games per participant stopping at the natural end, $F(2, 53) = 2.316$, $p =$ .109, see Figure 4.3. The finite 20-node game with unknown end produced the highest percentage of games reaching the natural end ($M = 13.22$; $SD = 15.63$), followed by the finite 20-node game ($M = 6.78$; $SD = 11.40$), and the finite 8-node game ($M = 4.94$; SD = 8.16), but these differences failed to reach statistical significance.

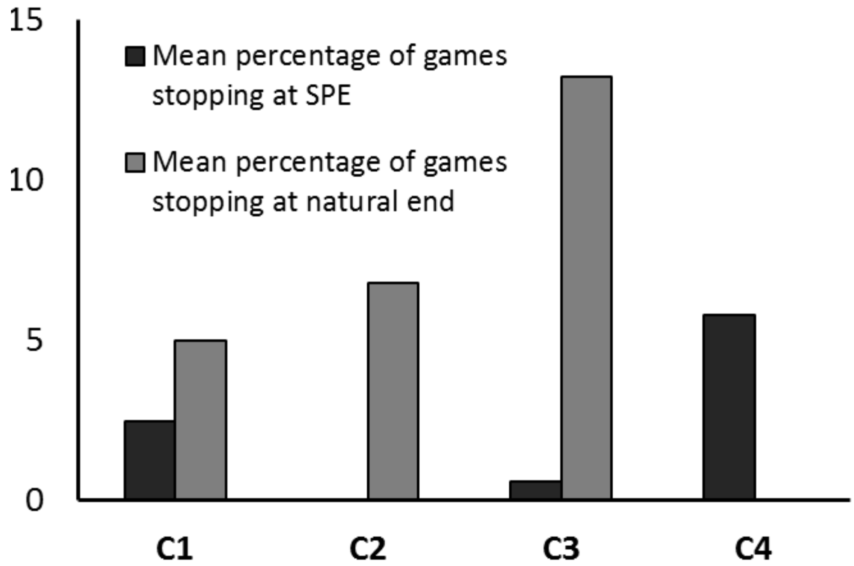


Figure 4.3. Mean percentages of games per participant stopping at the Subgame-perfect equilibrium (SPE) and at the natural end per condition (C1 = finite 8-node; C2 = finite 20-node; C3 = unknown, finite 20-node; C4 = random termination).

As regards the standardised mean exit points calculated for Conditions 1-3 (all characterised by finite games), a one-way ANOVA showed that the experimental manipulation had a significant effect, $F(2, 51) = 11.179$, $p < .001$, $\eta_p^2 = 0.30$, see also Figure 4.4. Post-hoc comparison indicated significant differences between Condition 2 (finite 20-node game) and both other treatment conditions (Tukey HSD tests yielded $p < .01$ in both cases). The finite 20-node Centipede game produced the highest overall cooperation levels (*M* = 0.77; *SD* = 0.05), followed by the finite 20-node game with unknown end (*M* = 0.64; *SD* = 0.14) and lastly the finite 8-node game (*M* = 0.6; *SD* = 0.06).

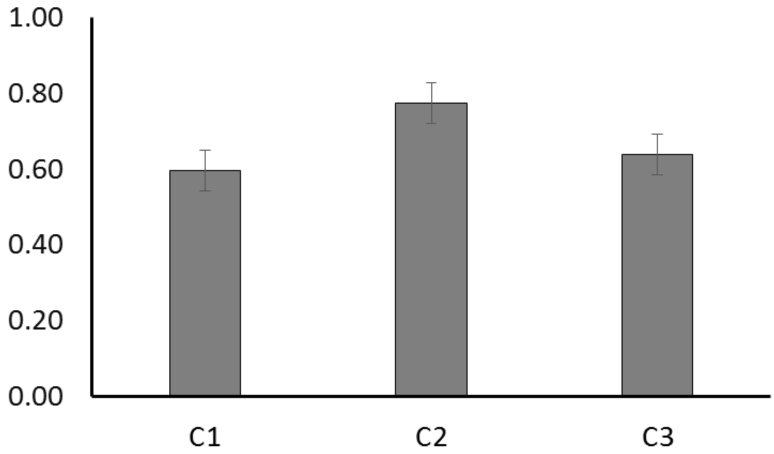


Figure 4.4. Means of standardised mean exit points per participants for all three treatment conditions using finite games (C1 = finite 8-node; C2 = finite 20-node; C3 = unknown, finite 20-node).

The standardised mean exit point per game round for Conditions 1-3 are displayed in Figure 4.4. The sequence plots for the two conditions with known game lengths do not show any discernible patterns of either increasing or decreasing scores with greater experience in the game. The times series of Condition 3 (finite 20-node game with unknown end), however, displays an overall increase of cooperation from an initial mean exit proportion of around 0.3 to a maximum of over 0.9 on the 19th game round.

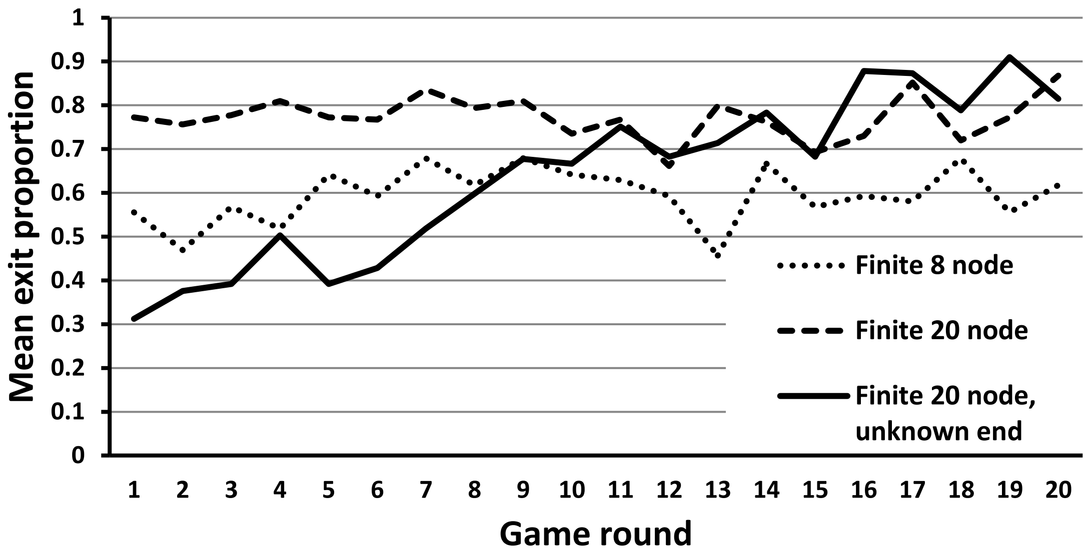


Figure 4.5. Mean exit proportions per game around across Conditions 1–3.

Time series analyses were carried out to further investigate these patterns across game rounds. The SPSS Expert Modeller identified an autoregressive integrated moving average (ARIMA) model with the parameters (0, 0, 0) for Conditions 1 and 2. These values of zero indicate that (a) the mean exit proportions were not influenced significantly by the means from previous rounds, (b) there was no significant overall (linear or non-linear) data trend, and that (c) the data did not include any random shocks impacting significantly on the mean exit proportions to follow. Put simply, no temporal pattern could be found for the scores of the two conditions with known game lengths.

For the 20-node game with unknown end, however, the SPSS Modeller identified a different model: The best fit was an exponential smoothing model with a Holt linear trend, indicating a linearly increasing score pattern. The stationary R^2 model fit statistic was calculated to estimate the model's goodness of fit. With an R^2 value of .27, the model can explain almost 30% of the variance of the data, and indicates a superior fit compared to a simple mean model used as a baseline for comparison. Additionally, the Ljung-Box statistic Q was calculated to test whether the model was correctly specified. The value of $Q(16) = 15.91$, ($p = .46$) showed that no significant patterns in the data set were unaccounted for by the Holt linear model identified.

4.2.3: Discussion

This study aimed to investigate whether game length and termination rule can influence decision making in the Centipede game. Cooperation levels were compared across four different treatment conditions including two conditions with finite game ends known to the participants (8-node and 20-node respectively), one finite 20-node condition with unknown game end, and an indefinitely extended condition with random game termination.

As in previous Centipede research, a very small percentage of games adhered to the subgame-perfect equilibrium and was terminated at Node 1. While all finite game conditions (Conditions 1-3) yielded mean percentages per participant of less than 2.5%, the indefinite games with random computer stopping produced a significantly larger percentage of almost 6% of games per participant stopping at the first node. It is likely that the additional risk associated with a possible STOP move by the computer led participants to act more cautiously and defect earlier in this condition.

As regards the percentage of games reaching the game's natural end—a measure of unconditional cooperation and altruism— the finite game conditions all produced moderate to high numbers (Condition 4 was excluded from the analysis due to its indefinite nature). With a mean of 13% of games per participant reaching the final exit point in Condition 3 (finite 20-node game, unknown end), this was a higher result compared to the 7% in Condition 2 (finite 20-node) or the 5% found in Condition 1 (finite 8-node game). However, the difference failed to reach statistical significance—a result that can be attributed to the high data variability between participants which increased the standard deviation values.

While the results therefore have to be treated with caution, it is still notable that Conditions 2 and 3 of identical game length produced very different mean percentages of cooperative moves at the natural end. It is likely that the full information game of Condition 2 with its highly salient natural end improved BI reasoning, thereby incurring end-game effects of increased defection towards the end. Condition 3 with incomplete information, on the other hand, lacked a salient end point because its natural end was concealed from participants, and thus impeded BI reasoning.

Finally, the standardised mean exit point was considered as a measure of average cooperation levels in each game condition. Again, Condition 4 was excluded from the analyses due to its indefinite nature. Statistical comparison indicated that Condition 2 (finite, 20-node game) produced significantly more cooperation compared to Condition 3 (finite 20-node game, unknown end) and Condition 1 (finite 8-node game).

It thus appears that increasing the length of finite games may lead to an overall increase of cooperation *if* the natural end of the game is known. The effect may be due to the increased number of alternating, cooperative moves in the longer game, which is likely to invoke a stronger norm of reciprocity between participants, thereby promoting cooperation.

The difference between the two 20-node games with known and unknown end, whereby unknown ends reduced overall cooperation, is interesting. A possible explanation could be the increased uncertainty present in Condition 3 with unknown game end. The participants had to consider not only their co-players' likely actions but also the possibility of sudden game termination due to the unforeseen natural game end. When examining Figure 4.2 which displayed exit proportions at each decision node of the four different conditions, the relatively high percentages of STOP moves at Nodes 5, 6, and 7 in Condition 3 is striking. It is possible that the experimental design was responsible for this spike in defection. In the condition with unknown end the total number of exit nodes could not be displayed in order to conceal the game length from the participants. Thus, the participants only saw excerpts of the game tree displaying eight decision nodes at a time. It seems likely that, with a view to managing the uncertainty of Condition 3, participants initially used the eight-node visual frame as an anchor for the expected game length. If they expected the game to end after eight moves, defection around Nodes 5, 6, and 7 would be in line with previous observations in shorter games. This explanation links in with the findings of increased cooperation over time in this treatment condition. It seems likely that the majority of participants started out with a conservative expectation of the game length, partly influenced by the display, which they re-adjusted based on their experience during the experiment. Once they learned that the natural end lay beyond Node 8, their caution decreased and cooperativeness increased as a consequence, thus leading to later exit moves in later rounds of the game.

Finally, even though Condition 4 was excluded from this statistical analysis, it is noteworthy that the exit moves in this indefinite game version with random stopping followed a very different pattern compared to the other three conditions. Even when disregarding the early STOP moves by the computer, it appears that games were terminated much earlier with participants' defection rates peaking at Node 3. This is an interesting finding and could be attributed to increased caution when faced with the additional risk through random game termination.

Taken together, the findings indicate that increasing the length of an interaction with a finite and known end can promote cooperation among decision makers. This is likely due to the increased opportunity for alternating cooperation and the norms of reciprocity invoked in longer games. Interestingly, introducing elements of uncertainty and risk in longer interactions seems to yield a decrease in cooperation. When the end is unknown, participants' decision making is guided by their own expectations about the game length (for example influenced by the framing of the decision context) and these may be adjusted over time in the light of increased experience with the decision task. When the end of the game is determined at random, it appears that participants adopt very cautious strategies and defect comparatively early including higher proportions of games adhering to the subgame-perfect equilibrium. The defection rates are likely to be influenced by the STOP probabilities of the computer, but further research needs to be conducted in order to investigate the effects of random termination rules in more detail.

4.2.3.1: Limitations

This experiment suffered from two limitations both pertaining to Treatment condition 4 with indefinite end and random computer termination. Firstly, the data set was smaller compared to the data sets yielded by the other three treatments due to unforeseen data loss during a software crash. Instead of 20 game rounds, participants of this condition only completed an average of 17.22 game rounds, with some participants only finishing 14 rounds. This problem was further aggravated due to the high number of STOP moves by the computer which ended many games prematurely and restricted the number of possible moves of the participants.

Furthermore, because of the game's indefinite nature in this condition, its data could not be included in the statistical analyses that required dependent variables calculated using a fixed game end (i.e., proportion of games terminated at the natural end and the standardised mean exit points of all games completed). To overcome these limitations and continue the research on the effects of random termination rules, a follow-up experiment (Study 4) was conducted which is reported in the second part of this chapter.

4.3: Study 4

Following on from Study 3 which investigated the effects of game length and different termination rules on cooperation in the Centipede game, Study 4 aimed to investigate games with random termination rules more closely. Random game termination was initially introduced to provide a methodological implementation of indefinite game repetitions and thereby offer an alternative to finitely repeated games (Roth & Murnigham, 1978). Unlike more traditional games with known, finite horizons (e.g. Selten & Stoecker, 1986), this termination rule involves players being aware at all times of the probability that a further game round will be played but not which particular round will be the last. Random game termination was claimed to avoid endgame effects (i.e., an increase of defection towards the game's end) and to allow for the study of infinitely extended games (Dal Bó & Fréchette, in press; Fréchette & Yuksel, 2016; Normann & Wallace, 2012). Random game termination rules may thereby increase real-life applicability of repeated games because human social interactions are rarely characterised by complete-information contexts with finite horizons (Dal Bó, 2005; Jiborn & Rabinowicz, 2013).

Most experimental research using random termination designs was conducted on the repeated Prisoner's Dilemma game. Roth and Murnighan's (1978) first investigation of random termination rules in repeated Prisoner's Dilemmas suggested that lower termination probabilities increased cooperation compared to higher probabilities. More recently, Dal Bó (2005) conducted a comprehensive experiment on repeated Prisoner's Dilemmas with three different random termination rules and expected lengths of one, two, and four game rounds respectively. Additionally, they compared these treatments to finite-horizon games with matching numbers of expected game rounds. The results confirmed the earlier findings of Roth and Murninghan, suggesting that increasing the likelihood of game continuation increased cooperation levels. Furthermore, the results showed that participants were likely to cooperate more in the infinite-horizon games compared to those of a finite length, even if matched for expected game length.

However, only few studies investigated random termination rules in games other than the repeated Prisoner's Dilemma game (e.g., Engle-Warnick & Slonim, 2004), and no empirical research has studied random termination rules in the Centipede game. Furthermore, no experiment has examined increasing or decreasing likelihoods of random termination. Normann and Wallace (2012), for example, compared two different, fixed STOP probabilities of the computer.

Consider again the neighbourly relationship of alternating childcare support which was presented as an example situation in the introduction of this chapter. Random termination of the relationship through external factors beyond the neighbours' control is possible and could follow several different functions. In its simplest form, the probability of the relationship being terminated by an external factor could take on a fixed value. For example, it is possible to imagine a lethal accident cutting the relationship short. Following each cooperative action by either neighbour, an accident could occur by chance, thus rendering either one of the neighbouring families unable to further engage in baby-sitting. The probability of such an accident would be fixed (e.g. 1/4) and its value would depend on the general riskiness of the neighbours' lifestyles.

In a slightly different variation of this scenario, one of the families could be living in a rented house from which the landlord could evict them at any time. The landlord may envisage the property as his own future retirement home or as the prospective house for his children. In this scenario, the landlord's choice would be the external factor potentially ending the neighbours' relationship prematurely. While the initial probability of the landlord evicting his tenants may be very low, the probability would increase over time.

Finally, consider this third variation of the baby-sitting scenario. The families may have moved to the neighbourhood at an early age and with uncertain job prospects. Like many young professionals, they may initially depend on short-term work contracts or insecure temping jobs with zero-hour contracts. Given the initial job insecurity, a long-term stay in the area may be questionable, yielding a high early likelihood of forced relocation. Thus, job insecurity could be another external factor terminating the cooperative interaction between the neighbours. Over time and with increasing work experience, however, job security and financial stability are likely to improve, thus leading to a decreasing probability of the relationship being terminated by environmental factors.

Drawing on the example situations outlined above, Study 4 investigated Centipede games with varying rules of random termination. A 24-node Centipede game with the same linearly increasing payoff function as in Study 3 was chosen for this experiment. So far, this is the longest Centipede decision sequence ever studied in the laboratory, and it is twice as long as Nagel and Tang's (1998) version (see Chapter 1).

To reduce problems of comparability of the treatment conditions, which were identified as a design limitation in Study 3, finite games only were used which allowed for the calculation of mean exit points. However, as Selten, Mitzkewitz, & Uhlich (1997) pointed out, infinitely repeated games are not feasible in practice. Experimental participants always know that the game will have a finite duration and that the time slot they signed up provides an effective upper bound. Consequently, no experimental game would ever be expected to be infinite.

Specifically, this study aimed to compare four Centipede games A: no random game termination, B: random termination with a constant termination probability, C: random termination with increasing probability, and D: random termination with decreasing probability. All these treatments shared the same maximum game length of 24 nodes but were designed to differ in their expected game lengths as based on the random termination probabilities. While Condition A without random termination had an expected game length of 24 nodes, all random termination treatments had lower expected lengths of approximately 4, 9, and 2 nodes respectively. Previous literature reviewed above (e.g., Dal Bó, 2005) showed that random termination games of shorter expected lengths produced lower cooperation in the repeated Prisoner's Dilemma game compared to games with longer expected lengths. Consequently, we hypothesised a similar decrease of cooperation in Centipede game treatments where the computer was statistically more likely to end the game earlier. More specifically, we used the order of expected game lengths presented above to arrive at our predictions of cooperation levels in the individual treatment games. Based on this order, Condition D with an expected length of just over 2 decision nodes was hypothesised to yield the lowest cooperation levels, followed by Condition B and Condition C. Dal Bó (2005) reported that games with fixed lengths decreased cooperation compared to games with random termination rules. However, their treatment games were matched for expected game lengths. Given that our fixed-length game presented in Condition A was characterised by a comparatively high expected length of 24 decision nodes, we hypothesised that this treatment would yield higher levels of cooperation compared to all random-termination treatments in the experiment.

To increase the quantity of data collected compared to Study 3, this experiment included two large testing sessions per treatment condition which were preceded by extensive software testing to prevent unexpected computer crashes and data loss during the experiment.

4.3.1: Method

This method section contains details of the study's participants (Section 4.3.1.1), the design (Section 4.3.1.2), materials (Section 4.3.1.3), and procedure (Section 4.3.1.4).

4.3.1.1: Participants

A total of 148 undergraduate psychology students from the University of Leicester—23 males and 125 females—with a mean age of 19.34 years (*SD* = 2.86) participated in the experiment. All participants received course credits for completing the study. Additionally, they were incentivised with a between-subjects random lottery system. One person per testing session received the payoff from a randomly selected game which the individual had completed during the session. The mean cash remuneration of the four participants selected was £14.36.

4.3.1.2: Design

All participants were randomly allocated to one of four treatment conditions with different Centipede games. Each game offered a maximum of 24 participant moves, and the combined payoffs of both players at each node increased linearly from 4 at Node 1 to 100 at the natural end. The four treatment conditions varied only as regards the probability δ of random game termination by the computer (see Figure 4.6), as follows. A: No random termination; B: A constant termination probability $\delta_B = \frac{1}{4}$ following each subject move; C: An increasing termination probability $\delta_C = 0, \frac{1}{44}, \frac{2}{44}, ..., \frac{21}{44}, \frac{22}{44};$ and D: A decreasing termination probability $\delta_D = \frac{22}{44}, \frac{21}{44}, ..., \frac{2}{44}, \frac{1}{44}, 0$. In Condition C, the probability of game termination by the computer steadily increased from 0 at the first node to $\frac{1}{2}$ at the last node. Hence, at the first node the computer never chose to terminate, and at the game's end (i.e., the computer's 24th decision node) it terminated the game in 50% of the cases. Conversely, in Condition D, the probability of game termination by the computer steadily decreased from $\frac{1}{2}$ at the first node to 0 at the last node. Hence, at the first node the computer chose to terminate in 50% of the cases, and at the game's end it never terminated. In both Conditions C and D, the mean value of δ is $\frac{1}{4}$. Based on the above probabilities, the expected termination points T by the computer were calculated to be as follows: Condition A, T_A = 24.00; Condition B, T_B = 4.00, Condition C, T_C = 8.99, Condition D, T_D = 2.13.

All games across the four treatment conditions shared the same natural end after Node 24, and the mean exit point was calculated as a measure for general cooperation levels. Importantly, for Conditions B, C, and D, all exit points resulting from computer termination were excluded from the analyses. This was done to prevent any confounding effects from the computer's exit moves whose frequency varied across treatments.

Additionally, the subjects' cooperation rates were normalised by dividing a player's number of GO moves by the total number of moves across all twenty game rounds. This measure provided a more accurate indication of individual cooperation levels. Furthermore, it took into account the fewer decision opportunities in the three treatments with random termination rules while also capturing the cooperative moves made in games which were prematurely terminated by the computer.

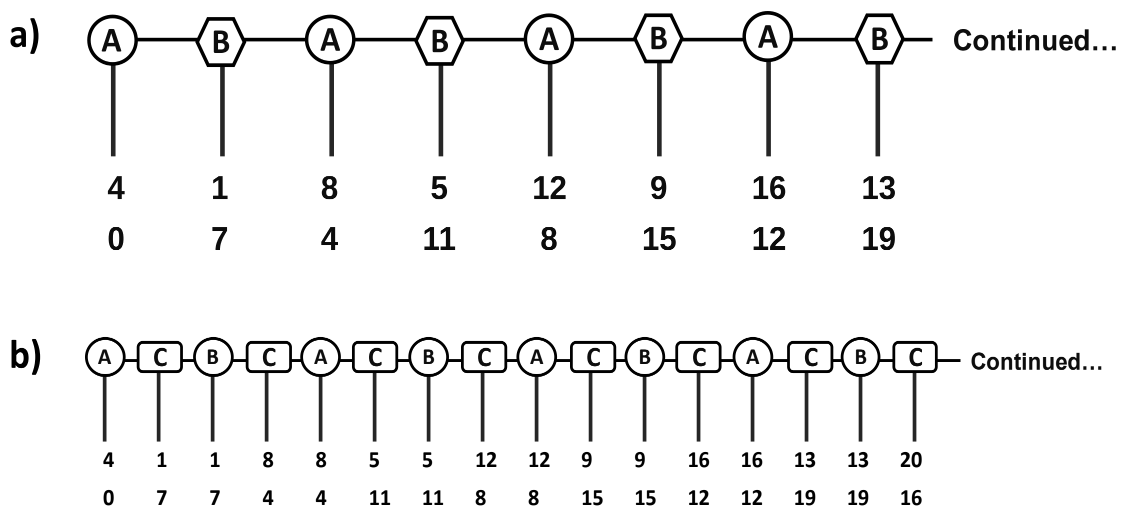


Figure 4.6. Games trees used in Study 4: (a) Game tree used for Condition 1: Finite 24-node game; (b) Game tree used for Conditions 2, 3, and 4: Finite games with random computer termination.

4.3.1.3: Materials

The testing sessions were carried out in a large computer laboratory. Each participant was seated at a computer desk, with all desks generously spaced out in the laboratory to avoid any communication between participants. For the anonymous game interaction, a similar custom-made web application was used as in Study 3. The participants were presented with the game tree of their respective treatment condition. They saw game excerpts of eight participant nodes at a time and the display shifted by eight nodes once the game continued beyond the eighth node. The display shifted again to the game's final eight decision nodes, if the participants reached the 16th node. Additionally, the experiment included a paper-based comprehension test to check for the understanding of the game's basic features as well as the different termination rules.

4.3.1.4: Procedure

For each of the four treatment conditions, two testing sessions were conducted, each of which contained between 16 and 22 participants and took approximately 50 minutes to complete. The participants were instructed to only focus on their own computer screens and not communicate with any other participants, and the same two experimenters checked that these rules were followed at all times. After completing the consent form, participants were presented with detailed instructions on their computer screens. They could work through the slides in their own time, and had the opportunity to ask questions at any time. Subsequently, they were asked to fill in a short comprehension test. The experimenters checked all responses and corrected any misunderstandings. Then, the actual experiment was started. The computer assigned all participants to a player role for the entire testing session. The participants ignored the identity of their co-players, and they were randomly re-paired after each game that was played. As in the previous study, the web application provided them with real-time feedback on their co-players' moves. Each participant completed 20 rounds of their Centipede games. Then, one participant was randomly drawn for the lottery win.

4.3.2: Results

The proportion of games ending at each exit node for the different treatments are shown in Figures 4.7 and 4.8. For the graph in Figure 4.8, the games terminated by the computer were excluded to achieve easier comparability between treatments.

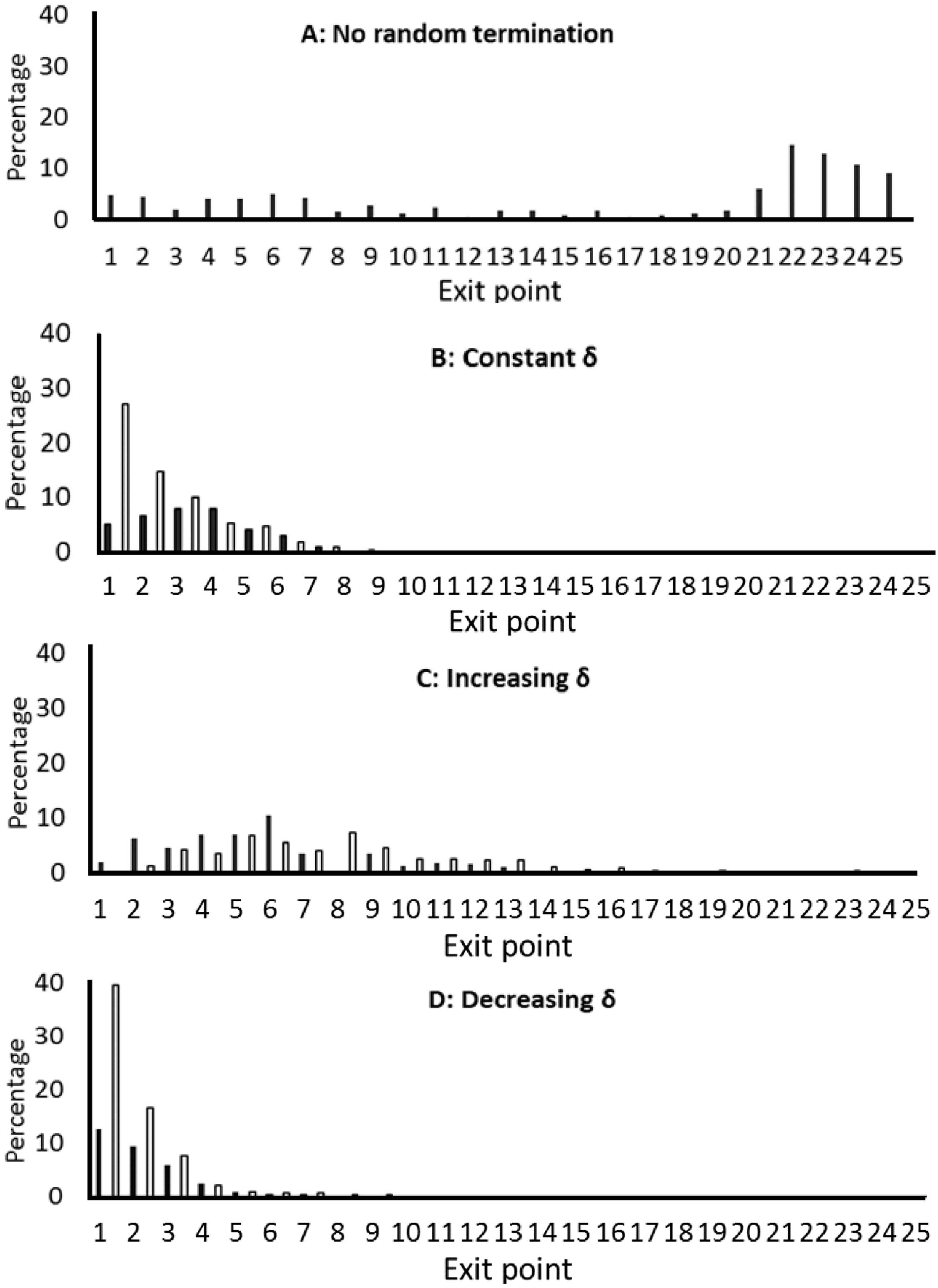


Figure 4.7. Mean exit points for the four treatment conditions including games terminated by the computer (computer moves are shown in grey).

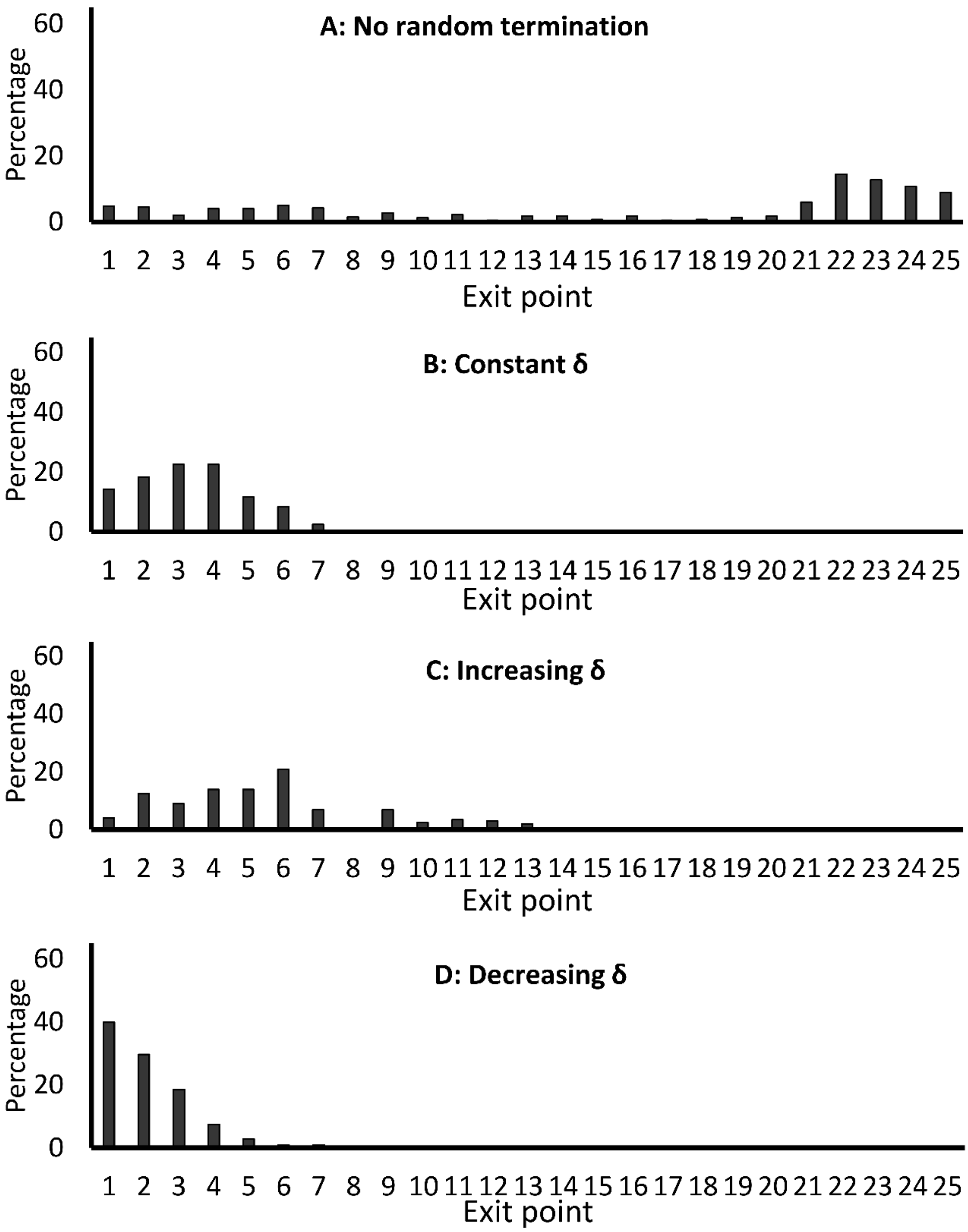


Figure 4.8. Mean exit points for the four treatment conditions excluding games terminated by the computer.

As can be seen in Figure 4.7, a large proportion of games in the treatment conditions with random computer stopping were terminated by the computer. In Condition B (constant δ) this proportion amounted to 0.65, in Condition C (increasing δ) it was 0.49, and in Condition D (decreasing δ) it was 0.68. Hence, in Condition C more than half of the games were terminated by the subjects, whereas in the other two treatment conditions with random termination only around a third of the games were ended by either subject.

Taking a closer look at Figure 4.8, excluding those games terminated by the computer, the distributions of subjects' exit moves show marked differences across treatment conditions. While in Condition A (no random termination) more than 50% of the games were stopped after the 20th exit point, not a single game in the other treatment conditions was stopped after the 20th exit point. In Condition B (constant δ), games stopped by subjects followed a near normal distribution, with most game exits occurring at the third or fourth decision node and no game continuing beyond the eighth decision node. In Condition C (increasing δ), the pattern also resembled a bell-shaped distribution but the dispersion was larger. Most subjects exited this treatment condition at Node 6, but some games continued for longer, with 19 being the highest exit point. Finally, the exit distribution of Condition D (decreasing δ), showed an almost linear decrease across exit points. The vast majority of games (40%) exited by subjects stopped at Node 1, 30% stopped at Node 2, 20% stopped at Node 3, and the final 10% stopped at Nodes 4, 5, 6 and 7.

Comparing the mean exit points of the games exited by subjects, a one-way ANOVA showed that the experimental manipulation had a significant effect, $F(3, 144) = 182.495$, $p < .001$, $\eta_p^2 = 0.792$, see also Table 4.1. Condition A without random computer termination produced the highest mean exit points, followed by Condition C with increasing probability, Condition B with constant probability, and lastly Condition D with decreasing probability. Post-hoc comparison using Tukey HSD tests indicated significant differences ($p < .01$) between all four treatment conditions apart from Condition B (constant δ) and Condition D (decreasing δ), which did not differ significantly from each other.

Table 4.1

Expected Game Length and Cooperation Rate

Treatment	No Termination	Constant δ	Increasing δ	Decreasing δ
Expected game length *T*	24.00	4.00	8.99	2.13
Exit points, *M* (*SD*)	15.84 (5.14)	3.34 (0.68)	5.79 (1.59)	2.24 (0.67)
Cooperation rate, *M* (*SD*)	.92 (.10)	.86 (.10)	.92 (.06)	.80 (.22)

A second one-way ANOVA was conducted to compare the normalized cooperation rates (i.e., the proportion of GO moves per total moves) per subject across the different treatments. Again, significant differences found, $F(3, 144) = 7.155$, $p < .001$, $\eta_p^2 = 0.13$, see also Table 2. Condition C with increasing probability and Condition A without random termination both produced the highest, almost identical, cooperation rates. These were followed by Condition B with constant probability, and Condition D with decreasing probability. Post-hoc comparison showed significant differences between Condition D (decreasing δ), and Conditions A (no random termination) and C (increasing δ), (Tukey HSD tests yielded $p < .01$ in both cases).

The mean exit points per game round for all four conditions are displayed in Figure 4.9. Only the graph of Condition A (no random termination) shows a discernible temporal trend, indicating an increase of cooperation over rounds. Specifically, the mean exit points increased from a value of 8.5 in Round 1 to a value of just under 20 in Round 20. Time series analyses confirmed the visible learning pattern in Condition A. The SPSS Modeller identified an exponential smoothing model with a Holt linear trend, indicating a linearly increasing score pattern. The stationary R^2 model fit statistic was calculated to estimate the model's goodness of fit. With an R^2 value of .66, the model can explain almost 70% of the variance of the data, and indicates a superior fit compared to a simple mean model used as a baseline for comparison. Additionally, the Ljung-Box statistic Q was calculated to test whether the model was correctly specified. The value of $Q(16) = 15.89$, ($p = .46$) showed that no significant temporal structure in the data set was unaccounted for by the Holt linear model identified.

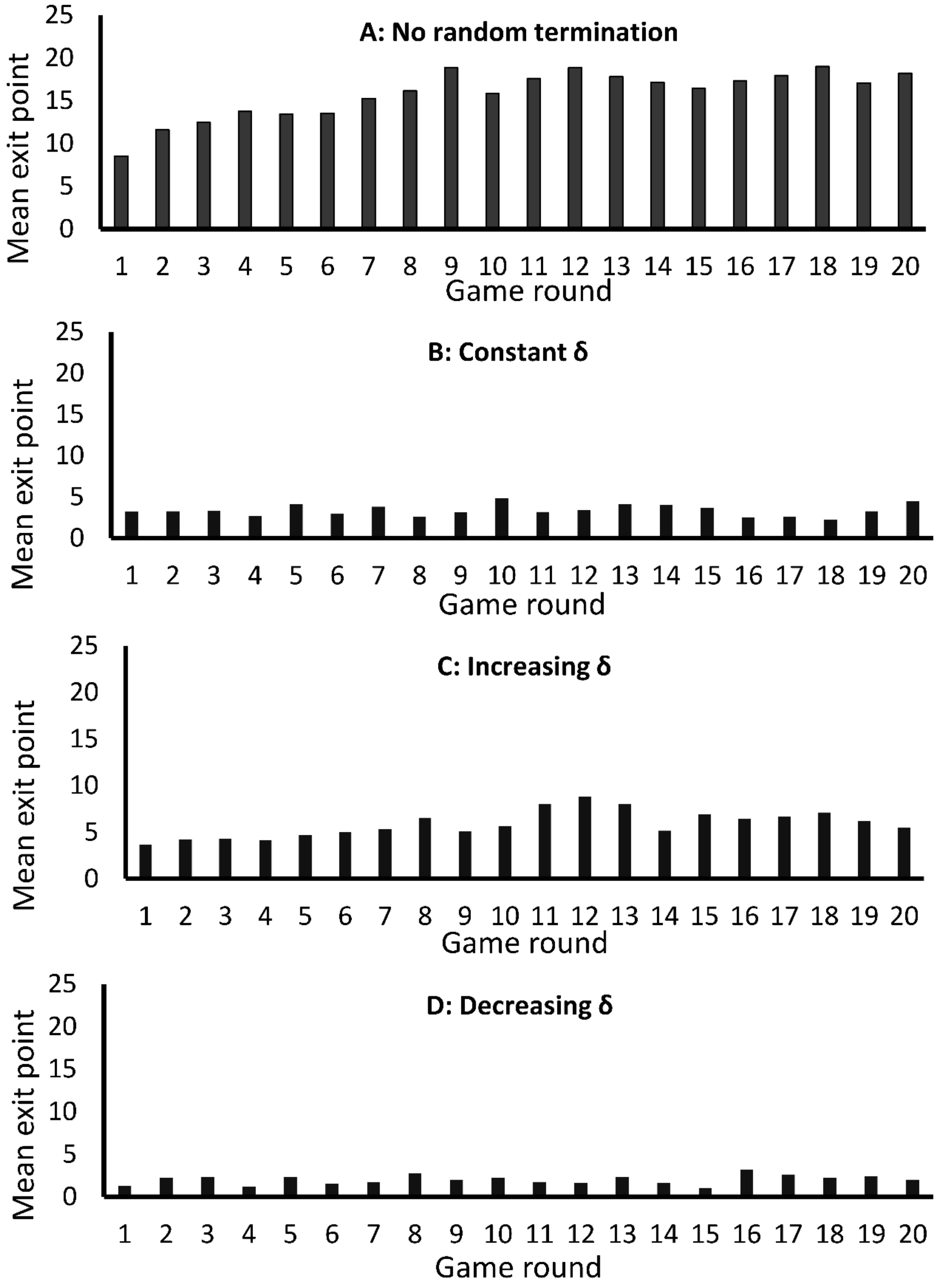


Figure 4.9. Mean exit points per game round for the four treatment conditions.

4.3.3: Discussion

This experiment aimed to follow up on Study 3 by conducting a more comprehensive investigation of random termination rules in the Centipede game. Particularly, it was tested if different rules of random stopping by the computer (fixed, increasing and decreasing STOP probability) affected the cooperation levels of human participants. All treatment conditions with random computer termination were controlled for average termination probability across the 24 decision nodes (the mean probability was $\frac{1}{4}$ for each treatment). However, the treatments varied regarding their expected termination points, ranging from T_D = 2.13 to T_C = 8.99. The present study improved limitations of the previous design employed in Study 3 by investigating larger samples and using finite games which allowed for simpler comparison between treatment conditions.

Overall, the results showed large differences between the four treatment conditions with participants' mean exit points varying significantly across treatments. Condition A (no random termination) yielded significantly higher mean exit points than Condition C (increasing δ), and both of these treatments yielded significantly higher means than Conditions B (constant δ) and D (decreasing δ). Matching the participants' mean exit points with the respective games' expected game lengths (as based on the random termination rules), the values of mean exit points follow the same order as the values of the expected game length. More specifically, games with a higher expected game length were stopped later than those with a lower expected game length. This finding is in line with our hypotheses, and it supports previous experimental results (e.g., Dal Bó, 2005; Roth & Murnighan, 1978)

Interestingly, however, the decrease of the mean exit points was less severe than what could have been expected from the drastic decrease of expected game length across treatments. For example, while Condition A's expected game length of 24 nodes was 12 times higher than the expected game length of Condition D (2 nodes), the mean exit point of participants in Condition A was only 7.07 times higher than in Condition D. This indicates that the participants' cooperativeness did not increase proportionately with the games' expected length.

Indeed, the comparison of participants' cooperation rates across treatment conditions confirmed this finding. Cooperation rates were surprisingly high across all treatments with 98% of participants choosing GO more than half of the time, and more than 10% of participants always choosing GO. Significant differences in cooperation rates between treatments became apparent, but these differences did not follow the data patterns previously identified when using mean exit points as dependent variable in the analyses. Condition A (no random termination) and Condition C (increasing δ) yielded comparable mean cooperation rates of approximately .92. Condition B (constant δ) produced a mean rate of approximately .86, and Condition D (decreasing δ) generated the lowest cooperation rates (.80). However, due to comparatively high variances within groups, the only significant differences were found between Condition D and Conditions A and C, indicating that only Condition D with the lowest expected game length $T_D = 2.13$ resulted in a significant decrease of participants' cooperativeness compared to the control condition without random termination. An explanation for the large variances within groups could be the importance of individual differences influencing cooperation rates. While the treatment condition had an impact on behaviour, other-regarding preferences (e.g. cooperative social value orientations) may have accounted for some of the data variance (e.g. Pulford, Krockow, Colman, & Lawrence, 2016). Additionally, numeracy skills could have had an impact on decision making. The disproportionally large number of cooperative choices in treatments with shorter expected game lengths could be explained by the participants' inability to successfully predict likely exit points from the computer's termination probabilities. In future investigations, any confounding effects of numeracy and mathematical ability could be avoided by informing participants about the expected game length of their treatment before the start of each experiment. Another possibility would be to control treatment conditions for expected game length (rather than mean termination probability), while presenting participants with different termination rules.

From an examination of trends, it appears that learning occurred only in the treatment condition without random computer termination. In the standard 24-node game, cooperation increased linearly with increasing experience in the game, reaching a very high mean exit point of almost 20 in the final game rounds. Hence, learning occurred in the opposite direction of equilibrium play. This is an interesting finding, as the majority of experimental Centipede game investigations reported decreases in cooperation over time (McKelvey & Palfrey, 1992; Rapoport, Stein, Parco, & Nicholas, 2003). Our learning effects could be explained by the linear payoff function and comparatively low risk associated with each GO move in Condition A of the present study. Another reason may be the greater game length, which offers more opportunities for reciprocal cooperation (see Study 3 of this thesis).

Taken together, the findings suggest that when linear Centipede games are combined with different rules of random game termination through the computer, the participants' mean exit points typically decrease. However, participants' cooperativeness as assessed by the more accurate measure of cooperation rates may be affected only in treatments with very extreme conditions such as very low expected game lengths. In this experiment, only Condition D with decreasing termination probability and an expected game length of approximately two decision nodes led to a significant decrease in cooperativeness compared to the control condition. Future research should investigate the effects that individual differences may have on cooperation levels in Centipede games and repeated Prisoner's Dilemmas with random termination rules. Interesting variables to investigate could be social value orientation and general numeracy skills.

4.4: General Discussion

Chapter 4 aimed to increase the Centipede game's applicability to real-life decision contexts by investigating games of varying lengths and with different termination rules. These design changes were made to acknowledge the fact that many human relationships have a long horizon with an end, which may be unknown to the decision makers or randomly determined by external factors beyond the decision makers' control.

Study 3 compared four treatment conditions including a (a) standard 8-node Centipede game, (b) 20-node game, (c) 20-node game with unknown game end, and (d) indefinitely extended Centipede game with random computer termination (1/6 probability). The findings showed that longer games elicited higher cooperation levels than shorter games but only if the game end is known to the participants. A possible explanation of this finding is the increased opportunity for alternating cooperation and the norms of reciprocity invoked in longer games. Overall, the introduction of uncertainty and risk in longer sequences appeared to reduce cooperation. However, while the participants in the condition with unknown game end were initially very uncooperative, their cooperation levels increased significantly over time once they developed a more accurate idea of the game length. In the condition with random game termination, participants seemed to adopt very cautious strategies, defecting very early in the game. However, no final conclusions about this treatment condition were possible because of limited amount of data and a lack of comparability of games across testing sessions.

Study 4 extended the first experiment of this chapter and conducted a careful comparison of treatment conditions with different termination rules. The four treatments included a (a) 24-node standard Centipede game, (b) 24-node game with fixed STOP probability of 1/4 after each participant move, (c) 24-node game with increasing STOP probability after each participant move, and (d) 24-node game with decreasing STOP probability after each participant move.

While all the rules of random stopping significantly decreased the mean exit points compared to the control condition, a novel cooperation measure—the percentage of STOP moves per participant—indicated that cooperativeness only decreased in the most extreme condition of random stopping which was characterised by an initial STOP probability of 1/2. Variation in cooperativeness within groups was high which points to the important influence of individual difference variables in addition to the experimental manipulation. Learning effects were found in the condition without random stopping with cooperation increasing over time. This finding is in slight contrast with the results of the previous experiment where no learning was evident in the game condition of high game length and known end. It is possible that this difference is due to random variations in participant samples, with certain individuals being more perceptive to feedback than others.

4.5: Conclusions

Overall, this chapter made an important contribution to the research on Centipede games by offering more life-like models of decision situations and by proposing a novel measure of cooperation—the percentage of STOP moves—to adequately analyse more complex Centipede data. It appears that decision sequences with far but finite horizons may elicit higher cooperation levels than sequences with shorter horizons or those characterised by an unknown or random game end. While the possibility of external game termination significantly decreases the mean exit points of participants, cooperativeness as measured by the percentages of STOP moves may only be reduced in extreme cases with very high STOP probability. Some learning patterns may occur, usually leading to an increase in cooperation across game rounds, but these patterns may depend on individual differences of the randomly sampled participants.

Chapter 5: Cross-cultural Comparison of Cooperation in the Centipede Game

The previous two chapters chiefly focused on specific task variables (i.e., the payoff function and the number of game repetitions) and their respective influences on cooperative behaviour in the Centipede game. In contrast, Chapter 5 aims to examine the importance of individual differences in trust, risk-taking, SVO as well as the mediating role of national culture. Two experiments comparing British/European and Japanese participants in the Centipede game are reported. Section 5.1 provides a general introduction to the chapter. Section 5.2 describes the first experiment (Study 5) which tested the use of commitment-enhancing tools in Japan and the UK. Section 5.3 reports the findings from the second experiment (Study 6) which used games with incomplete payoff information while maintaining the cross-cultural design component. A general discussion and conclusions are provided in Sections 5.4 and 5.5.

5.1: Background

In the face of rapid globalisation, international collaboration is key for ensuring economic growth and progress. Consider, for example, two international business firms that take turns in sharing expertise in order to design a new product. Cooperation in the form of investing personnel and resources is always costly in the short term and potentially risky if the other firm does not reciprocate. However, mutual and repeated cooperation could lead both firms to launch the new product successfully and flourish in the long run. Business collaborations of this type are frequent and often take place across continents. Examples are partnerships between the US computer and Japanese automobile industry as well as UK–Japanese collaborations in the robotics sector.

In these global examples of repeated, reciprocal interactions, cultural differences may play an important role that could affect cooperation and, ultimately, the success of international collaborations. Japanese society, for example, is historically characterised by close-knit communities with strong interpersonal bonds relying on assurance-based trust, examples of which include highly committed, loyal interactions within business groups (so-called *keiretsu*) and typically life-long employment with the same company. Western entrepreneurship, on the other hand, has been found to place a stronger emphasis on innovation, for example through staff turnover (e.g., Tiessen, 1994). These different understandings of business management alongside intercultural variations in prosociality, risk-taking, and trust may be important factors determining the success of international business relationships.

Again, the Centipede game can be used as a tool to study the cooperative turn-taking described above in a controlled laboratory environment. However, so far, no cross-cultural research has been published on this game. In the context of global business partnerships, of particular interest for comparison are industrialised nations with distinctly different religious and cultural backgrounds including, for example, the United Kingdom contrasted with Japan (Hofstede, 2001b).

5.1.1: Cross-cultural differences between Japan and the UK

A concept that has received much theoretical and empirical attention in the context of economic growth and development is the cultural dimension of *individualism* versus *collectivism* (e.g., Hofstede, 2001a; Hofstede, Hofstede & Minkov, 2010; Triandis, 1995). It refers to the respective focus on either the individual or the collective within society. Japan was found to score comparatively low on individualism (although not as low as neighbouring Asian countries such as China or Vietnam), pointing to a relatively small cultural emphasis on personal independence (Hofstede, 2010). According to Hofstede's survey data, the UK, on the other hand, was characterised by one of the highest individualism scores in the world (exceeded only by other Anglo countries such as the US and Australia), thus indicating strong values of individual autonomy. However, Hofstede's (2010) original research on the topic, which was conducted from the 1960s onwards and only used highly educated participants (all skilled employees of the international company IBM), has been challenged on a number of grounds, including the representativeness of national samples (e.g., Schwarz, 1994; Voronov & Singer, 2002) and the use of self-report measures with individualist or collectivist cultural values having been claimed to lack the necessary explicitness for self-report (e.g., Oyserman, Coon, & Kemmelmeyer, 2002). Additionally, Voronov and Singer (2002) questioned the dimension's theoretical validity, and in particular its assumed bipolarity, with individualism and collectivism being presented as two mutually exclusive cultural values at opposite ends of a spectrum. Ho (1993), for example, argued that collectivism (in Asian countries) places a larger emphasis on personal relationships than the welfare of an entire social group, and therefore does not necessarily oppose individualism. Additionally, country-specific research has demonstrated inconsistencies in Japanese individualism scores, with trends toward higher scores over time (Matsumoto, 1999; Takano & Osaka, 1999). Indeed, Yamagishi (1988a; 1988b) questioned the concept's usefulness in the context of Japanese culture. Yamagishi employed public goods games with opportunities for sanctioning to explore collectivism in Japanese and American people, and found that behavioural differences in cooperation were not based on different values but could instead be explained by societal structures (e.g., the existence of strict rules and opportunities for punishment that deter defection in Japanese society). In an evaluative review, Voronov and Singer (2002, p. 474) concluded: "Clearly, individualism and collectivism do not exist within people's minds but, rather, manifest themselves in people's behaviour, which is determined by the social context."

Consequently, it has been suggested that the Japanese type of rule-enforced collectivism is better conceptualised as *assurance* or *assurance-based trust*, serving the individual's personal gains in the long run (Voronov & Singer, 2002; Yamagishi, 1988a; 1988b; Yamagishi & Yamagishi, 1994). Yamagishi and Yamagishi attributed assurance-based trust to stable, committed relationships with higher prevalence in Eastern—particularly Japanese—culture. This type of trust was contrasted with the spontaneous, *general trust* exhibited toward strangers, which was stated to have higher prevalence in Western cultures. According to this distinction, assurance-based trust does not necessitate a belief in the benevolence of the other person but is based on the "knowledge of the incentive structure surrounding the relationship" (Yamagishi & Yamagishi, p.132).

This theory of trust has been supported by a number of empirical studies. In Hayashi et al.'s (1999) cross-cultural experiment on Prisoner's Dilemma games, cooperation of Japanese participants was significantly improved by introducing a sense of control. Using sequential versions of the original game, where the two players decided one after the other whether to cooperate or to defect, they compared the choices of Player 1 and Player 2 in Japan and the US, either with or without perfect information about both players' moves. In contrast with the American sample, Japanese participants in the role of Player 1 cooperated significantly more often under conditions of perfect information than in the other treatment conditions. This was attributed to a sense of control experienced by the first decision makers, who expected their own choices to influence co-players' subsequent actions, with a cooperative move anticipated to elicit reciprocity.

Similarly, Kiyonari, Yamagishi, Cook, and Cheshire (2006) conducted a US–Japanese comparison of decision making in Trust games. After two players received the same initial endowment, Player 1 had to decide whether to play safe by keeping the endowment or to trust the co-player by handing over the endowment, which would subsequently be doubled by the experimenter. Upon receipt of Player 1's doubled endowment, Player 2 then had the choice between either reciprocal cooperation, by returning a share of the doubled endowment to Player 1, or defection, in which case Player 2 kept the full amount. In the American sample, more trust was exhibited by Players 1 and less reciprocity was shown by Players 2 than in the Japanese sample, suggesting that general trust was higher but trustworthiness and reciprocity were lower than in Japan. Extending this study's findings, Kuwabara et al. (2007) found higher levels of general trust exhibited by US than Japanese players in a variation of the Trust game played with strangers. However, the Japanese sample showed increased trust when each participant was repeatedly paired with the same co-player.

Taken together, the above findings demonstrated that Japanese participants, in contrast with US participants, cooperate more frequently in decision situations (a) when they have an increased sense of control; (b) when their decision is preceded by a cooperative move of the co-player; and (c) when they find themselves re-matched with a previous, and thus familiar, co-player. This lends support to Yamagishi and Yamagishi's (1994) trust theory, according to which assurance-based trust—necessary for stable relationships—is more prevalent in Japan than in Western nations. It also appears that Yamagishi and Yamagishi's understanding of assurance-based trust as an ecological or structural guarantee of cooperation permeates all Japanese relationships with a relevant interpersonal history of bilateral, reciprocal cooperation, even in the absence of formalised incentives for cooperation or deterrents of defection.

Finally, the proposed differentiation in trust shows interesting parallels with self-construal theory (Markus & Kitayama, 1991; Voyer & Franks, 2014). This theory states different types of self-concepts: People with more independent self-concepts place a stronger emphasis on their personal characteristics, while people with more interdependent self-concepts define themselves more frequently in terms of successful relationships. Self-construal theory has been widely used in applied social and cognitive psychology (e.g. Howard, Gardner, & Thompson, 2007; Mandel, 2003). Furthermore, research suggested that Asian cultures have tendencies to generate more interdependent self-concepts (e.g., Christopher & Skillman, 2009), which would foster assurance-based trust as claimed by Yamagishi and Yamagishi.

5.1.2: Chapter aims

Although many studies (e.g., Berigan & Irwin, 2011; Cox, Lobel, & McLeod, 1991; Wong & Hong, 2005) have investigated the relationship between culture and cooperation, no previous studies comparing British and Japanese decision making in dynamic relationships have been published. The two studies reported in this chapter follow up on the findings from US–Japanese cross-cultural studies on short sequential games. One aim is to extend the research by using longer game interactions—Centipede games—allowing for investigation of longer-term reciprocal relationships. Centipede games may, in fact, be highly relevant to Japanese society, as they arguably provide much closer models of the tight family and business bonds upon which Yamagishi and Yamagishi (1994) based the Japanese concept of trust. Indeed, when looking at the above factors (a) to (c) that were found to elicit Japanese assurance-based trust in previous experiments—sense of control, opportunity for reciprocity, and repeated interaction with the same other player—the Centipede game appears to be a decision context that combines them all. Arguably, an initial amount of general trust comes into play when first entering the Centipede-type interaction with a complete stranger. However, as reviewed in Chapter 1, previous research found hardly any participants who ended the interaction at the first decision node (McKelvey & Palfrey, 1992), and the qualitative research presented in Chapter 2 suggested that early activity bias, curiosity, and a wish to probe the co-player were at least partly responsible for the low termination rates at Node 1 (see also Krockow, Pulford, & Colman, 2016b). Although the relationships between players were not manipulated in either of the two experiments presented in this chapter, initial concerns of general trust seem to be overruled by different motives, and the more predictive type of trust for decision making in Centipede games is likely to be the assurance-based trust of stable partnerships. Given that this type of trust was suggested to be typical of Japanese society, it was hypothesised that, while both European and Japanese samples would deviate from the Centipede game's subgame-perfect Nash equilibrium recurrently and thus rarely terminate at Node 1, the Japanese participants would cooperate significantly more and exit significantly later in the game than the European samples. Whereas this general hypothesis applied to both experiments presented in this chapter, each individual study added specific research questions, with Study 5 examining the use of commitment-enhancing tools and Study 6 investigating decision making in the face of incomplete information.

5.2: Study 5

The first cross-cultural experiment compared cooperation in Centipede games between European and Japanese participants, while offering commitment-enhancing tools for additional insurance in the game.

Rather than merely comparing game choices of Japanese and European participants in the Centipede game, this experiment further manipulated social certainty in the game and tested for cultural preferences regarding relationship commitment. This was achieved by employing a research paradigm originally developed by Gerber and Wichardt (2011) in order to investigate BI reasoning in the Centipede game. Their experiment compared decision making across three game conditions including a standard Centipede game and two conditions with optional tools to improve players' commitment and payoff certainty in the game. The *bonus tool* in Condition 2 involved offering the co-player an incentive, at a personal cost *b*, for not ending the game. This incentive was deducted from the payoff of any player who used the tool and added to the co-player's payoff if, and only if, the player with the tool chose a STOP move. In contrast, the *insurance tool* available in Condition 3 required an initial monetary sacrifice at cost *c* that was deducted from all payoffs to a player who used this tool in the game. This cost, however, was reimbursed if the co-player chose to STOP at any point in the game. Both tools were designed to change the subgame-perfect Nash equilibrium, removing the theoretical grounds for stopping the game at Node 1. Even though both instruments were—in theory—equally effective, the bonus tool required lower levels of iterated reasoning for participants to understand its benefits. In line with the authors' predictions, the participants chose the comparatively simpler bonus tool more frequently than the insurance tool, but the use of either tool resulted in significantly later game exits and therefore higher cooperation levels. The authors interpreted the findings as evidence for limited reasoning skills in the majority of participants, and as an explanation for the frequent deviations from the Centipede game's Nash equilibrium.

However, whereas usage of the tools designed by Gerber and Wichardt (2011) could indeed indicate BI reasoning skills, other-regarding preferences—for example considerations of commitment and social certainty—may also play a role. The purchase of either tool requires an initial commitment, as it involves voluntarily reducing the personal payoffs at certain decision nodes in the game. Consequently, the present study employed Gerber and Wichardt's research paradigm to study cross-cultural differences in commitment and dealing with uncertainty.

In addition to the standard Centipede game, which was administered as a control condition, this study included a bonus condition and an insurance condition, where tools could be purchased by the players at the beginning of each game that they played. Figures 5.1 and 5.2 show a standard Centipede game, and illustrate the effects on payoff functions of typical combinations of tool use (i.e., in the event that only Player A opts for the bonus or the insurance respectively). For each figure, the top part shows the original Centipede game without tool purchase. The game tree in the centre shows the payoffs when only Player A decides to purchase the tool. Finally, the bottom part of the figure displays the new payoff function for the respective game after applying the changes caused by tool purchase.

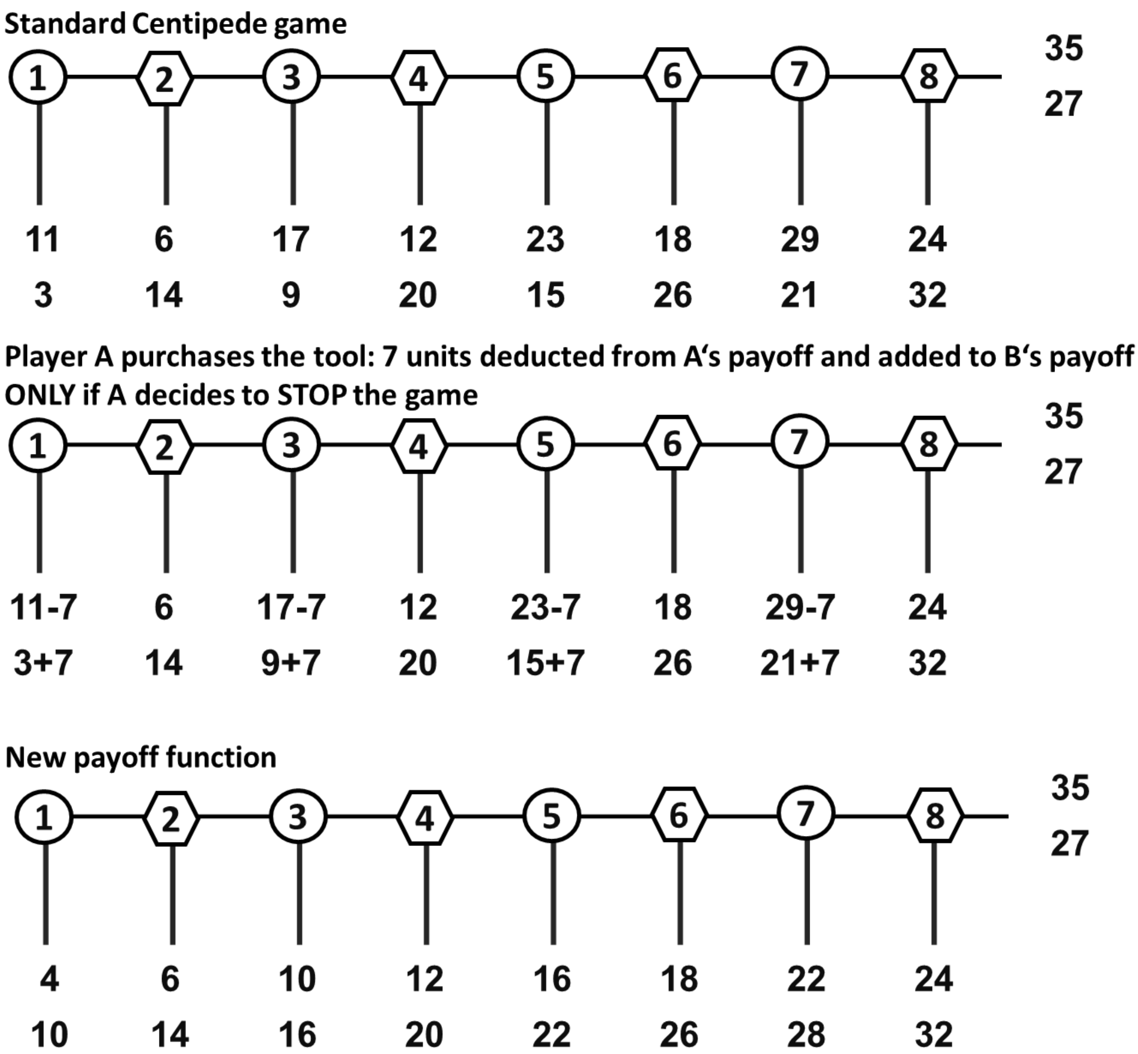


Figure 5.1. Bonus condition: Changes to the standard payoff function if Player A decides to purchase the bonus tool.

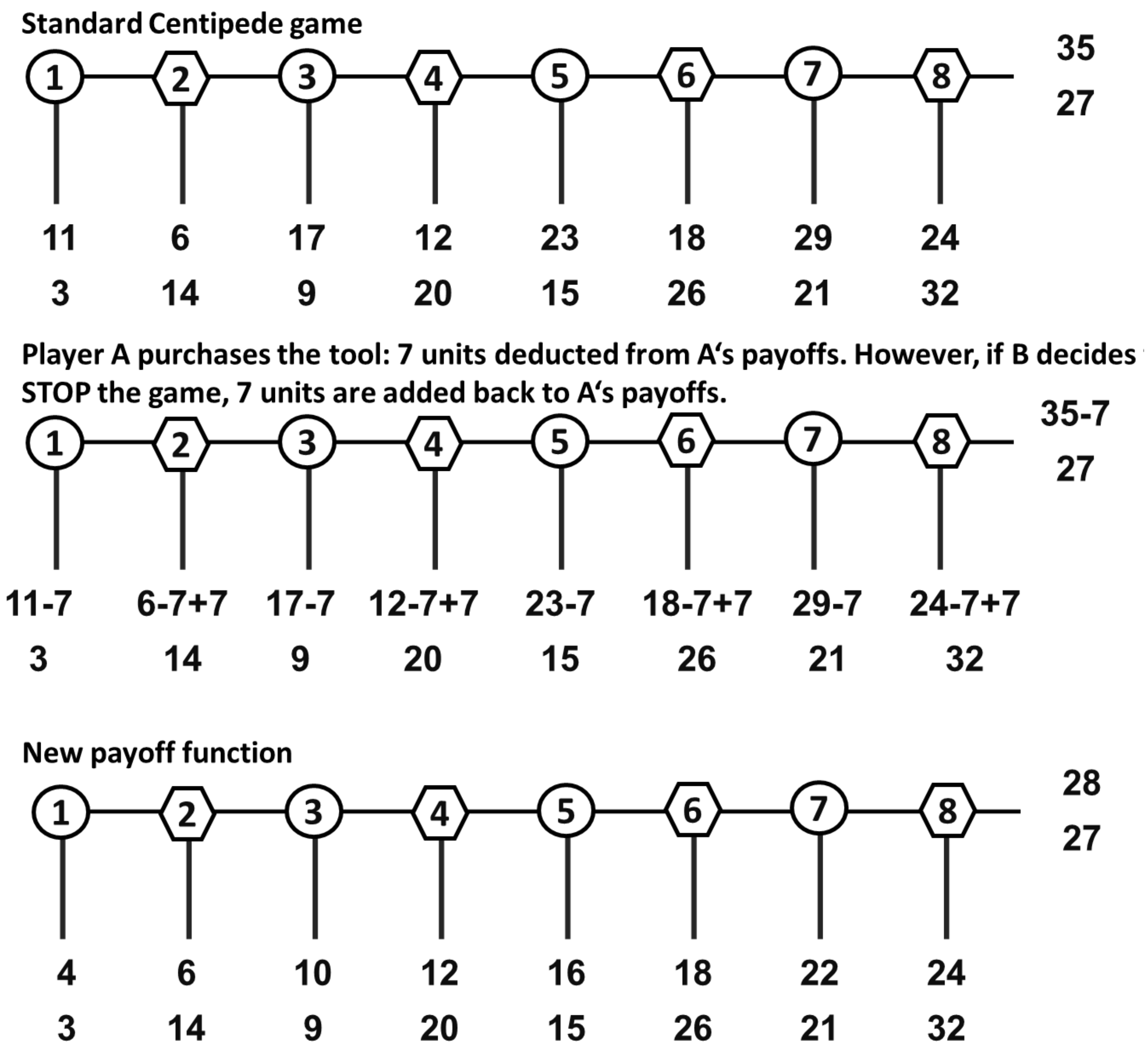


Figure 5.2. Insurance condition: Changes to the standard payoff function if Player A decides to purchase the insurance tool.

In line with Gerber and Wichardt's (2011) original design, the bonus tool in the present experiment involves offering the co-player an incentive at a personal cost for not stopping the game. In particular, 7 monetary units are taken from the individual who purchases the tool (i.e., Player A in the example) and added to the co-player's payoff only in the event of that individual's STOP move (i.e., at odd-numbered exit nodes). Examining the consequent changes to the payoff function, it becomes evident that both players' payoffs are affected by Player A's purchase of the bonus and, as a result, both players' payoffs strictly increase from one decision node to the next until reaching Node 8. This change to the payoff function also alters the game's Nash equilibrium solution: Applying BI reasoning, neither player has a rational reason to terminate the game before the 8th decision node.

With regard to the insurance condition, tool purchase involves an initial monetary sacrifice that is deducted from all personal payoffs in the game. Consequently 7 monetary units are deducted from all of Player A's payoffs: see Figure 5.2. The tool further includes reimbursement of the insurance cost in case of a STOP move by the co-player. This is reflected in the repayment of 7 monetary units to Player A at all even-numbered nodes (i.e., at those nodes where Player B could choose to terminate the game). As regards the final payoff function after applying the changes caused by the insurance, only Player A's payoffs are affected by the tool purchase in this condition, resulting in a strict increase from one node to another. As in the bonus condition, these changes alter the game's Nash equilibrium solution, now mandating cooperation up until Decision Node 8, due to Player A no longer having an incentive to defect in the game.

As outlined above, both tools require an initial commitment, because their purchase involves voluntarily reducing personal payoffs at certain decision nodes in the game. Moreover, both instruments have very similar consequences: they change the payoff function and create higher social certainty. The new game-theoretic solutions prescribe cooperation until the near-end across both tool conditions and thus foster reciprocal GO moves. Given the obvious benefits of choosing GO in the altered Centipede games, the co-players' intentions are also easier to predict. Nevertheless, whereas the bonus tool affects both players' payoffs, yielding easily observable consequences that do not require any perspective-taking, this is not the case for the insurance tool. Buying insurance affects only the payoffs of the insured player and leaves the co-player with the original payoff function of alternatingly increasing and decreasing payoffs. In order to recognise the benefits of the insurance tool (i.e., the lack of incentive for the insured player to defect), the co-player has to perform iterated reasoning, taking into account the insured player's incentives and likely intentions.

To sum up, usage of both tools measures commitment and preference for social certainty, a condition that is successfully achieved by both tools. These aspects could be of particular importance to the Japanese participants, who are historically used to close, committed relationships with low uncertainty. However, the two tools differ in simplicity with only the insurance tool requiring higher cognitive reasoning skills.

Comparing the bonus and the insurance conditions can, therefore, expose variations in cognitive abilities.

It was therefore hypothesised that in both Japan and Europe, the comparatively simpler bonus tool would be chosen more frequently than the insurance tool. For both samples, the commitment-enhancing tools were expected to significantly increase cooperation compared to games without tool purchases, ultimately leading to higher cooperativeness in the two game conditions with optional commitment-enhancing tools than in the standard game condition. Due to the higher need for social certainty attributed to the Japanese participants, it was further hypothesised that the Japanese would purchase significantly more commitment-enhancing tools than the Europeans.

Finally, to control for any confounding effects of individual difference variables other than assurance-based trust, this study included several personality questionnaires. Whereas previous research on the Centipede game has suggested that SVO plays a role in decision making (Pulford, Krockow, Colman, & Lawrence, 2016; Pulford, Colman, Lawrence, & Krockow, 2017; Krockow, Pulford, & Colman, 2016b), very little empirical games research has been conducted into the effects of SVO on decision making of Japanese participants. Yamagishi et al. (2013), in the only comprehensive study to date, found similar SVO proportions in their Japanese sample compared to the results from previous Western studies (e.g., Balliet, Parks, & Joireman, 2009). Most Japanese participants were classified as either cooperative or individualistic and very few were characterised by one of the more extreme orientations—altruistic or competitive. The Japanese results, however, lacked conclusiveness due to the use of different categorical SVO measures (Ring measure and Triple-Dominance measure) which were found to have poor test re-test reliability (the authors reported 57.7% for the Ring measure) and did not show a strong correlation across questionnaires (r = .38). To overcome previous measurement problems, this study used the recently introduced, continuous “Slider measure” of SVO, which was suggested to provide a more accurate and reliable assessment of SVO than previous categorical measures (Murphy, Ackermann, & Handgraaf, 2011).

Another individual difference variable with potential impact on decision making in the Centipede game is risk-taking. Previous Centipede studies manipulated the risk associated with each GO move (i.e., the amount by which the personal payoff decreased at the following node) and found that higher risk led to earlier exits in the game (e.g., Horng and Chou, 2011; Krockow, Pulford, & Colman, 2015). Moreover, a study by

Cook et al. (2005) suggests that risk-taking is likely to differ between Japanese and Western participants. Cook et al. manipulated riskiness of cooperation in Prisoner's Dilemma games by varying values of the "sucker's payoff." Japanese participants were found to cooperate less in high-risk games compared to US participants.

Finally, while the current experiment was designed to assess assurance-based trust indirectly, it does not allow for any direct conclusions regarding levels of general trust, which Yamagishi and Yamagishi (1994) defined as a spontaneously exhibited trust towards strangers in the face of social uncertainty. It is possible that general trust affects decision making in the Centipede game—particularly at the beginning of the game which, arguably, yields the highest amount of social uncertainty. Since general trust was found to differ across cultures with the Japanese scoring particularly low (Yamagishi, 1988), it is an important variable to consider in this cross-cultural study. Consequently, the present study included measures of SVO, risk-taking/risk-perception and general trust, and tests for cross-cultural differences as well as any effects on decision making in the Centipede game. Based on the studies reviewed above, it was expected that SVO would not differ significantly between Japan and Europe, with results showing similar proportions of cooperative and individualistic individuals and very few individuals with extreme SVOs (i.e., altruistic and competitive). However, significant differences were hypothesised pertaining to risk-taking and general trust, with Japanese participants expected to score lower on both measures than European participants. Finally, it was predicted that individual differences in SVO, risk-taking and trust would show significant correlations with cooperativeness in the Centipede game. Higher levels of prosociality, risk-taking and trust were expected to be positively related to cooperation in the game.

5.2.2: Method

The section below details information about the participants (Section 5.2.2.1), the Design (Section 5.2.2.2), Materials (Section 5.2.2.3) and Procedure (Section 5.2.2.4) of this experiment.

5.2.2.1: Participants

The sample comprised 60 Japanese nationals from Hokkaido University in Japan and 54 European (mostly British) participants from the University of Leicester in the UK. All participants were undergraduate students. In Japan, the sample comprised

34 males, 25 females and one of unknown gender, with a mean age of 18.81 years (*SD* = 0.71). The sample in the UK included 9 males, 44 females and one of unknown gender, with a mean age of 18.65 years (*SD* = 0.94). The Japanese sample received a show-up fee of ¥1000 ($8.14) and the European sample received course credit. Importantly, whereas compensation for participation differed across the two samples, the incentive schemes for decision making in the actual experimental games were identical. In both countries, a between-subjects random lottery incentive system was used to incentivise choices in the games. In particular, from each of the 6 testing sessions (three sessions in Japan and three in the UK), one participant was randomly chosen to win a payoff from a randomly selected played game. The games' payoffs were converted into Japanese Yen and British Pounds Sterling at rates of 242.32 and 1.36 respectively, to result in comparable stakes and consequent payments. In Japan, the three lottery winners received an average of ¥5173.3 ($43.78), and in the UK, they won an average of £28.3 ($40.32).

5.2.2.2: Design

The experiment was based on a 2 (Sample) × 3 (Condition) design. The participants of both samples (Japanese and European) were randomly assigned to one out of three game conditions: (a) Standard Centipede game (Condition 1); (b) Centipede game with bonus tool (Condition 2); (c) Centipede game with insurance tool (Condition 3). The main dependent variable was again the mean exit point of the 20 game rounds an individual completed during the course of the experiment. To obtain a more individual measure of cooperation, less dependent on the choices of the co-player, the number of exit moves made by a participant across 20 games was assessed, with higher numbers of exit moves indicating lower cooperativeness. Additionally, to measure the level of commitment and preference for social certainty of an individual, the total number of tool purchases was calculated. A maximum score of 20 indicated very high commitment and strong preference for social certainty whereas lower scores suggested accordingly lower levels of commitment.

Finally, three individual difference variables—SVO, risk-taking/risk-perception, and trust—were derived from questionnaires. The SVO score was a continuous variable with higher scores indicating increasing prosociality. In addition, the continuous SVO score was retrospectively categorised to yield traditional SVO classifications. As stipulated by the creators of the SVO slider measure (Murphy, Ackermann, &

Handgraaf, 2011), scores below –12.04 qualified as competitive, scores up to 22.45 qualified as individualistic, scores up to 57.15 qualified as cooperative, and any scores above qualified as altruistic. For risk-taking and risk-perception, five sub-scale scores each were computed for the following risk categories: ethical, financial, health/safety, recreational, and social. High scores indicate high levels of risk-taking and risk-perception respectively. The trust score was calculated by adding trust ratings across five items, with high scores representing higher trust levels.

5.2.2.3: Materials

The testing sessions were conducted in large laboratories equipped with computer desks separated with dividing walls. All participants received colourfully illustrated instruction booklets—in Japanese or in English—with detailed explanations of example situations in the games (see Appendix C). They interacted in the games through z-Tree software (Fischbacher, 2007) on their computers, which provided real-time feedback about the co-players' choices and the outcome of the current as well as previous games. The Japanese participants were presented with a fully translated version of the software. To assess individual differences, paper copies of the following questionnaires were distributed: (a) six-item SVO slider measure (Murphy, Ackermann, & Handgraaf, 2011); (b) 30-item Domain-specific risk-taking (DOSPERT) scale and respective risk-perception scale (Blais & Weber 2006); and (c) the first five items of Yamagishi and Yamagishi's (1994) scale on general trust. All Japanese materials were translated from English into Japanese by the Japanese project collaborators. The only exception was the DOSPERT scale of which a Japanese version was already available from the original authors online.

5.2.2.4: Procedure

Six testing sessions were conducted, comprising 20 participants each in Japan and 18 participants each in the UK. Each testing session lasted between 60 and 75 minutes. After filling in the consent form, the participants read through the instruction booklets in their own time. Then, the participants were given a short comprehension test that the experimenters checked for any misunderstandings. Once everybody had fully understood the instructions, the computerised experiment was started. The program randomly assigned each participant a player role (Player A or B) retained for the whole experiment. The participants completed 20 rounds of the Centipede game with random and anonymous re-pairings after every round. In the game conditions with either bonus or insurance tool, the players were given the option to purchase a tool before the start of each round. The choices of both players were subsequently revealed on the screen and the game payoffs incorporating any changes due to tool purchases were displayed. All participants were compensated for their time with a show-up fee or course credits, and the randomly chosen lottery winner in that session additionally received the payoff from a randomly selected game they completed in the experiment.

5.2.3: Results

The results section is subdivided into three parts which focus on the analysis of exit points (Section 5.2.3.1), the analysis of tool purchases (Section 5.2.3.2) and the analysis of individual difference variables (Section 5.2.3.3) respectively.

5.2.3.1: Analysis of exit points

Overviews of game terminations per exit node for the three game conditions are depicted in Figure 5.3. Across all conditions, striking differences between Japan and Europe are evident. In Condition 1 (standard game), the exit points of the Japanese participants are skewed toward the right of the figure, indicating late game exits, with the two most frequent exits points being Node 6 and, notably, the game's natural end (Node 9)—almost 30% of games each terminated at those exit points. Not a single game exited on Node 1. In contrast, the European sample produced much earlier game exits with the data skewed toward the left. The two most frequent exit points with approximately 20% of game terminations each were Nodes 2 and 3, and not a single game reached the natural end.

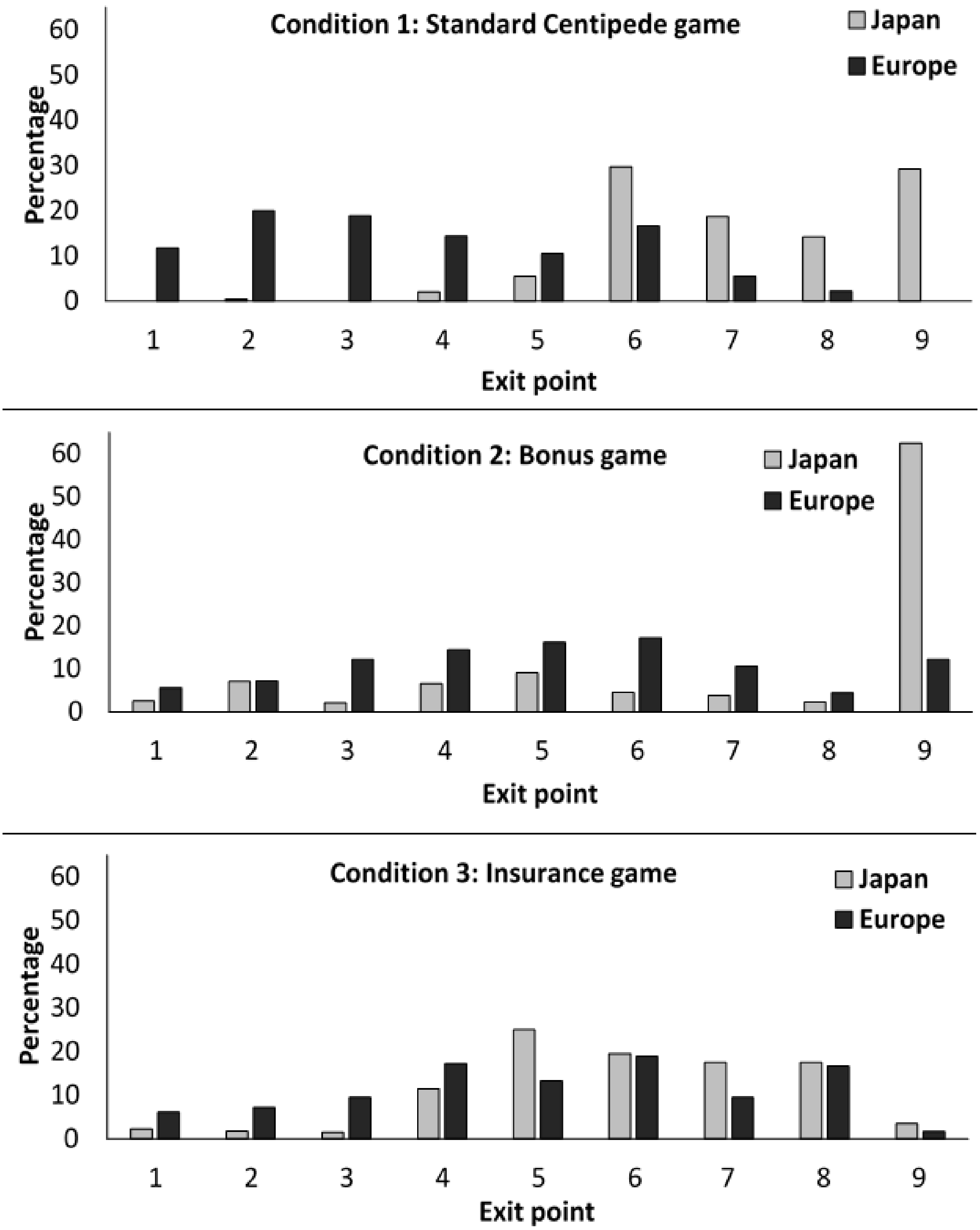


Figure 5.3. Percentages of game terminations per exit point across game conditions and samples.

In Condition 2 (bonus game), completely different exit patterns were found. Across both countries, game terminations show a wide spread across all exit nodes. The Japanese data feature a large spike at Node 9, with a remarkable 62.5% of games reaching this natural end. For the UK, Nodes 5 and 6 show the highest percentages of game exits with 16.1% and 17.2% respectively but this condition also yielded a substantial percentage of games reaching the natural end (12.2%).

Condition 3 (insurance game) again yielded large data spreads for both samples, with game exits at all terminal nodes. Over 90% of Japanese games ended at Nodes 4–8, and only 3.5% reached the natural end. The European sample produced very mixed results, with the most frequent exit points being Nodes 4, 6, and 8 (all between 16.5 and 19%) and very few games terminating at Node 9 (1.7%).

A two-way ANOVA tested for effects of sample and game conditions on the mean exit points. Means, standard deviations and 95% confidence intervals are displayed in Table 5.1. There was a significant main effect of sample; the mean exit points of the Japanese sample (*M* = 6.81; *SD* = 1.15) were significantly higher than those of the European sample (*M* = 4.69; *SD* = 1.1), $F(1, 108) = 145.153$, $p < .001$, $\eta_p^2 = .57$. Another main effect was found for the game condition, $F(2, 108) = 7.359$, $p < .005$, $\eta_p^2 = .12$. For both samples taken together, the insurance condition produced the lowest exit points (*M* = 5.54; *SD* = 0.86), followed by the standard game condition (*M* = 5.59; *SD* = 1.96) and then the bonus condition (*M* = 6.28; *SD* = 1.54). Post-hoc comparison using Tukey HSD tests indicated significant differences between the bonus condition and both other game conditions ($p < .005$). However, these results have to be interpreted with caution, as the two factors also significantly interacted, $F(2, 108) = 19.217$, $p < .001$, $\eta_p^2 = .26$, indicating that the effect of the game condition depended on the sample. In Japan, the first two conditions produced similar mean exit points. The insurance condition, however, produced significantly lower results ($p < .001$). In Europe, on the other hand, the standard game produced significantly lower exit points than both the bonus game and the insurance game, ($p < .001$).

Table 5.1

Mean Exit Points, Standard Deviations, and 95% Confidence Intervals per Sample and Game Condition

	C1: Standard condition	C2: Bonus condition	C3: Insurance condition	Total
Japan	7.23 (0.84) [6.82, 7.65]	7.27 (1.34) [6.86, 7.70]	5.92 (0.64) [5.51, 6.34]	6.81 (1.15) [6.57, 7.05]
Europe	3.76 (0.92) [3.32, 4.20]	5.18 (0.86) [4.74, 5.62]	5.12 (0.88) [4.68, 5.56]	4.69 (1.10) [4.43, 4.94]
Total	5.59 (1.96) [5.19, 5.80]	6.28 (1.54) [5.92, 6.53]	5.54 (0.86) [5.22, 5.83]	5.80 (1.55) [5.57, 5.92]

To check for any confounding gender effects in the context of different gender proportions across the two samples, a three-way ANOVA was carried out, investigating the effects of gender in addition to those of the sample and game condition on mean exit points. No significant main effect of gender was found, $F(1, 100) = 2.152$, $p = .145$, nor any two-way or three-way interactions including gender.

To test for learning effects, temporal exit patterns across the 20 game rounds were examined. Figure 5.4 displays the temporal data for each game condition and country. The time series do not show any consistent upward or downward trends for the data, indicating that participants did not adapt their choices in the games based on their experiences from previous games. This was further supported by non-significant results from time series analysis.

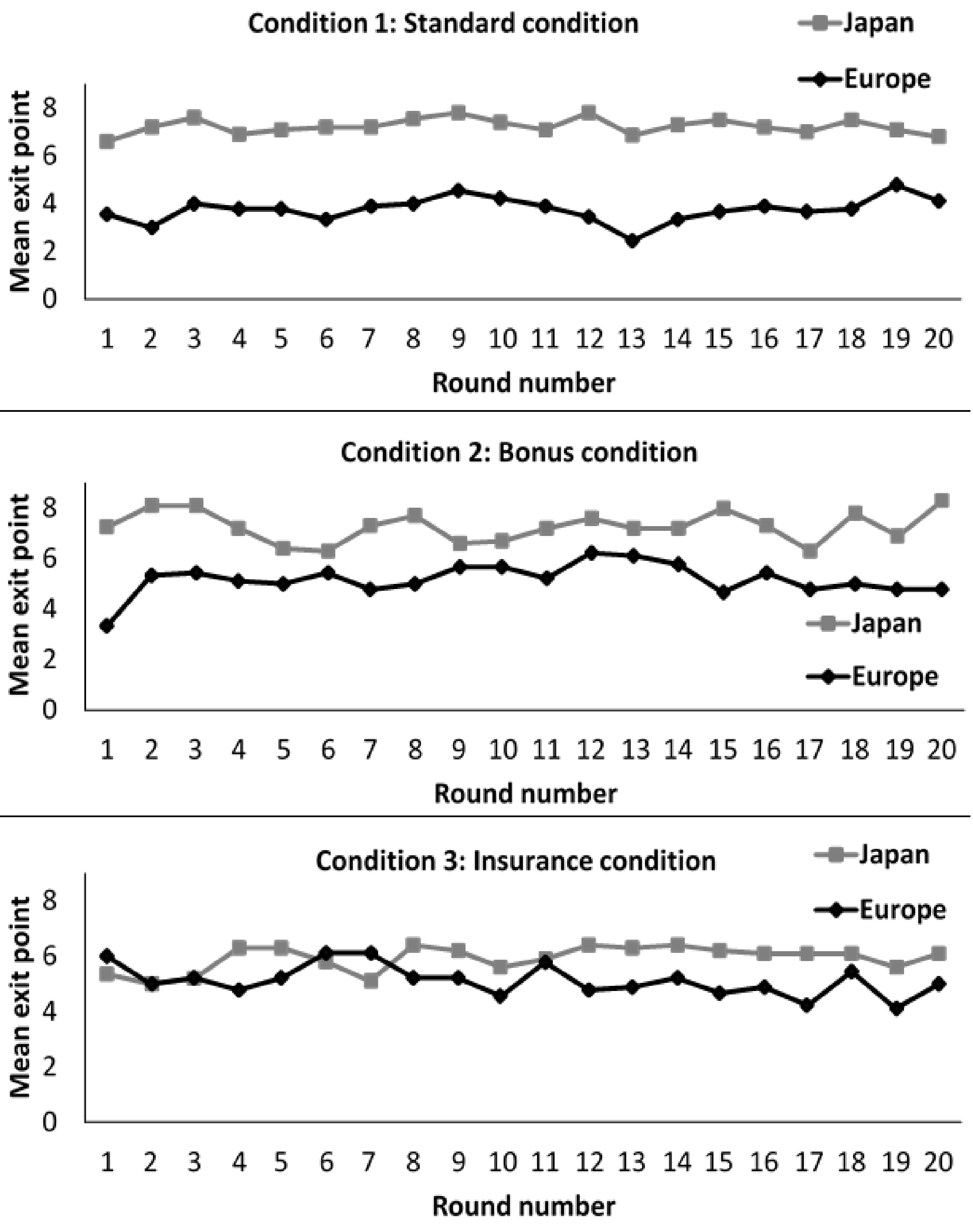


Figure 5.4. Mean exit points per game round across the three game conditions and two samples.

5.2.3.2: Analysis of tool purchase

Figure 5.5 reveals large differences between countries in the bonus condition: In Japan less than a third of all games (32.5%) were played without a bonus purchase of either player. For most games, only one player purchased a tool, but there was also a substantial percentage of games (11.5%) where both players purchased the bonus. In the UK, the percentage of games with no tool purchases was more than twice as high as in Japan (76.1%) and in only 23.3% of games did one player chose the bonus tool. The number of games with both players purchasing tools was negligible (only a single game out of 180).

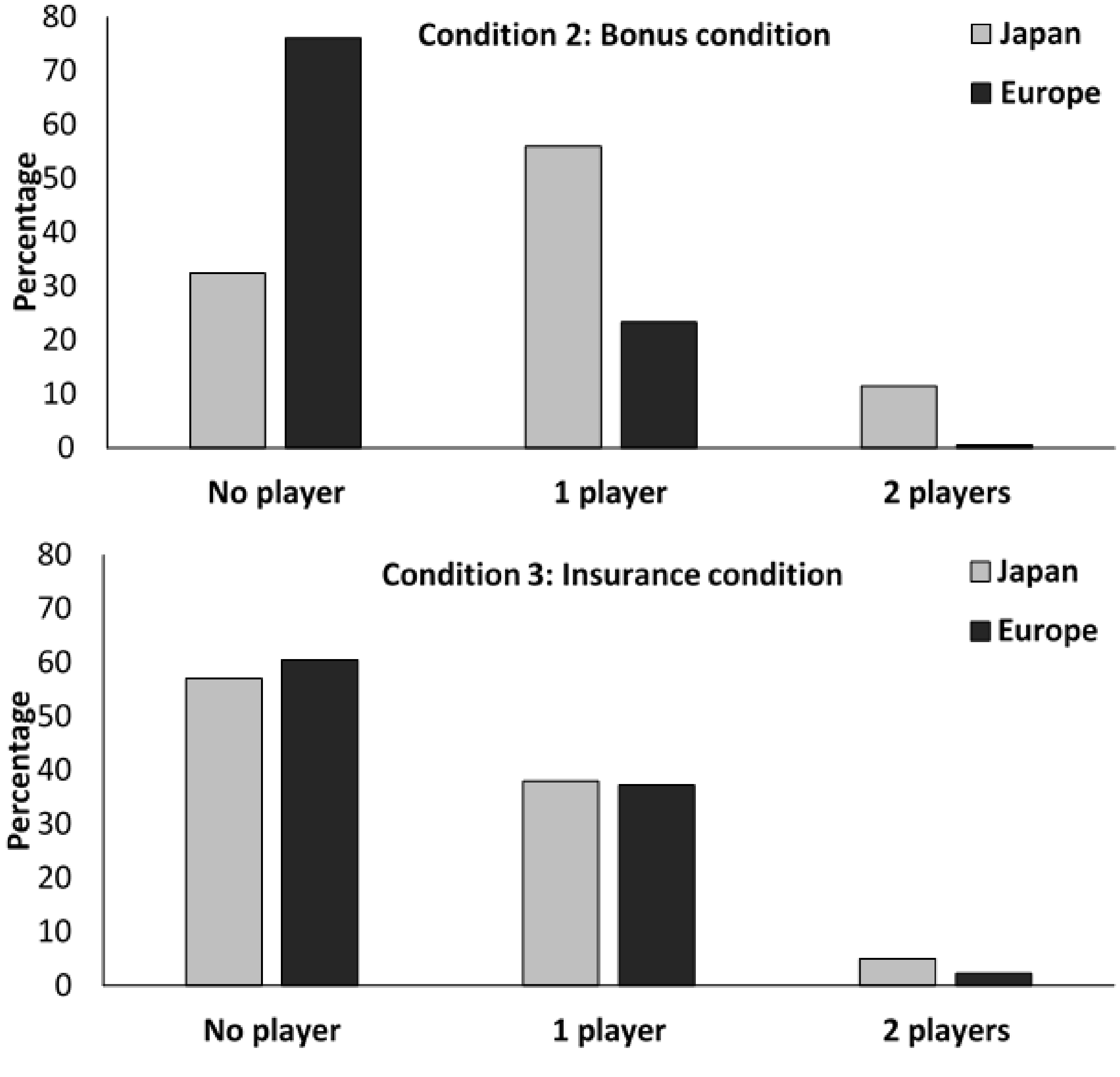


Figure 5.5. Percentage of games where no, one or two players purchased tools across the bonus and the insurance game conditions and the two samples.

For the insurance condition, the cross-cultural differences were less pronounced. Across both samples, the majority of games were completed without an insurance tool purchase and 40% of games where played following the tool purchase of one player.

The proportion of games in which both players purchased a tool was very low in both samples (≤ 0.05).

A two-way ANOVA was carried out to investigate the effects of sample and game condition on the number of tools purchased per participant (out of a possible 20), (see Figure 5.6). Means, standard deviations and 95% confidence intervals are displayed in Table 5.2. The mean number of tools purchased in Japan (*M* = 6.35; *SD* = 7.52) was significantly higher than in Europe (*M* = 3.31; *SD* = 3.91), $F(1, 72) = 4.83$, $p < .05$, $\eta_p^2 = .063$. No main effect, however, was found for the game condition, $F(1, 72) = 0.247$, $p = .62$, and the interaction between the two independent variables was also non-significant, $F(1, 72) = 3.029$, $p = .086$.

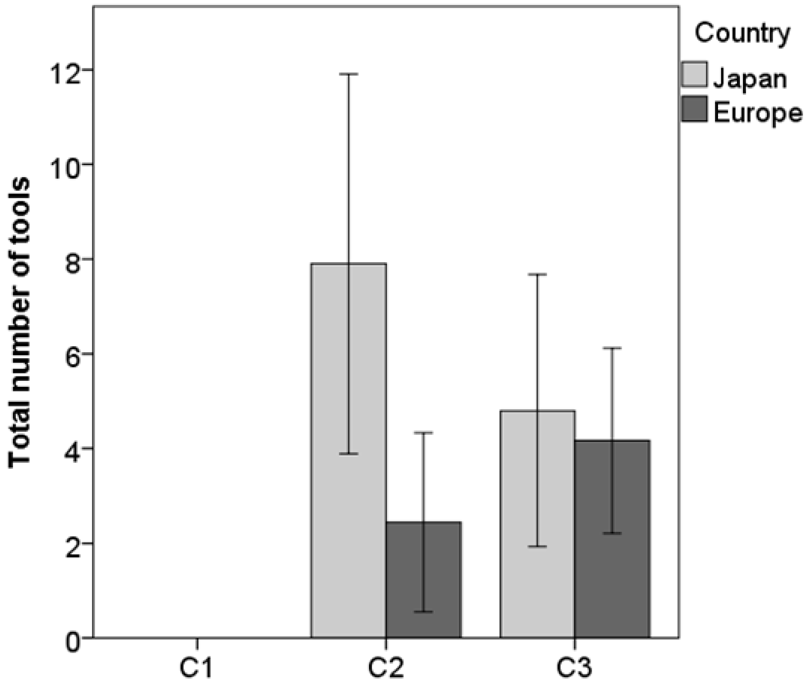


Figure 5.6. Mean number of tool purchases per participant across game conditions (C1 = Standard condition; C2 = Bonus condition; C3 = Insurance condition) and samples.

Table 5.2

Mean Numbers of Tools Purchased, Standard Deviations, and 95% Confidence Intervals per Sample and Game Condition

	C2: Bonus condition	C3: Insurance condition	Total
Japan	7.90 (8.57) [5.21, 10.59]	4.80 (6.13) [2.11, 7.49]	6.35 (7.52) [4.45, 8.25]
Europe	2.44 (3.81) [-0.39, 5.28]	4.17 (3.93) [1.33, 7.00]	3.31 (3.91 [1.30, 5.31]
Total	5.32 (7.21) [3.22, 7.13]	4.50 (5.15) [2.53, 6.44]	4.91 (6.24) [3.45, 6.21]

Temporal patterns in tool purchase are shown in Figure 5.7. Time series analysis revealed a learning curve of the Japanese participants in the Insurance condition, with the number of tool purchases increasing across rounds. The SPSS Expert Modeller identified an exponential smoothing model with a Holt linear trend as the best fit of the data, thus indicating a linearly increasing number of tools purchased. The stationary R^2 model fit statistic was calculated to estimate the model's goodness of fit. With an R^2 value of .32, the model can explain more than 30% of the variance of the data, and indicates a superior fit compared to a simple mean model used as a baseline for comparison. Additionally, the Ljung-Box statistic Q was calculated to test whether the model was correctly specified. The value of $Q(16) = 7.17$, ($p = .97$) showed that no significant patterns in the data set were unaccounted for by the Holt linear model identified. The Expert Modeller identified no significant learning patterns pertaining to tool purchase in any of the other game conditions.

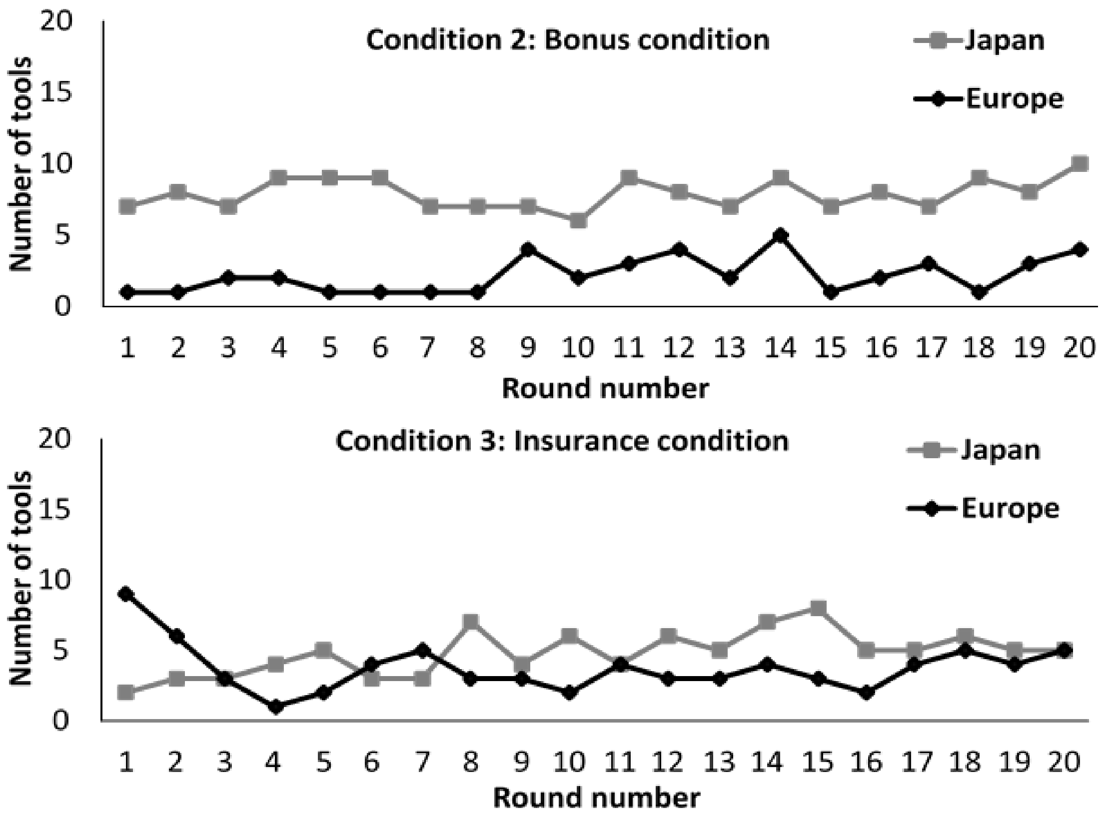


Figure 5.7. Total numbers of tools purchased per game round in the bonus and insurance conditions across samples.

Additional analyses were conducted to compare the exit points of games where no player, one player or both players had purchased tools. Figures 5.8 and 5.9 show the percentages of games terminating at each exit point across game conditions and samples. When looking at the graphs for games where no player purchased a tool (zero-tool games), large differences become apparent between the standard game (without the option to purchase a tool) and the two conditions with tools available. The Japanese data, which are highly skewed to the right in the standard game condition, are skewed more to the left side of the graph in the zero-tool games of the bonus and insurance game conditions. In the UK, on the other hand, the opposite can be observed, with overall higher exit points in the tool conditions compared to the standard Centipede game.

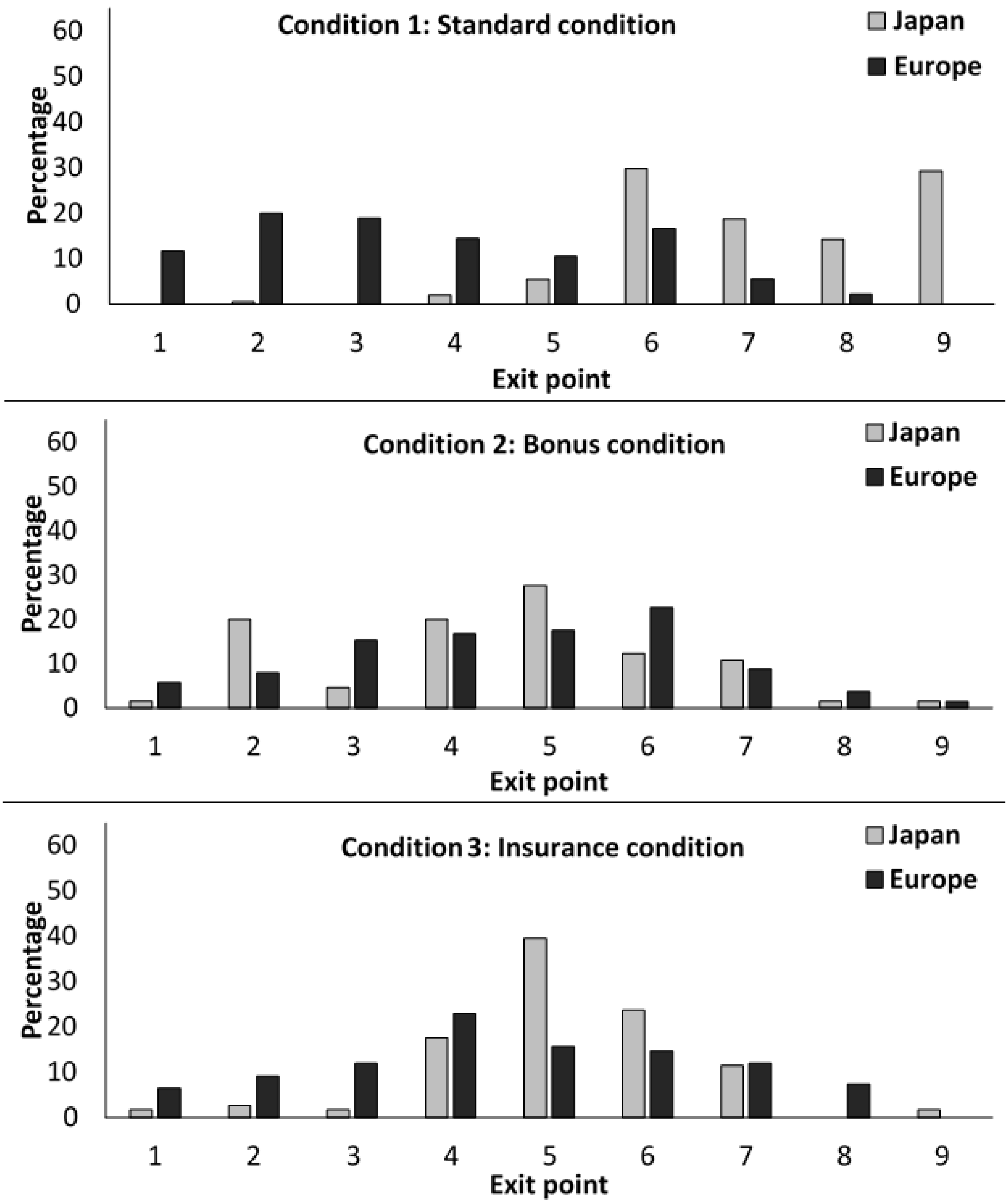


Figure 5.8. Percentages of game terminations per exit node when no tools purchased.

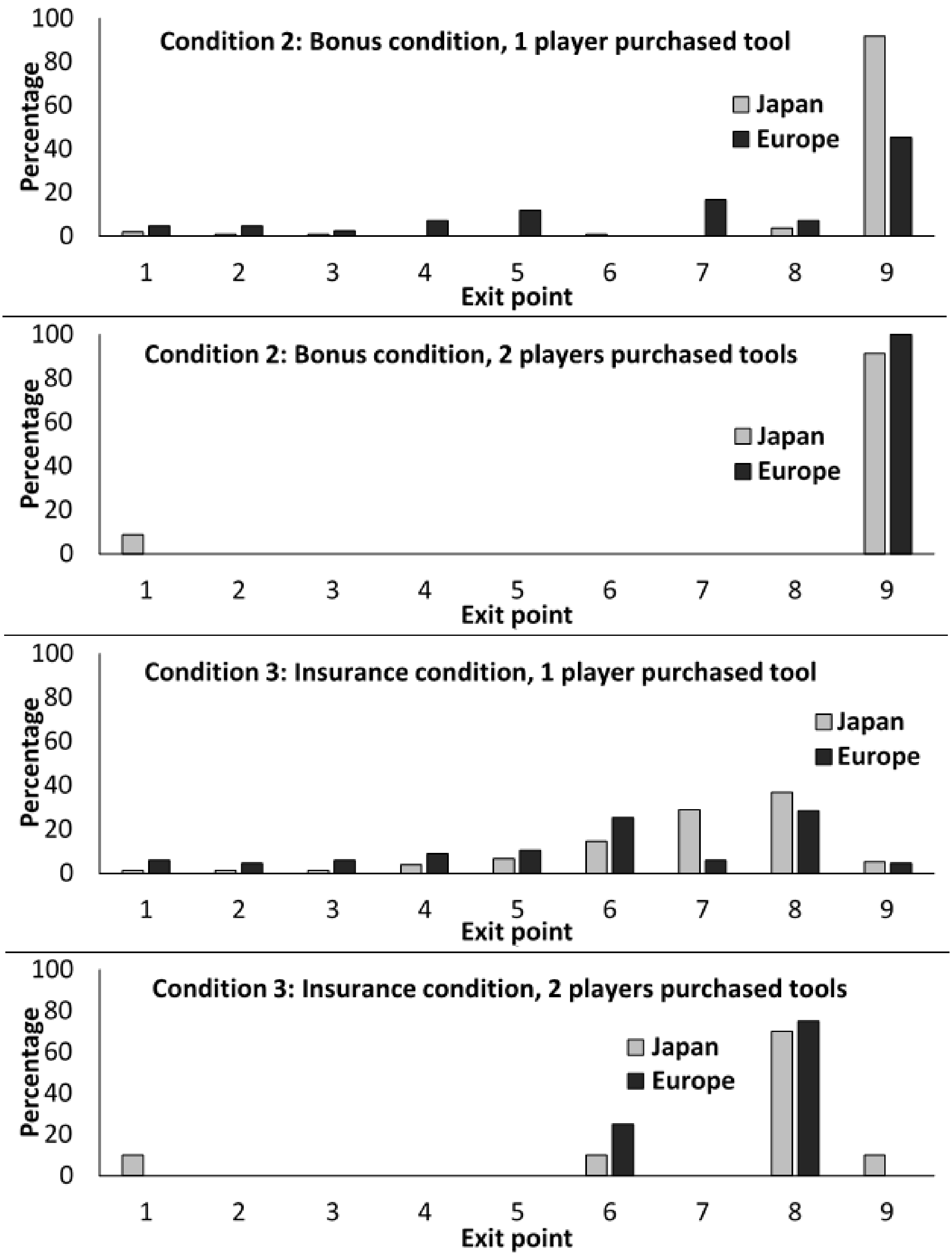


Figure 5.9. Percentages of game terminations per exit node when tools were purchased.

A two-way (Sample × Game condition) ANOVA examining the effects on exit points of zero-tool games confirmed these observations. Means, standard deviations and 95% confidence intervals are presented in Table 5.3. Overall, the Japanese sample produced significantly higher exit points (M = 5.76; SD = 1.36) than the European sample (M = 4.3; SD = 1.03), $F(1, 104) = 68.209$, $p < .001$, $\eta_p^2 = .40$. On the whole, the standard game produced significantly higher mean exit points (M = 5.59; SD = 1.96) than the zero-tool games of the bonus condition (M = 4.66; SD = 0.96) and the insurance condition (M = 4.84; SD = 0.84), $F(2, 104) = 9.108$, $p < .001$, $\eta_p^2 = .15$. Finally, there was a significant interaction of the two factors, $F(2, 104) = 38.785$, $p < .001$, $\eta_p^2 = .43$, suggesting that the effect of the game condition on mean exit points of zero-tool games differed depending on the sample. In Japan, the standard game produced significantly higher mean exit points than the bonus and the insurance game, $p < .001$. In contrast, the European sample yielded significantly lower mean exit points in the standard game compared to the bonus condition and the insurance condition, $p < .05$.

Table 5.3

Mean Exit Points, Standard Deviations, and 95% Confidence Intervals for Zero-Tool Games per Sample and Game Condition

	C1: Standard condition	C2: Bonus condition	C3: Insurance condition	Total
Japan	7.23 (0.84) [6.82, 7.65]	4.74 (0.94) [4.30, 5.18]	5.11 (0.57) [4.72, 5.50]	5.76 (1.36) [5.46, 5.93]
Europe	3.76 (0.92) [3.32, 4.20]	4.59 (1.00) [4.17, 5.00]	4.55 (1.00) [4.13, 4.96]	4.30 (1.03) [4.06, 4.54]
Total	5.59 (1.96) [5.19, 5.80]	4.66 (0.96) [4.36, 4.96]	4.84 (0.84) [4.54, 5.11]	5.04 (1.41) [4.83, 5.16]

Additionally, effects of the purchase of bonus and insurance tools on the game outcomes were examined. Looking at Figure 5.10, it is obvious that the tool purchase by either one or two players drastically changed exit points in the games. Across both samples and game conditions, the purchase of tools increased cooperation. In the Japanese bonus condition, the change is most visible, with over 90% of all games reaching the final end. However, the extreme results of the European samples for games with tool purchases by both players (in the bonus condition, 100% reached Node 9, and in the insurance condition, 75% reached Node 8) need to be interpreted with caution, as these data were based on only a single case in the bonus condition and 4 cases in the insurance condition.

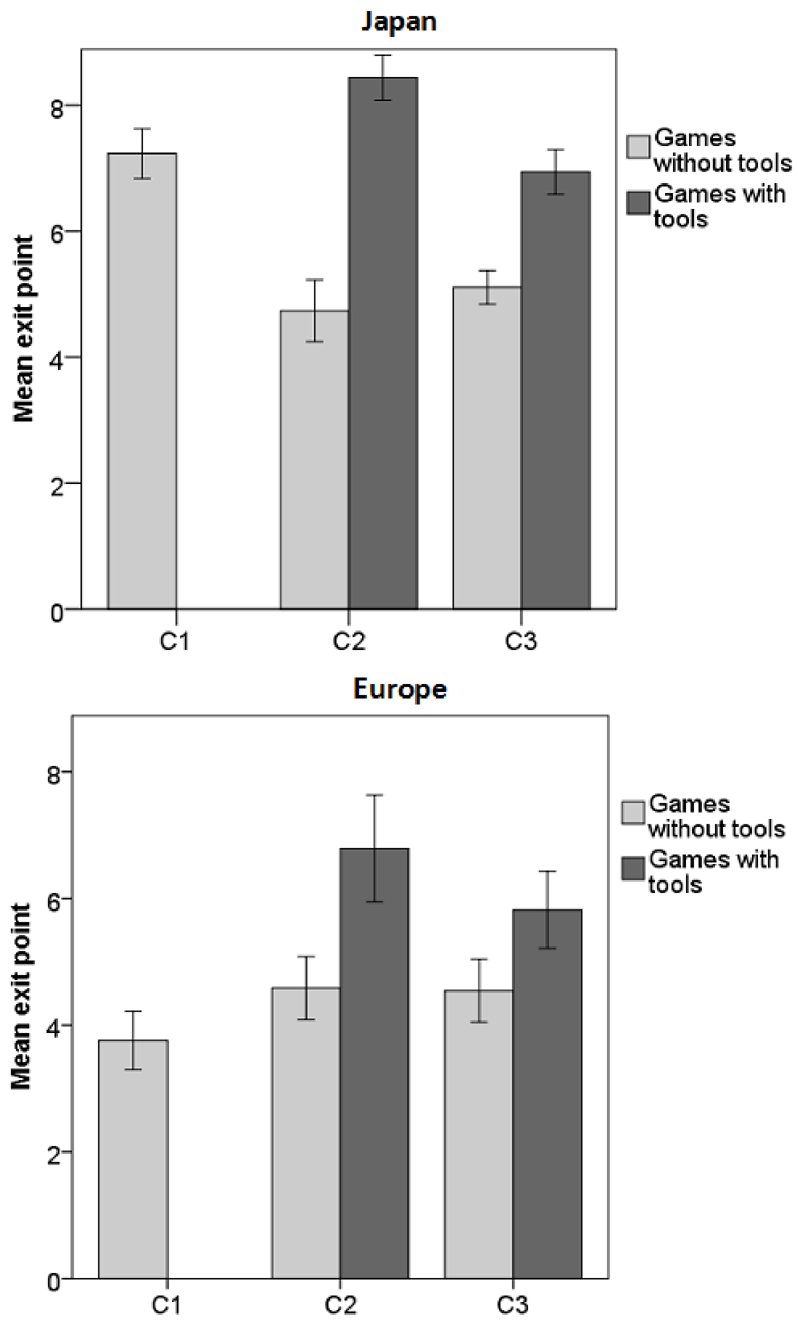


Figure 5.10. Mean exit nodes for games with and without tool purchases across game conditions and samples.

For additional statistical analyses, the data from games in which either one or two players had purchased tools were combined. To investigate the relative effectiveness of the tools in increasing commitment and cooperation, a between-within-subjects ANOVA compared the participants' mean exit points for zero-tool games and games in which one or two players had chosen tools, while testing for differences between the two samples and game conditions (bonus and insurance condition). Means, standard deviations and 95% confidence intervals are displayed in Table 5.4. The analysis showed a significant difference between the mean exit points of games with and without tools, $F(1, 67) = 191.855$, $p < .001$, $\eta_p^2 = .74$, with zero-tool games yielding a mean exit point of 4.74 ($SD = 0.90$) and games with tool purchase yielding a mean of 6.96 ($SD = 1.48$). There was also a significant interaction between the within-subjects factor (games with or without tool purchase) and the sample, $F(1, 67) = 10.216$, $p < .01$, $\eta_p^2 = .13$, indicating that in Japan, the differences between the mean exit points of zero-tool games ($M = 4.93$; $SD = 0.76$) and games with tool purchases ($M = 7.63$; $SD = 1.09$) were significantly larger than the differences observed in Europe (zero-tool games: $M = 4.56$; $SD = 0.98$; games with tool purchases: $M = 6.31$; $SD = 1.54$). Additionally, the results demonstrated a significant interaction; for the bonus game condition, the differences between the mean exit points of zero-tool games and those of games with tool purchases were significantly larger than the differences observed in the insurance game condition, $F(1, 67) = 18.244$, $p < .001$, $\eta_p^2 = .21$. No significant three-way interaction was found for the variables of interest, $F(1, 67) = 2.026$, $p = .159$.

Table 5.4

Mean Exit Points, Standard Deviations, and 95% Confidence Intervals per Sample, Differentiating Between Zero-Tool Games and Games with One or Two Tool Purchases

		C2: Bonus condition	C3: Insurance condition	Total
Zero-tool Games	Japan	4.74 (0.94) [4.29, 5.18]	5.09 (0.58) [4.68, 5.50]	4.93 (0.78) [4.61, 5.22]
	Europe	4.59 (1.00) [4.16, 5.01]	4.55 (1.00) [4.13, 4.97]	4.57 (0.98) [4.27, 4.86]
	Total	4.66 (0.96) [4.36, 4.97]	4.83 (0.84) [4.53, 5.11]	4.74 (0.90) [4.53, 4.95]
Games with Tool Purchase	Japan	8.45 (0.85) [7.86, 9.05]	6.94 (0.74) [6.40, 7.49]	7.63 (1.09) [7.30, 8.10]
	Europe	6.79 (1.69) [6.23, 7.35]	5.82 (1.22) [5.26, 6.38]	6.31 (1.54) [5.91, 6.70]
	Total	7.57 (1.59) [7.21, 8.03]	6.40 (1.14) [5.99, 6.77]	6.96 (1.48) [6.72, 7.29]

5.2.3.3: Analysis of individual difference variables

Descriptive statistics are presented in Table 5.5. The continuous SVO scores did not differ significantly between Japanese and European samples, $t(110) = -.442$, $p = .659$, with both showing mean scores at the lower end of the cooperative SVO spectrum. An additional chi-square test of independence compared the numbers of participants falling within each SVO category for the two samples. Again, there was no significant difference, $\chi^2(3, N = 112) = 4.651$, $p = .199$. In Japan, 50% of participants qualified as cooperative, 46.6% as individualistic and 3.4% as altruistic. In Europe, 63% of participants were classified as cooperative, 35.2% as individualistic and the remaining 1.8% as competitive.

Table 5.5

Descriptive Statistics for SVO, Trust and Risk-Taking

	Country	
	Japan	UK
SVO, continuous	24.29	25.50
	(15.14)	(13.68)
Trust	20.05	20.35
	(6.03)	(5.73)
Risk-taking		
Ethical risk-taking	12.83	12.36
(e.g. Having an affair with a married man/woman)	(5.03)	(4.40)
Financial risk-taking	9.80	13.28
(e.g. Betting a day's income at the horse races)	(4.66)	(4.70)
Health/safety risk-taking	15.37	17.52
(e.g. Driving a car without wearing a seat belt)	(5.66)	(6.35)
Recreational risk-taking	15.56	22.94
(e.g. Going camping in the wilderness)	(6.54)	(9.34)
Social risk-taking	26.34	29.65
(e.g. Admitting that your tastes are different from those of a friend)	(4.83)	(4.27)
Risk-perception		
Ethical risk-perception	26.14	24.79
(e.g. Having an affair with a married man/woman)	(4.60)	(5.16)
Financial risk-perception	31.50	31.19
(e.g. Betting a day's income at the horse races)	(7.01)	(5.73)
Health/safety risk-perception	30.86	30.38
(e.g. Driving a car without wearing a seat belt)	(5.58)	(5.22)
Recreational risk-perception	27.47	24.68
(e.g. Going camping in the wilderness)	(5.48)	(7.02)
Social risk-perception	18.19	18.33
(e.g. Admitting that your tastes are different from those of a friend)	(5.41)	(4.65)

With regard to the risk-taking scores from the different subscales, no significant differences were found between Japanese and European participants on ethical risk-taking, $t(110) = .526$, $p = .60$. However, on all other subscales, including financial risk-taking, $t(110) = –3.937$, $p < .001$, health/safety risk-taking, $t(111) = –1.899$, $p = .06$, recreational risk-taking, $t(111) = –4.903$, $p < .001$, and social risk-taking, $t(110) = –3.826$, $p < .001$, the Japanese scores were significantly (or near-significantly) lower than the scores from the European participants. With regard to risk-perception, no significant differences were found between the two samples apart from the recreational sub-scale, $t(110) = –2.362$, $p = .02$, which indicated higher risk-perception in the Japanese participants. Comparing the general trust scores, no significant differences were found, $t(112) = –.273$, $p = .155$. With mean trust scores of 20.05 in Japan and 20.35 in Europe (out of a possible 35 points which indicate perfect trust), both samples showed moderately high levels of general trust.

For the combined group of Japanese and European participants, a Pearson product-moment correlation revealed a significant relationship between the continuous SVO score and the number of exit moves an individual made, $r = –.236$, $n = 112$, $p = .012$, showing that higher prosociality was related to lower numbers of exit moves. Additional analyses for the risk-taking scores revealed significant correlations between mean exit points and financial risk-taking, $r = –.246$, $n = 112$, $p = .009$, health and safety risk-taking, $r = –.190$, $n = 113$, $p = .044$, recreational risk-taking, $r = –.335$, $n = 113$, $p < .001$, and social risk-taking, $r = –.203$, $n = 112$, $p = .032$. In all cases, lower risk-taking was associated with higher mean exit points. No significant overall correlation was found for general trust and mean exit points, $r = –.057$, $n = 114$, $p = .545$.

5.2.4: Discussion

This experiment focused on cross-cultural differences in trust and cooperation between Japanese and European nationals using the Centipede game as a behavioural decision task. In particular, previous concepts of trust proposed by Yamagishi and Yamagishi (1994) were tested that differentiated between two types of trust: general trust in situations of low social certainty with higher prevalence in US/Western participants and assurance-based trust in prolonged relationships of higher social certainty with higher prevalence in Japanese participants. Given the sequential nature of the Centipede game, which includes two individuals repeatedly interacting with one another and offers opportunities for repeated mutual reciprocity, it was hypothesised that Japanese participants would cooperate more frequently than European participants due to their higher levels of assurance-based trust. This general hypothesis was confirmed: Whereas both samples recurrently deviated from the Nash equilibrium solution in the standard Centipede game (i.e., a STOP move at Node 1), the Japanese participants exited significantly later compared to the Europeans. In fact, the percentage of Japanese games reaching the natural end was unusually high (almost 30%)—previous Centipede studies conducted in Western countries reported percentages of no more than 16.5% (Bornstein, Kugler, & Ziegelmeyer, 2003), with most studies reporting percentages below 5% (e.g. McKelvey & Palfrey, 1994). These findings indicate very high cooperation levels of Japanese participants in the Centipede game that are likely to be linked to higher levels of assurance-based trust.

5.2.4.1: Use and effects of commitment-enhancing tools

Using a research paradigm by Gerber and Wichardt (2009), this study further included two game conditions offering tools designed to enhance social certainty and commitment in the game. The comparatively simpler bonus tool condition involved offering the co-player a bonus for not exiting the game, whereas the insurance tool required initial payment in order to receive an insurance payment in case the co-player decided to terminate the game.

It was predicted that tool purchase in the bonus condition would be significantly more frequent than in the insurance condition. However, whereas in Japan bonus purchase was more frequent than insurance purchase—67.5% of games in the bonus condition were completed with at least one player having purchased the tool compared to 43% in the insurance condition, the mean number of tool purchases per individual did not differ significantly across conditions—mainly due to high variances within the groups. In Europe, no significant differences were found, either. Moreover, the insurance tool was, in fact, used more often than the bonus tool. However, tool purchase rates in general were low: 76.1% of games in the bonus condition and 60.1% in the insurance condition were played without any tool purchases prior to the start of the games. These findings are in contrast with previous results of Gerber and Wichardt (2009) who found striking differences in the usage of the two tools—whereas only 23% of the games in their bonus condition were completed without either player choosing the tool, in the insurance condition, this figure was as high as 73.5%. The present, non-significant results could be explained by the detailed and illustrated instruction materials which presented the participants with all possible payoff scenarios resulting from their tool purchase. Also, the software used in this experiment included an automatic update of the game's payoff function to reflect any tool purchases by the respective players. This payoff update was not available in Gerber and Wichardt's original software and its presence in this study could have reduced the participants' cognitive load—particularly in the more difficult insurance condition—which ultimately led to less pronounced difference in tool usage.

Little learning was evident as regards the use of either bonus or insurance tools. Only in Japan, there was a linear increase in the use of insurance tools, indicating that the participants gradually learned the benefits of this type of tool. For the European sample, however, no temporal patterns were found.

The next hypothesis concerned cooperation levels in games where at least one tool had been purchased. In line with the predictions, opting for either the bonus tool or the insurance tool significantly increased cooperation compared to games of the same game condition where no tool had been chosen. Furthermore, this effect was confirmed across both Japan and Europe, indicating that—once applied—both tools' benefits were recognised by the participants, leading to an improvement of commitment and social certainty in the games. However, the effects of the tools differed depending on the country and the game condition. Overall, the purchase of commitment-enhancing tools led to larger increases of cooperation in Japan compared to Europe, indicating a better understanding of the tools' benefits among the Japanese participants. Furthermore, the bonus tool was more effective in increasing cooperation compared to the insurance tool, suggesting that—once the changes of the tools had been applied—the benefits of the bonus tool were easier to comprehend than the insurance tool.

The next hypothesis, which had projected lower cooperativeness in the standard game condition compared to the bonus and insurance conditions, was only partly confirmed. In Europe, the control condition yielded significantly lower cooperation levels than the two tool conditions whereas the bonus and the insurance conditions did not differ significantly from one another. In Japan, on the other hand, cooperation in the standard game produced similar mean exit points compared to the bonus condition, and both the standard and the bonus conditions yielded significantly higher cooperation than the insurance condition.

A more detailed look at the tool conditions, conducting separate analyses of exit points for games where no player, one or two players had purchased tools, provided further insight. Comparing the standard Centipede game with the zero-tool games from the bonus and insurance conditions showed significant differences in cooperativeness in the Japanese participants between all three conditions, with the standard condition being the most cooperative, followed by the insurance condition and, lastly, the bonus condition. Given that the payoff structures of these games were identical, these results are surprising. A possible explanation could be signalling effects of the initial choice against the bonus or insurance in the respective tool conditions. It appears that the refusal to purchase a tool was interpreted as a refusal to commit and a sign for likely defection early in the game. As a result, assurance-based trust is likely to have been lowered for these zero-tool games which ultimately explained earlier defection—particularly in the slightly simpler bonus condition.

However, despite the low levels of cooperativeness in the zero-tool games of the bonus condition, the condition produced similar mean exit points compared to the standard game condition. This finding can be explained by the high number of bonus choices which led to significantly later exit points in those games affected. Overall, the very high cooperation levels of the games with bonus choices balanced out the very low cooperation levels of the games without bonus choices, consequently producing seemingly similar mean exit points as the standard game condition.

In the insurance condition, on the other hand, tool choices were less frequent and the insurance tool—despite improving cooperation compared to zero-tool games—was significantly less effective than the bonus. Hence, the games with insurance choices failed to balance out the low cooperativeness of the games without insurance choices, therefore producing significantly lower mean exit points overall compared to the standard and the bonus conditions.

Hence, it appears that offering bonus and insurance tools in Japan to increase security in the game can increase cooperation, but only if at least one player per game actually opts to purchase the respective tool. If neither player chooses the tool, then these decisions could be interpreted as initial signals of non-cooperation by the participants, ultimately resulting in earlier exits in the game. These findings are in contrast with the study by Gerber and Wichardt (2010) which reported no differences between the exit points of the control condition and of the zero-tool games from the bonus and insurance conditions.

The same comparison of zero-tool games was conducted for the European sample and produced almost opposite results compared to Japan: The zero-tool games of the bonus and insurance conditions yielded significantly higher cooperation levels than the standard game condition. This suggests that in Europe, the mere offer of a commitment-enhancing tool—regardless of whether the players actually chose it—led to more committed and more cooperative strategies in the game. This finding could be explained by priming effects where the instructions about commitment-enhancing tools and the recurrent offers of tool purchase primed the participants to exhibit more commitment in the following decision tasks.

The higher cooperation levels of the zero-tool games due to priming effects of the tool availability, in combination with the higher cooperation levels of games where either one or two players had purchased tools, can explain the overall higher cooperativeness of European participants in the bonus and insurance conditions compared to the control.

As predicted, tool purchase was significantly more frequent in Japan than in Europe. These results suggest a higher need of social certainty and commitment among the Japanese participants, and they corroborate previous trust theories stating the historically close relationships in Japanese society as a reason for higher commitment, loyalty and assurance-based trust compared to Western cultures (Kiyonari, Yamagishi, Cook, & Cheshire, 2006; Yamagishi & Yamagishi, 1994; Yuki, 2003; Yuki, Maddux, Brewer, & Takemura, 2005).

5.2.4.2: Individual difference variables

With regard to the influences of individual difference variables, SVO scores were found to be very similar between the two samples corroborating previous studies investigating SVO prevalence such as Yamagishi et al. (2013) and Balliet, Parks, and Joireman (2009). These non-significant findings support the questions raised regarding previously stated cultural differences in individualism and collectivism (e.g., Oyserman, Coon, & Kemmelmeyer, 2002; Voronov & Singer, 2002). If the cultural dimension of individualism (Hofstede, 2010) is indeed a meaningful concept in this context, then Japan—a nation previously identified as largely collectivist—should surely have produced more prosocial SVO scores than the largely individualistic UK. Since this was not the case, the present findings lend support to Voronov and Singer’s claims that the difference between individualism and collectivism may be merely behavioural and not reflective of true differences in underlying social values.

The predicted differences in risk-taking and general trust were only partly confirmed. As expected, risk-taking scores in Japan were significantly lower across four out of five sub-scales while risk-perception remained similar to the European participants. These results indicate higher risk-aversion in Japan with the exception being ethical risk taking (e.g., having an affair with a married main/woman) where the self-reported likelihood of engaging in risky activities appears to be similar as in Europe. These differences in risk-taking are in agreement with previous experimental evidence for lower cooperation in risky games by Japanese compared to US participants (Cook et al., 2005).

General trust, however, did not differ across Japan and Europe as both samples scored moderately high on the general trust questionnaire. This is in contrast with repeated findings of lower general trust in Japanese participants compared to Western (US) participants (e.g., Kiyonari et al., 2006; Yamagishi & Yamagishi, 1994). It is possible that European participants differ from US participants and are, in fact, similarly trusting in situations of low social certainty as Japanese participants. Another explanation for the surprising results could be the short trust questionnaire that was used to measure general trust. Future research could follow up on these results and conduct more inclusive cross-cultural comparisons of general trust, comparing a number of different Western and non-Western nations.

Finally, correlations between individual differences and cooperation measures in the games were examined. It was predicted that higher levels of prosociality, risk-taking and general trust would be positively related to cooperativeness. Indeed, SVO was correlated with cooperativeness and it was found that higher prosociality was associated with higher levels of cooperation. However, whereas significant correlations were also found for four out of five risk-taking scales, the relationships were negative rather than positive: Lower risk-taking was associated with higher cooperation levels in the games. This unexpected result can be explained by the fact that the Japanese participants, who were generally more risk-averse than the European participants, were more cooperative in the games. However, a causal relationship with low risk-taking resulting in high cooperation can be ruled out, because the significant correlations disappeared for most game conditions when running separate correlation analyses for the Japanese and the European samples.

5.3: Study 6

The second cross-cultural experiment set out to follow up on Study 5. Using the same Centipede game, this experiment aimed to increase the game's applicability to real-life decision contexts by introducing treatment conditions with incomplete information. The bulk of research on experimental games has focused on decision-making contexts with clearly defined rules, known payoffs, and complete information of these. Complete information is achieved if all decision makers involved in the game are informed about all rules of the game and the payoffs to themselves and all other players in every possible outcome of the game, and if all players know that all players know that all players know these facts, and so on ad infinitum.

Nevertheless, games with limited payoff information may be much closer models of real-life decision situations, where certain aspects of an interaction's possible outcomes may be unknown or at least uncertain. Only very few studies, including Croson's (1996) study on Ultimatum games, investigated experimental games with partial information. In this type of game, two participants are assigned to different roles—Proposer and Responder—the former of which receives an initial endowment that has to be shared with the Responder. Following the Proposer's decision regarding the proportion of the share, the Responder has to decide whether to accept or reject the offer, with rejection resulting in zero payoffs to both players. Croson found that if the Responders in the Ultimatum game did not know the overall pot of money at stake, the offers made by the Proposers were significantly lower than offers in a control condition where the size of the pot was known. The study further showed that in Ultimatum games with complete payoff information, offers presented as percentages (rather than as absolute payoffs) led to a significant increase in rejection rates and overall higher demands by the Responders, possibly because the relative payoff information increased inter-player comparisons and resulted in stronger considerations of fairness. Taken together, these findings indicate that the amount of payoff information as well as the framing of this information, either as absolute payoffs (total values) or as relative payoffs (percentages), could affect decision making in experimental games.

This experiment aimed to follow up on Croson's (1996) study and to test for the effects of incomplete payoff information in the Centipede game. In particular, this experiment compared (a) standard Centipede games (Condition 1); (b) complete-information games where the payoffs were framed as percentages (Condition 2); (c) incomplete-information games where participants knew only their personal absolute payoffs (Condition 3); and (d) incomplete-information games where participants received only relative payoff information about their share of an unknown pot of money (Condition 4). No significant differences between Treatment Conditions 1 and 2 were expected, as both are characterised by complete payoff information, albeit framed in different ways. This prediction contradicts Croson's (1996) findings of framing effects in Ultimatum games and can be explained with reference to the inherent differences between Ultimatum and Centipede games, Ultimatum games placing an even greater emphasis on fairness and payoff equality than Centipede games. By framing payoffs as proportions of the total amount of money at stake, Responders in the Ultimatum games were reminded of their inferior player roles and their lower prospective outcomes compared to the Proposer. In the Centipede game, despite the existence of player asymmetry, the payoff inequalities are more balanced, with participants in the role of Player A benefitting at uneven exit nodes and participants in the role of Player B benefitting at even exit nodes. Therefore, no framing effects were expected in the games of the present study.

However, it was predicted that as a result of the decreased predictability of the co-players' moves in games with incomplete payoff information and the consequent riskiness of cooperative GO moves, Centipede games with incomplete payoff information would yield significantly lower levels of cooperation than games with complete information.

Furthermore, Treatment 4, with relative payoff information only, was hypothesised to result in particularly low cooperation levels due to the increased emphasis on player inequality, which taps into prosocial concerns for fairness.

Finally, in order to pinpoint reasons other than assurance-based trust for any behavioural differences between countries and treatment conditions in the study, the same individual difference variables were assessed as in Study 5: SVO, risk-taking, and general trust.

5.3.2: Method

The section below details information about the participants (Section 5.3.2.1), the Design (Section 5.3.2.2), Materials (Section 5.3.2.3) and Procedure (Section 5.3.2.4) of this experiment.

5.3.2.1: Participants

The sample comprised 100 Japanese nationals recruited at Hokkaido University Japan and 80 UK nationals recruited at the University of Leicester. Whereas the first cross-cultural experiment reported in this chapter used a more heterogeneous UK sample which included both British and other European students, this experiment aimed to improve the method by homogenising the sample and recruiting UK nationals only. All participants were undergraduate students. The Japanese sample included 63 males, 33 females, and 4 of unknown gender, with a mean age of 19.14 years (*SD* = 1.02), all of whom were remunerated with ¥1000 (US$8.14) for participation. The UK sample consisted of 15 males and 85 females, with a mean age of 19.25 years (*SD* = 2.71), who received course credits for taking part. Again, all participants were incentivised with a between-subjects random lottery incentive system. Nine participants across countries (one per testing session) were randomly selected to receive their payoffs from a randomly chosen game they completed during the experiment. The games' payoffs were converted into the respective countries' currencies at the same rate as in Study 5. In Japan, the average lottery win per person was ¥5173.33 (US$43.72) and in the UK it was £17.53 (US$25.33).

5.3.2.2: Design

The study employed a 2 (Nationality) × 4 (Treatment Condition) factorial experimental design. The participants in both countries (Japan and the United Kingdom) were randomly assigned to one of the following four treatment conditions that varied in the amount and type of information provided about the payoffs: (a) Centipede game with complete information and payoffs displayed in monetary units (Condition 1); (b) Centipede game with complete information and payoffs displayed as percentages of a pot containing a known number of monetary units (Condition 2); (c) Centipede game with absolute information about own payoffs only (Condition 3); and (d) Centipede game with relative payoff information compared to the co-player only (Condition 4), (see Figure 5.11). Again, the main dependent variable was the mean exit point.

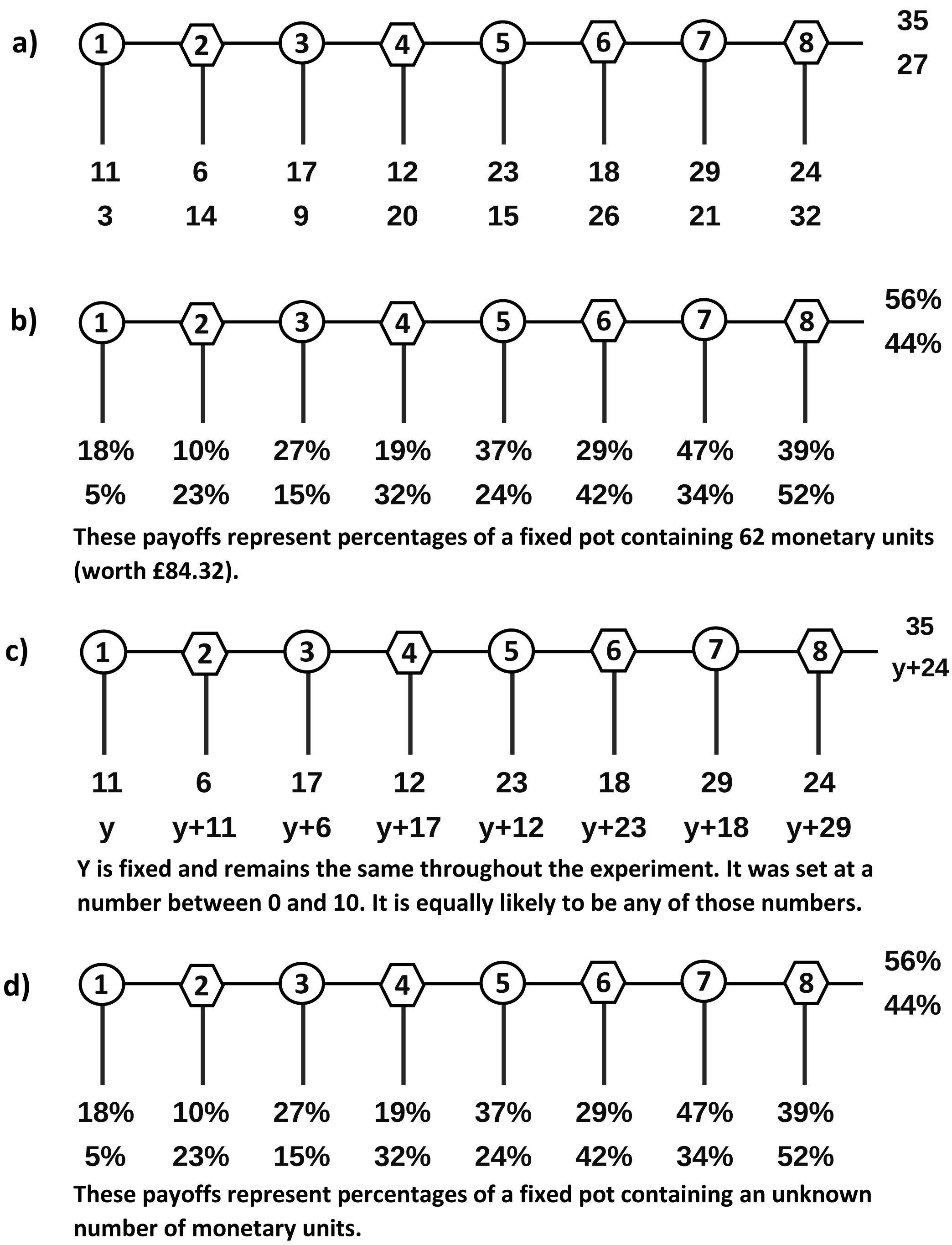


Figure 5.11. Four treatment conditions: (a) standard Centipede game; (b) standard game with payoffs framed as %; (c) games with absolute payoff information only; and (d) games with relative payoff information only.

For a behavioural measure of altruism, the number of games per individual reaching the natural end (Exit Node 9) out of 20 games in total was calculated, with higher numbers indicating higher levels of altruism. Additionally, the number of exit moves made by each individual across twenty game rounds was assessed again. Finally, three individual difference variables—SVO, risk-taking/risk-perception, and trust—were computed from questionnaire measures as described in Study 5.

5.3.2.3: Materials

The experiments were run in large computer laboratories in Japan and the UK. Participants were seated at individual computer desks—in Japan these were separated with dividing walls, in the UK by generous spacing of desks—and interacted in the Centipede game through a colourfully illustrated, custom-made web application with animated instruction pages. These pages contained the rules of the game, explained in simple and neutral lay terms.

The Japanese participants were presented with the instruction slides fully translated into Japanese. For the actual game interactions with real-time feedback, they received translation booklets containing pictures of example screens with Japanese translations of all English words and sentences. Across both countries, participants were given paper copies of the same questionnaires as were used in Study 5.

5.3.2.4: Procedure

The data were collected in testing sessions of exactly 20 participants at a time. Each treatment condition was run in one testing session. In Japan, an additional testing session was run for Condition 1 (standard Centipede game), because the first session contained an unusually high number of second-year students who had previously participated in other studies of experimental games and might be considered more experienced. Since no significant differences between the resulting two data sets were found, the data from the two sessions were combined for the results reported in this article. Each testing session lasted between 50 and 70 minutes. The participants were told not to communicate with each other and to switch off their cell (mobile) phones. The experimenters ensured that they were focusing on their own computer screens and materials at all times.

After the participants filled in the consent form, the computer randomly assigned each participant a player role (Player A or B) in which they remained for the rest of the experiment. Participants were then presented with the computerised game instructions. The experimenters encouraged questions at all times, and answers were provided in private. After reading the instructions, the participants completed a form assessing their understanding of the game and its payoffs. The experimenters checked all replies and quietly corrected the participants in case of mistakes. Subsequently, all participants completed 20 rounds of Centipede games. After each round, the computer randomly and anonymously selected a new co-player for each participant. The web application provided real-time feedback to participants of the choices of their co-players, the game outcomes, and the number of games left to complete. After the final game round, one participant was randomly selected as winner of the lottery payment. All participants received their show-up fee or course credits at the end of the testing session. The lottery winners also received their additional payments.

5.3.3: Results

The results section is subdivided into two parts which focus on the analysis of exit points (Section 5.2.3.1) and the analysis of individual difference variables (Section 5.2.3.2) respectively.

5.3.3.1: Analysis of exit points

A detailed overview of game terminations per exit nodes across treatment conditions and countries is provided in Figure 5.12. The game exit charts display mostly bell-shaped curves centred on varying modes depending on the treatment condition and the country. The Japanese exit curves show that Node 5 was the modal exit point in Condition 1 and Node 6 in Condition 2 (both with complete payoff information), Node 7 was modal in Condition 3 (absolute payoff information only) and, remarkably, that the final Exit Node 9 was the modal exit point in Condition 4 (relative payoff information only). In comparison with the Japanese data, the UK exit curves tend to peak more toward the left, indicating lower mean exit points and hence fewer cooperative moves. With the exception of Condition 3 (absolute payoff information only), which yielded a modal exit point of 4, all other UK treatment conditions were most frequently terminated at Node 5.

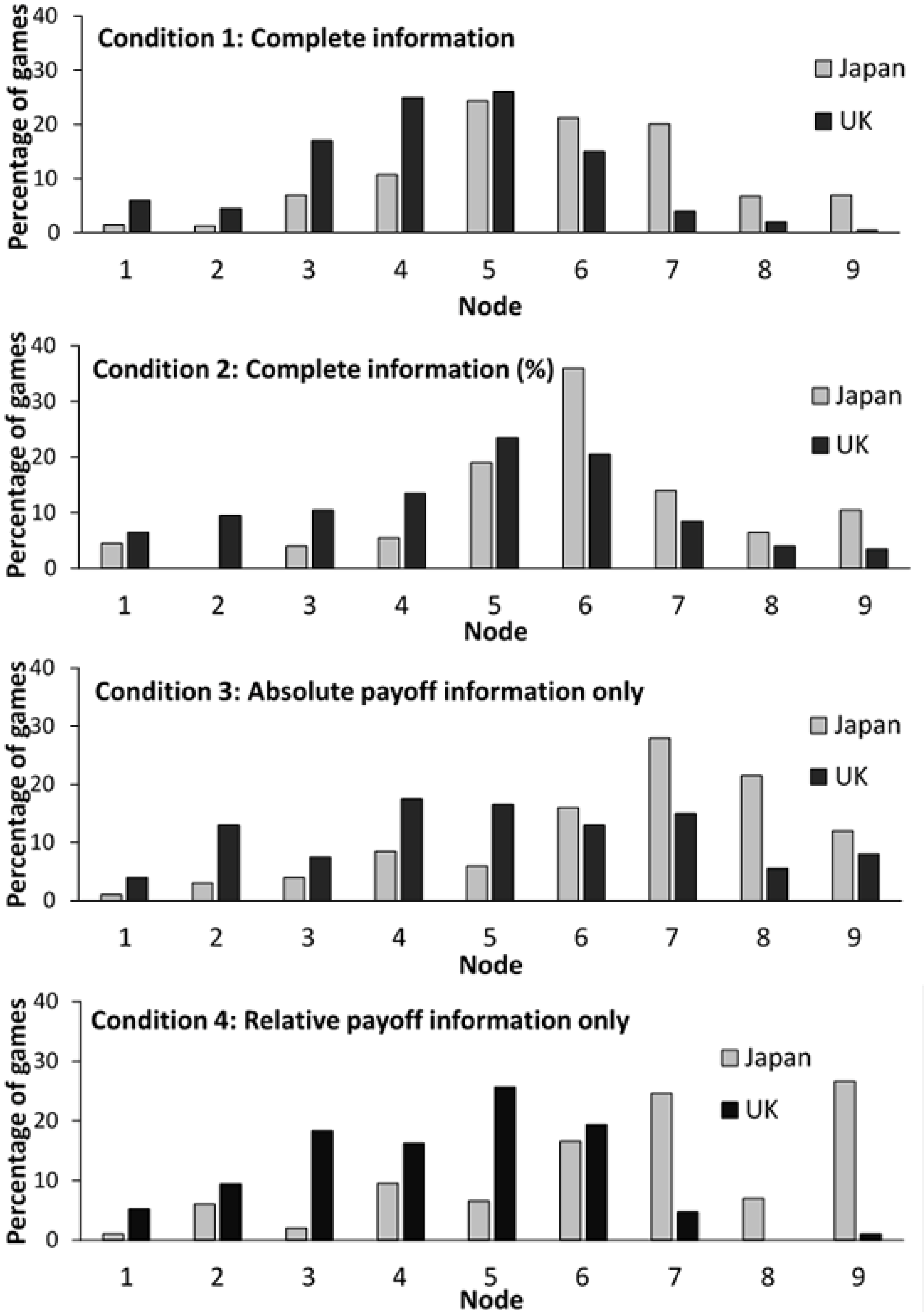


Figure 5.12. Percentages of games terminated at each exit point in Japan and the UK across the four treatment conditions.

A two-way ANOVA was carried out to test for effects of nationality and treatment conditions on mean exit points in the Centipede game. Descriptive statistics for each country and treatment condition are displayed in Table 5.6. A significant main effect was found for nationality, with the mean exit points of Japanese participants significantly higher (*M* = 6.13) than those of UK participants (*M* = 4.61), $F(1, 165) = 97.452$, $p < .001$, $\eta_p^2 = .46$.

Table 5.6

Mean Exit Points and Standard Deviations per Country and Treatment Condition

	C1: Complete information	C2: Complete information (%)	C3: Absolute information only	C4: Relative information only	Total
Japan	5.78 (0.91)	5.94 (0.99)	6.55 (0.79)	6.61 (1.37)	6.13 (1.01)
UK	4.35 (0.63)	4.75 (0.82)	5.04 (0.85)	4.31 (0.60)	4.61 (0.78)
Total	5.28 (1.07)	5.34 (1.08)	5.80 (1.11)	5.40 (1.46)	5.44 (1.18)

Treatment condition also had a significant effect: $F(3, 165) = 4.276$, $p < .005$, $\eta_p^2 = .10$. Given the additional finding of a significant interaction between nationality and treatment, $F(3, 165) = 2.949$, $p < .05$, $\eta_p^2 = .05$, the effects of the treatment conditions varied depending on the country where the experiments were conducted. In Japan, Condition 1 (complete information) had the lowest exit points (*M* = 5.78), followed by Condition 2 (complete information in percentages) (*M* = 5.94), Condition 3 (absolute payoff information only) (*M* = 6.55), and Condition 4 (relative payoff information only) (*M* = 6.61). Pairwise comparisons using Tukey-HSD tests indicated that the mean exit points in Condition 3 and Condition 4 were significantly higher than in Condition 1 and Condition 2 ($p < .05$). Conditions 1 and 2 did not significantly differ from each other, and neither did 3 and 4. In the UK, Condition 4 was found to have the lowest mean exit point (*M* = 4.31). This was followed by Condition 1 (*M* = 4.35), Condition 2 (*M* = 4.75), and Condition 3 (*M* = 5.04). Tukey-HSD post-hoc comparison showed that the mean exit point in Condition 3 was significantly higher than those in Condition 1 and Condition 4 ($p < .05$). Conditions 1, 2, and 4 did not differ significantly from one another.

In order to rule out confounding gender effects, given the different gender proportions across the Japanese and the UK sample, a three-way ANOVA was conducted, testing for the effects of gender in addition to nationality and treatment condition on mean exit points. The ANOVA revealed no significant main effect of gender on mean exit points, $F(1, 159) = 0.011$, $p = .918$, nor any two-way or three-way interactions including gender.

To examine factors determining altruistic behaviour in the Centipede game, an additional two-way ANOVA was carried out, testing whether nationality and treatment condition affected the mean number of games per individual that reached Node 9. The means and standard deviations are displayed in Table 5.7. A significant main effect was found for nationality, with the number of games per individual reaching Node 9 significantly higher in Japan ($M = 2.52$) than in the UK ($M = 0.65$), $F(1, 172) = 33.909$, $p < .001$, $\eta_p^2 = .17$.

Table 5.7

Mean Number of Games per Individual Reaching Node 9, Per Country and Treatment Condition

	C1: Complete information	C2: Complete information in %	C3: Absolute information only	C4: Relative information only	Total
Japan	1.40 (2.41)	2.10 (2.73)	2.40 (2.85)	5.30 (4.71)	2.52 (3.41)
UK	0.10 (0.31)	0.70 (0.98)	1.60 (1.31)	0.20 (0.41)	0.65 (1.03)
Total	0.97 (2.01)	1.40 (2.15)	2.00 (2.23)	2.75 (4.19)	1.69 (2.79)

Treatment condition was also found to have a significant effect, $F(3, 172) = 5.674$, $p < .005$, $\eta_p^2 = .09$. But again, an additional significant interaction between the two factors was found, $F(3, 172) = 6.896$, $p < .001$, $\eta_p^2 = .107$, as evidenced by the different effects of the treatment condition depending on the nationality of the participants. In Japan, Tukey-HSD post-hoc comparison showed that Condition 4, with relative payoff information only, produced significantly more altruistic end-moves than Condition 1 ($p < .001$), Condition 2 ($p < .01$), and Condition 3 ($p < .05$), which did not differ from one another. In the UK, it was Condition 3, with absolute payoff information, that yielded significantly more games reaching the final exit node than

Condition 1 ($p < .001$), Condition 2 ($p < .01$), and Condition 4 ($p < .001$), which did not differ significantly from one another (Tukey-HSD tests).

5.3.3.2: Analysis of individual difference variables

Several *t* tests were conducted to compare continuous SVO scores, trust scores, and different risk-taking and risk-perception scores between Japan and the UK. For each analysis, a Levene's test for equality of variances was conducted to ensure the assumption of homogeneity of variance was met. Violations of the assumption were found only for health/safety risk-taking and recreational risk-taking, where the UK sample showed significantly larger data variances than the Japanese sample ($p < 0.5$). The *t* test results for those variables therefore need to be interpreted with greater caution. The descriptive statistics are presented in Table 5.8.

Table 5.8

Means and SD (in Parentheses) for SVO, Trust and Risk-Taking by Country

	Country	
	Japan	UK
SVO, continuous	22.72	22.54
	(14.66)	(15.49)
Trust	19.43	20.7
	(5.55)	(6.37)
Risk-taking		
Ethical risk-taking	13.79	13.8
(e.g., Having an affair with a married man/woman)	(5.16)	(5.23)
Financial risk-taking	11.8	15.9
(e.g. Betting a day's income at the horse races)	(6.13)	(6.59)
Health/safety risk-taking	15.01	19.8
(e.g., Driving a car without wearing a seat belt)	(4.94)	(7.11)
Recreational risk-taking	17.29	22.09
(e.g., Going camping in the wilderness)	(7.83)	(9.1)
Social risk-taking	27.33	29.86
(e.g., Admitting that your tastes are different from those of a friend)	(4.68)	(5.7)
Risk-perception		
Ethical risk-perception	25.49	24.8
(e.g., Having an affair with a married man/woman)	(5.97)	(4.63)
Financial risk-perception	30.97	30.48
(e.g., Betting a day's income at the horse races)	(7.42)	(6.25)
Health/safety risk-perception	29.95	30.38
(e.g., Driving a car without wearing a seat belt)	(6.29)	(6.06)
Recreational risk-perception	26.88	26.04
(e.g., Going camping in the wilderness)	(6.58)	(6.36)
Social risk-perception	18.55	17.71
(e.g., Admitting that your tastes are different from those of a friend)	(5.13)	(5.36)

No significant differences were found between the SVO scores, $t(178) = 0.079$, $p = .937$, with participants of both countries producing mean scores falling within the boundaries of the cooperative SVO category but close to the individualistic category. Additionally, a chi-square test of independence was used to compare the numbers of participants falling within the individual SVO categories for each country. Again, no significant differences were found, $\chi^2(2, N = 180) = 0.936$, $p = .626$. In Japan, 53% of participants were categorised as cooperative, 46% as individualistic and 1% as competitive. In the UK, 56.25% of participants qualified as cooperative and the remaining 43.75% as individualistic.

Comparing the different risk-taking subscale scores, no significant differences were found between Japanese and UK participants on the ethical risk-taking subscale, $t(175) = 0.033$, $p = .973$. However, on all other subscales the Japanese participants scored significantly lower than UK participants, including financial risk-taking, $t(177) = –.304$, $p < .001$, health/safety risk-taking, $t(176) = 5.291$, $p < .001$, recreational risk-taking, $t(176) = –3.786$, $p < .001$, and social risk-taking, $t(177) = –3.259$, $p < .01$. As regards risk-perception on the individual sub-scales, no significant differences were found between countries. The lower risk-taking scores, in spite of similar risk-perception scores in Japanese participants, indicate higher risk-aversion of Japanese than UK participants.

With regard to the trust scores, no significant differences were found, $t(178) = –1.428$, $p = .155$. With mean trust scores of 19.43 in Japan and 20.7 in the UK (out of a possible 35 points, indicating perfect trust), participants across both countries showed moderately high levels of general trust.

For the total sample of Japanese and UK participants, a Pearson product-moment correlation revealed a significant negative relationship between the continuous SVO score and the number of exit moves an individual made for the two treatment conditions with complete information. Both correlations were negative—Condition 1, $r = –.343$, $n = 60$, $p < .01$, and Condition 2, $r = –.405$, $n = 40$, $p < .01$—thus demonstrating that the number of exit moves decreased with higher (more prosocial) SVO scores. However, much weaker non-significant correlations were found for these two variables in Condition 3 ($r = –.183$, $n = 40$, $p = .259$), and Condition 4 ($r = –.238$, $n = 39$, $p = .144$). Also, neither trust nor any of the risk-taking scores were correlated with the number of exit moves (see Figure 5.13).

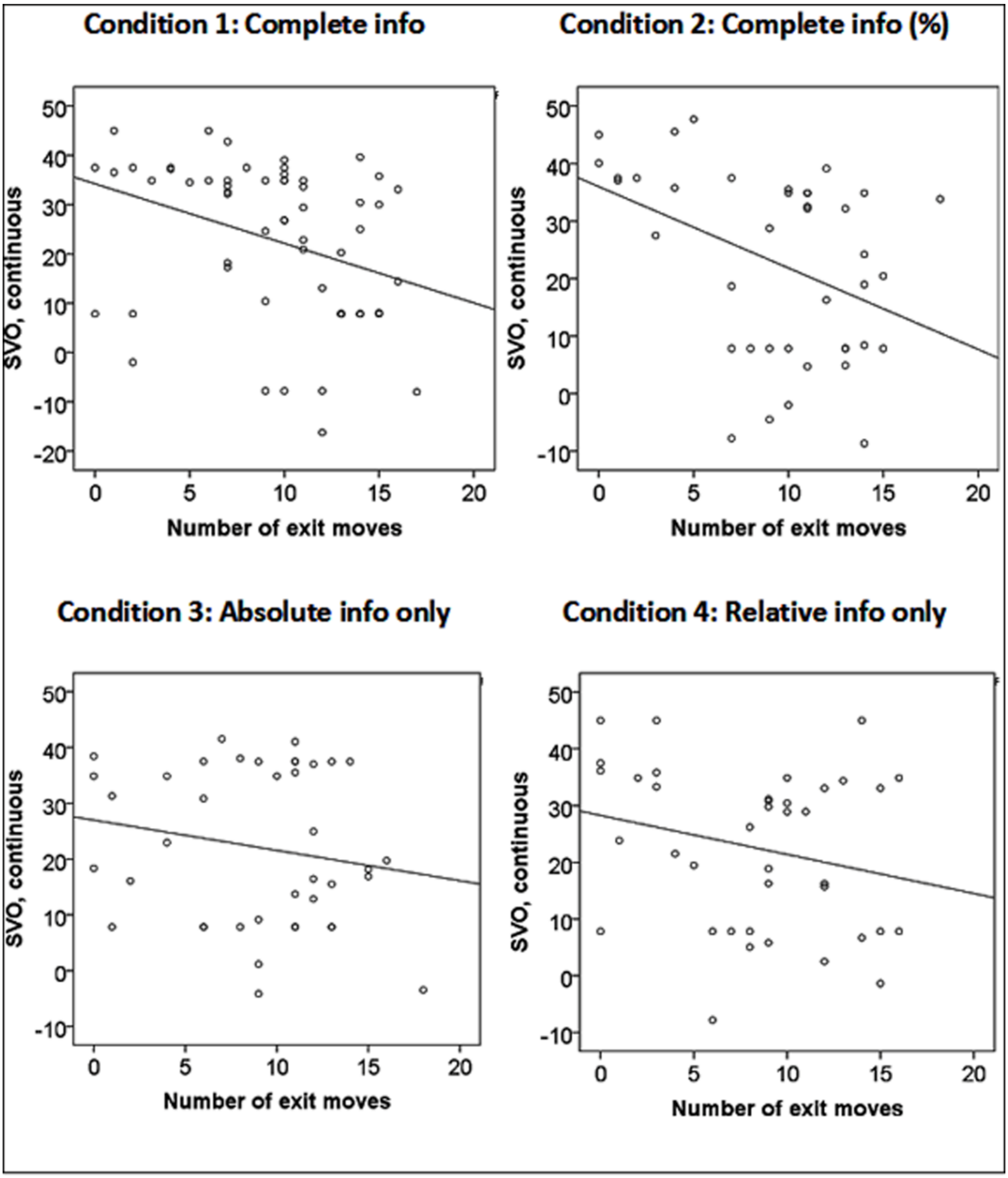


Figure 5.13. Scatterplots displaying continuous SVO score and number of exit moves for the four treatment conditions and best-fitting linear regression lines.

5.3.4: Discussion

This study reports the second cross-cultural experiment on decision making in the sequential Centipede game, comparing Japanese and UK nationals across four treatment conditions that differed in the amount of payoff information provided. The results demonstrate significant differences in cooperation levels between both countries and treatment conditions. The Japanese participants exited significantly later in the game and were thus significantly more cooperative than the UK participants across all treatment conditions. With regard to the number of games reaching the final exit point—an outcome dependent on an altruistic GO move by Player 2 at the penultimate node—the Japanese showed, once again, significantly higher scores than the UK participants. These findings support the first hypothesis, which predicted that repeated interactions with the same co-player in the Centipede game would elicit culturally typical assurance-based trust in Japanese participants (Yamagishi & Yamagishi, 1994), thus leading to higher levels of reciprocity, cooperation, and even altruism than among British participants. The results are further in line with those of Study 5 in spite of slightly different recruitment criteria for the two UK samples.

The treatment condition (i.e., amount of payoff information provided) was also found to influence cooperation, but the effects differed across countries. In Japan, the two treatment conditions with incomplete payoff information yielded significantly later game exits and hence higher cooperation levels than those with complete information. Notably, Condition 4 (relative information only) yielded a very large percentage of games reaching the natural end (26.63%), and statistical analyses revealed this result to be significantly higher than for both treatment conditions of complete information. In the UK, Condition 3, with absolute information only, led to a similar significant increase of cooperation compared to the standard Centipede game. It was also the condition with the highest percentage of games reaching the natural end (8%)—significantly higher than in all other treatment conditions. In contrast with the Japanese results, however, the other incomplete information treatment condition—relative information only—did not differ significantly from the standard Centipede game and elicited, in fact, the earliest exit moves out of all four treatment conditions.

Taken together, these results corroborate Croson's (1996) findings regarding the importance of quantity and type of payoff information provided in experimental games. In line with prior expectations, no significant differences between the two treatment conditions of complete information were found, demonstrating that the framing of the payoffs as either points (monetary units) or percentages did not affect decision making in the games.

However, the results strongly challenge the second prediction that incomplete information would reduce cooperation. A possible explanation could be that participants drew on previous experiences and were guided by their personal expectations about the likely stake sizes when making their choices in incomplete information games. In addition to the show-up fee, the maximum payment to be won in each session was £47.60/¥8481.20 (approximately US$71.60)—a large amount of money for almost any university student. It is likely that both samples anticipated the stakes to be much lower. In Japan, most participants had previously participated in economic decision-making experiments with different types of games and much lower stakes (of approximately ¥1000). In the UK, most participants had never participated in experiments with real financial incentives. As with previous literature pointing to the importance of stake sizes, suggesting that lower stakes yield higher cooperation levels in the Centipede game (Rapoport et al., 2003), lower payoff expectations could explain the observed cooperativeness in games of incomplete information. This explanation is intuitively convincing for Condition 4, with relative payoff information only. In this treatment condition, the participants did not have any information about absolute payoff size which they could anchor their expectations in. If payoffs were expected to be very small, the differences between personal payoffs at individual nodes might have lost salience to participants. Particularly the more experienced Japanese participants may therefore have continued their reciprocal cooperation up until the game's final end, thus explaining the high levels of behavioural altruism observed in this sample.

However, the explanation of lower payoff expectations may also—to a lesser extent— apply to Condition 3 which provided information on absolute payoffs of the individual and therefore gave participants an idea of the personal stake size. Even though participants had accurate expectations about their own payoffs in this treatment condition, this payoff information may not have been sufficient to lower cooperation levels overall because participants remained ignorant of their co-players' stakes. If participants expected their co-players to be incentivised with significantly lower payoffs, they might have anticipated higher cooperativeness from their co-players, in which case it would have paid off to match the level of expected cooperativeness and choose GO more frequently.

Interestingly, the UK results for Condition 4 (relative payoff information) are still unaccounted for by this explanation. It is possible that the UK participants were more sensitive to concerns of fairness and equality, which—as predicted by the third hypothesis—may have been triggered by the relative payoff information in Condition 4. The heightened attention to player inequality could thus have counteracted the influence of lower payoff expectations, ultimately leading to earlier exits and lower cooperation levels than the other incomplete information treatment conditions.

As regards the individual difference measures assessed via questionnaires, very similar results were found as in the first cross-cultural experiment. As expected, no significant differences were found between the SVO scores of Japanese and British participants.

Again, the Japanese participants were found to be significantly more risk-averse than the UK participants on four of the five risk-taking subscales (the exception being ethical risk-taking), whereas risk-perception for these scales was comparable. No significant differences in general trust were found.

As expected, continuous SVO was again found to be correlated with cooperation in the game. Higher SVO scores (indicating higher prosociality) were correlated with lower numbers of exit moves (higher cooperation levels) in the two treatment conditions with complete information only. A possible reason why incomplete information games did not show the same correlation with SVO as Conditions 1 and 2 could be that the small amount of information about the other player's payoffs was insufficient to trigger prosocial concerns.

Neither risk-taking scores nor general trust were correlated with cooperativeness of the participants.

5.4: General discussion

This chapter investigated on cross-cultural differences in trust and cooperation using two behavioural Centipede experiments with optional commitment-enhancing tools and incomplete information respectively. In both studies, Japanese participants cooperated more frequently than British/European participants in the reciprocal decision sequences. This supports previous trust theories that stated the Japanese to exhibit more assurance-based trust and thus cooperativeness in close, sequential relationships compared to Western participants (e.g. Yamagishi & Yamagishi, 1994). An easily observable manifestation of this relationship approach in everyday decision making is the Asian (business) custom of reciprocal gift-giving. More research is necessary to examine cross-cultural differences in decision making between Japanese and different Western cultures. In addition to North American and UK cultures, other European cultures characterised by higher levels of collectivism (e.g., Germany) could be of interest. Future studies could investigate choices across different economic games, contrasting one-shot (e.g., Prisoner's Dilemma) games necessitating general trust with sequential (e.g., Centipede) games relying on assurance-based trust.

The introduction of commitment-enhancing tools in Study 5 produced very different results in Japan and Europe. It was found that Japanese participants opted more frequently for commitment-enhancing tools than European participants, thus confirming their higher need for social certainty. Also, across both countries, the use of commitment-enhancing tools was found to increase cooperation levels compared to games where no tools were chosen. However, the most interesting evidence was provided by those games where neither participant had opted for a tool. In Japan, these games showed significantly lower cooperation levels compared to the control condition where no tool had been offered in the first place. This was explained by signalling effects, with the refusal to opt for a tool suggesting a lack of commitment and likely defection in the game. In Europe, however, quite the opposite effect was observed: Even in games where neither participant chose a commitment-enhancing tool, cooperation was significantly higher compared to the control condition. These findings point to priming effects of the available tools, which increased commitment by increasing its salience to the European participants. Hence, whereas the offer of commitment-enhancing tools improved mutual cooperation in Europe—whether or not a tool was actually purchased by the players in the respective game—more complex effects were found in Japan, where tools only increased cooperation if they were, in fact, chosen by the participants, and otherwise resulted in a decrease of cooperation.

Study 6 found that incomplete information in decision-making contexts may lead to an increase of cooperation. It is possible that personal expectations, particularly regarding stake size, guide choices in decision contexts of incomplete information, with expectations of high stakes leading to lower cooperation levels, and expectations of low stakes leading to higher levels. If applied to real-life business decisions, this suggests the importance of transparency about personal aims from the outset of each interaction or partnership in order to manage confounding beliefs. In order to test for influences of different expectations directly, follow-up research could induce expectations through framed task instructions and compare subsequent decision making between treatment conditions. Alternatively, a more comprehensive account of motivations underlying decision making in the context of incomplete information could be achieved by administering qualitative self-report measures.

5.4.1: Limitations

Whereas strong efforts were made to achieve comparability between the two cross-cultural samples in both studies, a few methodological limitations need to be considered when evaluating the results presented in this chapter. Due to the use of convenience samples in both countries, the gender distributions differed substantially. The Japanese sample included a much larger proportion of male participants than the UK sample. However, while this imbalance was not ideal, no evidence was found of gender effects on decision making in either experiment.

Furthermore, based on local customs, compensation procedures differed between the two countries. In the Japan, all participants expected a show-up fee for attending the experiment. In the UK, a well-functioning course-credit system was in place, with most participants preferring remuneration through credits rather than money. This difference in compensation has been acknowledged, but it is necessary to draw attention to the fact that the crucial behavioural incentives (i.e., the money at stake during the games) was identical for both samples.

Finally, it is important to point out differences in experience between the Japanese and UK students. Most Japanese students had previously participated in incentivized, economic experiments whereas most UK students had not. Importantly, however, no participant in either country had previously participated in the Centipede game.

5.5: Conclusions

To conclude, this chapter reported the first experimental results on cross-cultural differences in economic decision making between Japanese and British participants. The Japanese were more cooperative in repeated interactions typical of long-term business partnerships, and this could be explained by the higher levels of assurance-based trust that are characteristic of Japanese culture. When faced with optional instruments to enhance commitment in repeated relationships—including for example business contracts or relationship contracts (i.e., marriage)—Japanese people opt for these instruments more frequently than Europeans, suggesting a higher need for security and stability in their interactions. However, while the mere availability of such commitment-enhancing options increases cooperation in Europeans, the Japanese might be more sensitive to rejection (i.e., refusals to choose these options), ultimately lowering their trust and increasing their defection. Furthermore, nationals of both countries were affected by the amount of information provided about the decision context in which they operated, and they appeared to rely on previous experiences and consequent expectations to make decisions under conditions of incomplete information. Follow-up research is necessary to compare Japanese and European cultures on a wider range of decision tasks and to explore the relative importance of different types of trust.

Chapter 6: General Discussion

This thesis investigated factors influencing human cooperation in repeated interactions. Specifically, it examined cooperative choices in variations of Rosenthal's (1981) Centipede game through a systematic literature review and six new, empirical studies presented in Chapters 2-5. Each of these studies addressed a different research gap identified by the systematic review in Chapter 1. In this concluding chapter a summary of the literature review and the novel findings are presented in Section 6.1. Returning to the research question, Section 6.2 contrasts and evaluates the most popular theories of cooperation in the Centipede game based on the supporting experimental evidence. Section 6.3 provides a research outlook and recommends future directions. Final conclusions are drawn in Section 6.4.

6.1: Summary of empirical findings

The systematic literature review in Chapter 1 provided an introduction by outlining the rampant cooperation rates in Centipede-type interactions evidenced by research to date (e.g., McKelvey & Palfrey, 1992), and identifying a number of factors that have been shown to affect cooperation. Constant-sum payoff functions without the possibility for improving joint payoffs in the game were found to lead to earlier defection (e.g. Fey et al., 1992), while increasing-sum payoff functions—particularly linear ones—generally yielded higher levels of cooperation (e.g., Pulford, Colman, Lawrence, & Krockow, 2017). Riskier payoff structures including high payoff asymmetry between players were shown to decrease cooperation (Cox & James, 2012; Horng & Chou, 2012). Negative effects on cooperation were also found when increasing the number of alternating players (e.g., Murphy et al., 2006) and when individual decision makers were replaced by group decision makers (e.g., Bornstein et al., 2004).

6.1.1: New empirical findings

To enable comparison between the novel data and previous research findings, the main quantitative results of Studies 1-6—percentage of games reaching natural end, percentage of games stopping at subgame-perfect equilibrium, and standardised mean exit point—are displayed in Figures 6.1 and 6.2 which are modelled on Figures 1.3 and 1.4 from Chapter 1. Looking at Figure 6.1, it is striking that none of the studies reported in this thesis came close to the extreme percentages of equilibrium play reported by some of the earlier Centipede research. Cox & James' (2012) experiment, for example, produced results of up to 96% of games terminating at Node 1. In contrast, the highest percentage reported by any study of this thesis was 39.8% (see Study 4, Appendix D). A likely explanation could be that none of the six studies in this thesis used any of the extreme Centipede variations introduced by Cox & James including games with simultaneous move structure and time pressure. Instead, some of the particular game designs employed in this thesis yielded remarkably high cooperation levels with high percentages of games reaching the game's natural end. In particular, the testing sessions conducted in Japan—particularly when combined with optional commitment-enhancing tools—produced very high percentages of up to 65.2%. The qualitative Study 1 also reported a high percentage of games with unconditional cooperation (30%). This could be attributed to the particular matching design which repeatedly paired participants with the same other co-player, thus allowing for the development of longer-term cooperation and reciprocity across games. Figure 6.2 displays all studies in this thesis ordered by their standardised mean exit points. A large proportion of research reported in this thesis focused on linearly increasing Centipede games. Interestingly, the mean exit points do not appear to differ much across games of different structural categories (i.e., linear, exponential and competitive Centipede game variations). It is possible that other features of the games—including the random termination rules of Study 4 and the comparatively high risk cost in the linear games of Studies 5 and 6—blurred the lines between game categories and decreased importance of the overall payoff function. Hence, an analysis comparing linear, exponential and competitive game variations appears no longer helpful.

It is further important to note that since all studies in this thesis were conducted using the direct response method, the application of present findings to research using the strategy method might be problematic. The following sections 6.1.1.1–6.1.1.4 review and summarise the results of each individual study reported in this thesis in more detail, following the chapter structure they were presented in. Additionally, a comprehensive synopsis is provided in Appendix D.

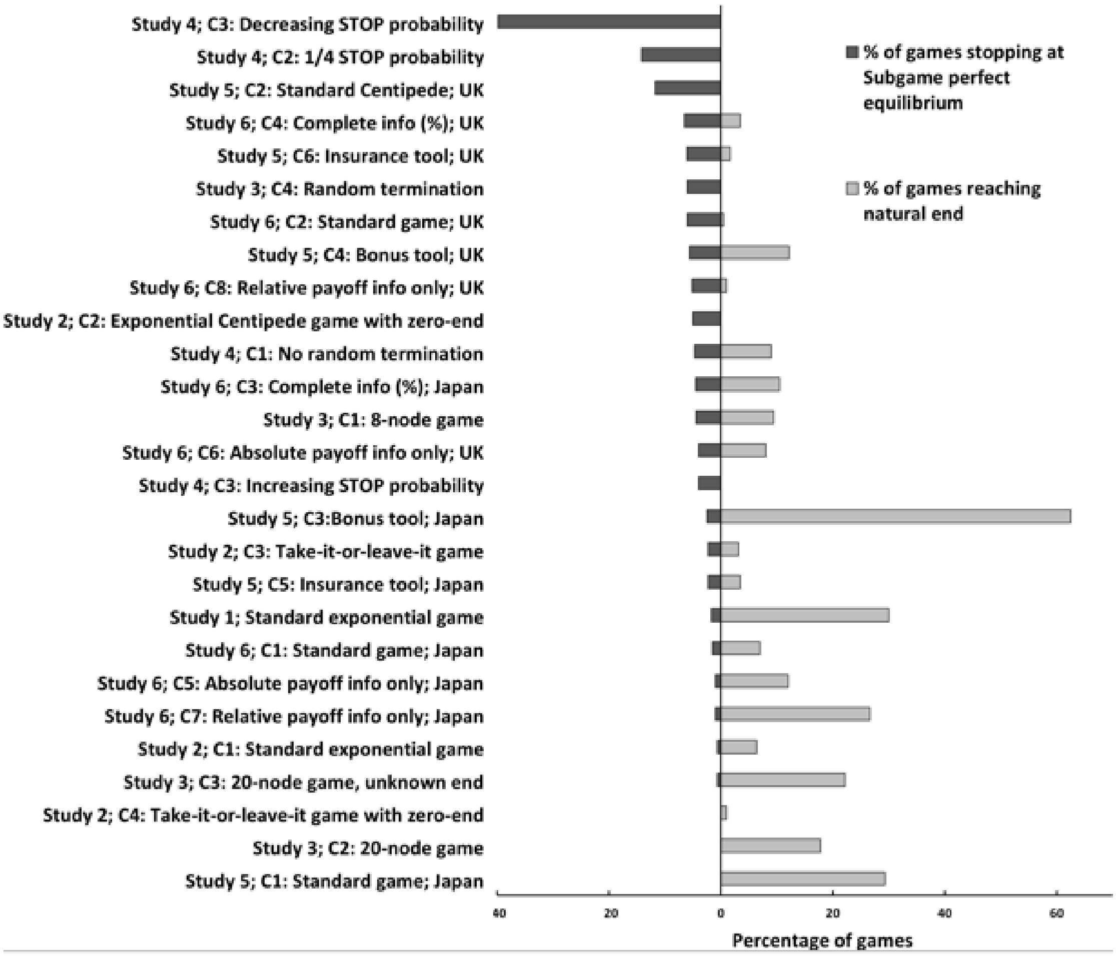


Figure 6.1. Game percentages ending at first and last terminal nodes across 23 treatment conditions ("condition" abbreviated "C").

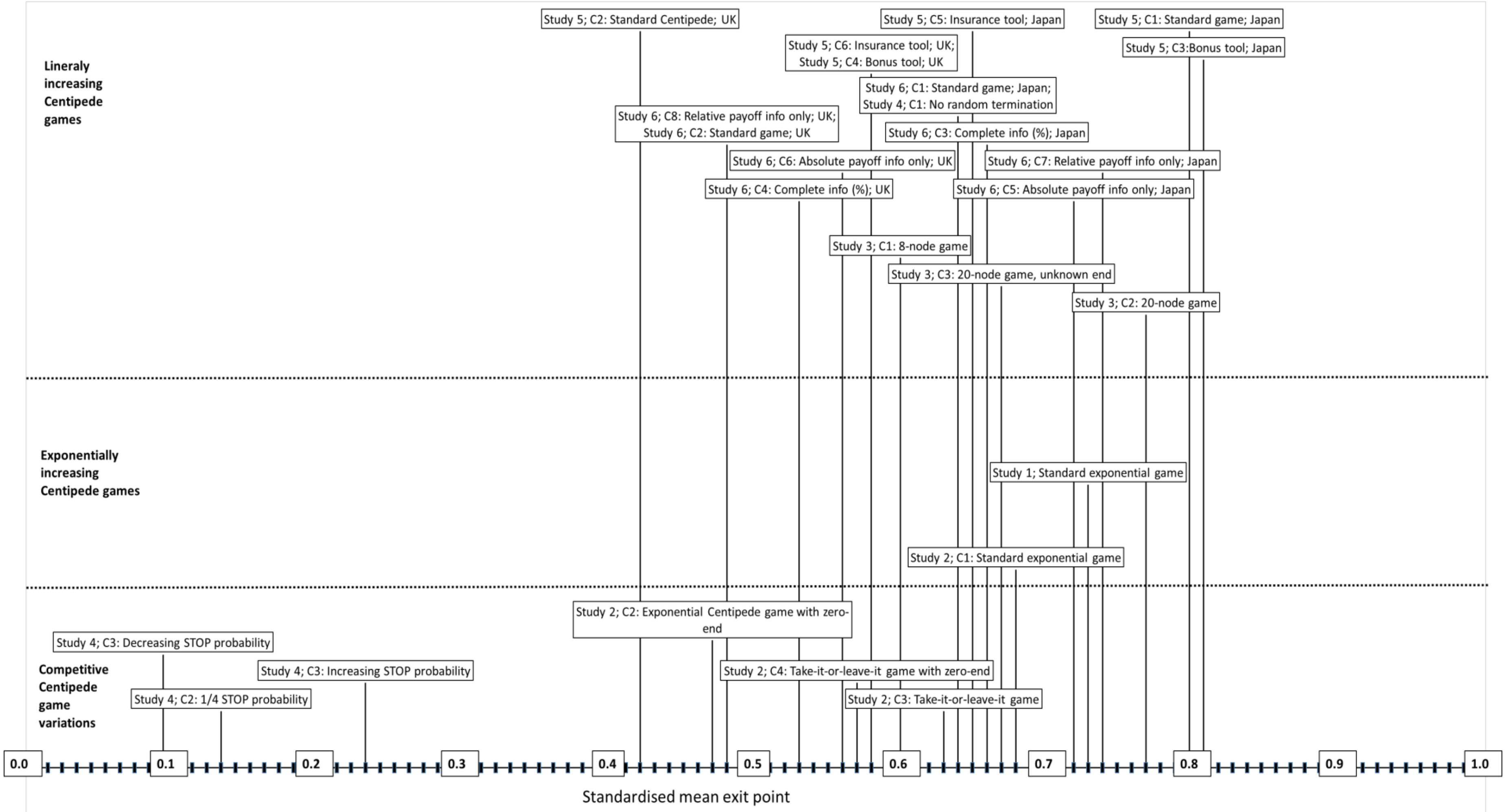


Figure 6.2. Standardised mean exit points across 22 treatment conditions reported in this thesis ("condition" abbreviated "C"), classified by payoff function types.

6.1.1.1: Chapter 2

Study 1 in Chapter 2 of this thesis presented qualitative data on decision making in the Centipede game. Using verbal protocol analysis, which produced a rich data set of intelligible thought processes during game play, a complex interplay of many different reasoning levels and motives was evidenced. Lower-level motives such as activity bias, probing, and curiosity seemed to play a large role for cooperation in the beginning of the game. Myopic maximax strategies of aiming for larger numbers were also frequently linked to cooperative choices. Other-regarding preferences such as prosocial value orientations appeared to become more prominent at later decision nodes, with altruistic and cooperative SVOs as well as a wish for completing the game being most commonly associated with a GO move at the final decision node.

Non-cooperative STOP moves, on the other hand, were mostly linked to an individualistic SVO and selfish considerations of risks and losses. The immediate STOP move at Node 1 was interpreted as particularly competitive. It was chosen only on one occasion in the experiment. While the respective defecting individual voiced strong spite and a motivation for retaliation for the early STOP move, the co-player displayed anger and frustration.

An additional—unexpected—finding concerned the participants' response times, which they appear to have strategically adapted to send non-verbal signals to their co-players. Deliberate delays in responding, for example, were frequently used to indicate discontent and to threaten the co-player with defection. The role of non-verbal communication between players needs further investigation and standardised response times could be used to reduce unwanted signalling between participants.

6.1.1.2: Chapter 3

Study 2 reported in Chapter 3 tested for the effects of subtle variations in payoff functions. Particularly, Take-it-or-leave-it and zero-end payoff functions had been used in previous studies without experimental control (e.g., Rapoport et al., 2003).

The increase of payoff inequality between the two players in a Take-it-or-leave-it Centipede game decreased cooperation significantly. Presenting the players with equal payoffs of zero at the final exit node, reduced cooperation even more. This could be explained by high salience of the zero-end which linked unconditional cooperation with a highly undesirable outcome. Interestingly, however, combining the two competitive game aspects in a single Centipede variation did not amplify their individual effects. While still reducing cooperation compared to the control condition, the Take-it-or-leave-it game with zero-end elicited higher cooperation levels than expected. This could be explained by a loss of salience of the zero-end when combined with the Take-it-or-leave-it function which also contained many zeroes. Taken together, the findings call for carefully controlled experimental designs when investigating decision making and cooperation. Even subtle variations in the games' payoff structures were shown to yield significant changes, and the interplay of these factors may yield unexpected and highly complex effects.

6.1.1.3: Chapter 4

Chapter 4 focused on increasing the games' real-life applicability by introducing longer game sequences, varying termination rules and the participants' knowledge thereof. Study 3 investigated the effects of game length and termination rules on cooperation in the Centipede game by applying a research design introduced by Normann and Wallace (2012). It was found that increasing the game length from 8 to 20 nodes increased cooperation but only if the game end was known to participants. While games with unknown ends yielded decreased endgame effects (i.e., higher defection rates just before the natural end), overall cooperation levels were reduced—possibly due to participants' expectations of shorter game lengths. These expectations, however, were adapted during the experiment, resulting in higher learning rates in the form of later defection with increasing experience in the game. Random game termination through the computer appeared to increase the percentage of games adhering to the Nash equilibrium outcome, and generally lowered cooperation levels.

Study 4 investigated the effects of three different rules determining random computer termination in the Centipede game. Findings showed that games with random termination by the computer yielded lower exit points than those without. This confirms the results of Study 3 which suggested the participants' responsiveness to the additional risk introduced by computer moves. However, based on a new measure of cooperation (percentage of STOP moves), it appears that only games with very high STOP probability may significantly decrease the cooperativeness of individual participants.

Taken together, these results suggest that a far, but finite horizon of relationships encourages higher levels of reciprocity and cooperation, whereas the introduction of uncertainty or risk may lead to earlier defection.

6.1.1.4: Chapter 5

Finally, Studies 5 and 6 of Chapter 5 provided a novel cross-cultural comparison between Japanese and British/European participants while controlling for the effects of SVO, risk-taking and general trust.

Across both studies, the Japanese participants were found to be more cooperative in the Centipede game which could be explained by higher levels of assurance-based trust characteristic of Japanese culture (Yamagishi & Yamagishi, 1994). Study 5 offered participants the optional (costly) choice of instruments to enhance commitment in their games. Again, the Japanese participants were more cooperative and chose the instruments more often than the European participants, which could be accounted for by a stronger need for security and stability in the Japanese interactions. Interestingly, the mere offer of commitment-enhancing tools increased cooperation levels in the European participants. The data in Japan, however, yielded quite different results. Overall, the offer of commitment-enhancing tools did not increase cooperation significantly compared to the control condition, which was due to a highly deterrent effect that the choice against using a tool had on cooperation. The Japanese appeared to be more sensitive to rejection (i.e., refusals to choose insurance measures), ultimately lowering their trust and increasing their defection when neither individual opted for the commitment-enhancing tool on offer.

Study 6 further demonstrated that both UK and Japanese nationals were affected by the amount of information provided about the decision context in which they operated. Following Croson (1996), the experiment manipulated the payoff information available to participants during the game, and introduced two conditions of incomplete information (i.e., relative and absolute payoff information only). In Japan, the two conditions characterised by incomplete information produced higher cooperation levels than those with complete information. A similar increase of cooperation was found in the UK for the condition with absolute payoff information only.

The results were interpreted to point to the importance of previous experiences and consequent expectations when making decisions under conditions of incomplete information. It is likely that participants of both nationalities expected lower stake sizes when they ignored the exact payoff values which, in turn, led to higher cooperation levels. However, follow-up research is necessary to compare Japanese and European cultures across a wider range of decision tasks (with and without incomplete information) and to explore the relative importance of different types of trust.

6.2: Why do people cooperate in the Centipede game?

The most fundamental question that needs to be answered is why anyone cooperates at all in Centipede games. Why do players not follow the rational prescription of game theory and defect at the earliest opportunity? The BI argument is compelling: it appears to lead inexorably to the conclusion that any rational player will defect at the earliest opportunity, and hence that every Centipede game should stop at the first decision node, unless Player A is irrational. Sections 6.1.1–6.1.6 discuss and evaluate six different theories for why human decision makers cooperate in the Centipede game, namely: possible invalidity of BI argument, cognitive burden explanation, common knowledge breakdown, virtual bargaining, fuzzy-trace theory, and other-regarding preferences.

6.2.1: Possible invalidity of BI argument

One possibility is that the BI argument may be less persuasive than it appears to be. To many people, it seems natural to defect at the end of the Centipede game but pathologically pessimistic to defect at the beginning (Aumann, 1992). Even people who understand the logic of BI perfectly and expect their co-players to act rationally appear to be inclined to reject it as the basis for playing the game. A prime example is the mathematician, game theorist, and Nobel laureate Reinhard Selten, who revealed that he would not follow BI in a game closely related to the Centipede game. He added: “My experience suggests that mathematically trained persons recognise the logical validity of the induction argument, but they refuse to accept it as a guide to practical behaviour” (Selten, 1978, pp. 132–133).

Another related reason why it is difficult to accept the BI solution is that it seems illogical to define rationality in terms of payoff maximisation when irrational players earn higher payoffs than rational players. Perfectly rational players can only ever earn the payoffs available in the Centipede’s back foot, whereas ordinary experimental participants almost invariably earn much more. Exactly the same contradiction applies in the repeated Prisoner’s Dilemma game, but the paradox seems sharper and more difficult to live with in the Centipede game. These intuitions cast doubt on the explanations based on cognitive burden and common knowledge breakdown, and they need to be factored in to any explanation of cooperation in Centipede games.

Another reason why it might be difficult to accept the BI argument is an unnatural hidden assumption, namely that expectations about co-players' future actions are unaffected by observations of their past actions (Colman et al., 2017). According to the BI argument, a rational player will defect at any decision node because of certain knowledge that the assumedly rational co-player will respond to a cooperative move by defecting immediately after. But at the third decision node, for example, a player knows that the co-player has already cooperated once, violating BI rationality; therefore, it could be argued that there is no obvious reason to expect this same co-player to defect at the next decision node.

Nobel laureate, mathematician, and game theorist Robert Aumann (1995, p. 12) was aware of this problem, and suggested a rationality "in its own right" to bypass the issue:

> Rationality of a player at a vertex *v* is defined in terms of what happens at vertices after *v*, his payoff *if v* is reached. The idea is that when programming his automaton at *v*, the player does so as if *v* will be reached – even when he knows that it will not be! Each choice must be rational "in its own right" – a player may not rely on what happened previously to get him "off the hook."

However, given that the standard Centipede game is a decision context characterised by complete and perfect information, the pretence of ignorance about previous moves in the game appears unjustified. Aumann's (1995) argument assumes that players retain their assumptions of their co-players' BI rationality even after observing evidence contradicting it, and many players may find this hard to swallow. This apparent weakness of the BI argument as applied to the Centipede game cannot explain why people cooperate, but it could explain why BI reasoning does not cause them to defect at the first opportunity.

6.2.2: Cognitive burden

A more popular explanation for why people do not typically follow BI (e.g., Gerber & Wichardt, 2010; Palacio-Huerta & Volij, 2009) is what shall be called the *cognitive burden* explanation. The basic idea is that BI is cognitively demanding and that most players lack the concentration, motivation, or strategic reasoning skills to understand it, and consequently they do not realise that it is in their own interests to defect as soon as possible. The fact that BI involves multiple iterative steps of argument, starting from the final decision node and working back to the first, is not necessarily problematic in itself. Extending an insightful observation made by Milgrom (1981), consider the following *Gedankenexperiment*. Suppose a teacher were to announce in a classroom full of 12-year-old children that "this lesson is cancelled because there has been a power cut." That information would immediately become common knowledge among the children, and they likely would have no difficulty understanding that every child knows it, knows that every child knows it, and so on ad infinitum, without having to compute any separate steps of the argument in their heads. The fact that the BI argument relies not only on iterated reasoning but also on *counterfactual conditionals*—for example, "What would I do if my co-player chose GO, although my co-player would not choose GO?"—adds an additional and possibly heavier layer of cognitive difficulty.

However, this may be beside the point, because there are reasons for believing that players' failure to follow BI does not arise from their inability to understand it. If cognitive burden is indeed the true explanation, then surely games that are repeated over many rounds should show rapid convergence to the subgame-perfect equilibrium and defection at the first decision node, as players gradually come to understand the problem better; but typically only very modest increases in early defection (sometimes none at all) have been observed in conventional two-player sequential-choice Centipede games (e.g., Fey et al. 1996; McKelvey & Palfrey, 1992; Pulford, Colman, Lawrence, & Krockow, 2017).

6.2.3: Common knowledge breakdown

A third, more subtle, explanation is that players deviate from BI because they do not expect their co-players to be fully rational. This will be called the *common knowledge breakdown* explanation. For example, Aumann (1995, p. 18) has argued that "CKR [common knowledge of rationality] is an ideal condition that is rarely met in practice; when it is not met, the inductive choice may be not only unreasonable and unwise, but quite simply irrational". Heifetz and Pauzner (2005) proved that if perfectly rational players ascribe some small probability to their co-players deviating from BI, then strong deviations from BI can occur. Note that this explanation retains the standard assumption that the players are rational; it relaxes only the assumption that this is common knowledge. The common knowledge breakdown explanation is reminiscent of a comment by Binmore (1987) that “good poker players do not play maximin [game-theoretically rational] strategies against those they have a good reason to suppose to be poor players. They deviate from the maximin strategy in the hope of exploiting the expected bad play of their opponents” (p. 196).

The common knowledge breakdown explanation can be traced back to an analysis by Kreps, Milgrom, Roberts, and Wilson (1982) of the finitely repeated Prisoner’s Dilemma game, in which a similar BI argument applies. The “Gang of Four” (as they are known in game theory circles) proved that two players who are themselves perfectly rational, but who each believe that there is a small probability that the other player is irrational, will deviate from equilibrium play to cultivate reputations for cooperativeness and elicit cooperation from their co-players. Indeed, the qualitative study reported in Chapter 1 (see also Krockow et al., 2016b) suggests that the most common motives for initial cooperation in the Centipede game include curiosity and probing (i.e., the wish to test the co-players’ strategies in the game). If both players know that they are rational, and both know that they know it, but do not know it to infinite recursive layers, then it is called mutual knowledge, rather than common knowledge, of rationality. Aumann (1992) has shown that “one can carry mutual knowledge of rationality to any finite level short of common knowledge, and still get the same effect: the players will be motivated to play mutually beneficial but seemingly irrational strategies” (p. 226). It is only with full common knowledge that BI becomes irresistible. This common knowledge breakdown explanation, in its various forms, has some appeal, but experiments designed specifically to test it in the finitely iterated Prisoner’s Dilemma game (Andreoni & Miller, 1993; Cooper, DeJong, & Forsythe, 1996) and the Centipede game (McKelvey & Palfrey, 1992) have shown that it cannot explain all violations of BI. Experimental results stubbornly suggest that some players behave cooperatively or altruistically irrespective of any knowledge or beliefs that they may hold about the rationality of their co-players.

6.2.4: Virtual bargaining

Perhaps there is a need for a new theory of social decision making to extend the previously dominant approach of best-reply reasoning which emphasised the importance of Nash equilibria. In this context, Misyak and Chater (2014) proposed virtual bargaining theory, suggesting that decision makers typically choose the option they would settle on if they were given the opportunity of open bargaining with each other. This theory could explain successful coordination of rational individuals in complex situations where best-reply reasoning does not yield a single, obvious solution to a given problem.

As an example context, Hi-Lo games were suggested, symmetric matrix games where two participants simultaneously choose between two strategies: “Hi” and “Lo” (Misyak, Melkonyan, Zeitoun, & Chater, 2014). If the participants fail to choose identical strategies, neither of them receives a positive payoff. If both participants choose “Hi”, both receive large, identical payoffs. If both participants choose “Lo”, both receive small, identical payoffs. Consequently, the game has two different Nash equilibria with “Hi” being the best reply to the co-player’s “Hi” strategy, and “Lo being the best reply to the co-player’s “Lo” strategy. Even though the solution to this decision context may appear to be intuitively simple and entail the mutually beneficial choice of “Hi”, there is no game-theoretic justification for selecting one Nash equilibrium over the other. Virtual bargaining theory could provide the missing link to explain why certain choice patterns emerge from individualistic reasoning despite the lack of theoretic underpinnings.

So far, this theory has only been applied to simultaneous move games with multiple equilibria. However, it may be possible to extend the virtual bargaining approach to sequential decision contexts such as the Centipede game where the unique subgame-perfect equilibrium is arguably counterintuitive. If participants were given the opportunity to openly bargain in the Centipede game, which combination of strategies would they choose? The solution to this question may not be as immediately obvious as in the Hi-Lo game. In fact, it may depend on the particular payoff function of the Centipede game in question and on personal preferences of the participants.

One possibility could be that two participants agree to play “GO” until both players have passed a certain minimum payoff threshold. This threshold could be defined as absolute value (e.g., £10) or as relative value (e.g., half of the highest individual payoff at stake). Another possibility could involve continuing all the way until the game’s natural end in order to receive the highest total amount of money possible from the experimenters.

In repeated Centipede games, a bargain might lead to the decision to alternatingly exit at the ultimate exit point (natural end), which yields a maximum payoff to Player A, and the penultimate exit point, which yields a maximum payoff to Player B. This way, the two players would take turns in receiving their highest possible, individual payoffs, which could be considered a fair and lucrative agreement for both. In any case, it would yield much better outcomes to both compared to repeated equilibrium play.

While the above bargaining solutions are speculative and would have to be examined in the context of a particular Centipede game, it is intuitively obvious that neither participant would negotiate to terminate the game with an immediate STOP move at Node 1. Such an agreement would be highly unlikely given that any other exit node (with the exception of Node 2) would yield higher payoffs to both.

Thus, while the virtual bargaining approach may not be able to predict the exact exit point in the Centipede game, it may explain the recurrent deviations from the game-theoretic solution in experimental investigations.

6.2.5: Fuzzy-trace theory

Related to the cognitive burden explanation, fuzzy-trace theory is grounded in the assumption that decision makers' reasoning skills and memory capacity is limited, which leads them to rely on simplified mental representations of any given problem (Reyna & Brainerd, 1991, 1995). More specifically, this social psychology theory maintains that decision makers encode information in two different ways. The first consists of verbatim representations referring to very detailed numerical information. The second consists of gist representations referring to the simplified, most essential information extracted from the verbatim representation.

Such gist representations could be categorical (e.g., some/none) or, if that is insufficient to make a choice, they could be ordinal in nature (e.g., more/less, larger/smaller, some/more). In complex decision situations such as the Centipede game, many decision makers may chiefly rely on their gist representations of the task when developing their strategies. By focusing on the gist or bottom line of a decision problem, they can simplify the task at hand, speed up the decision-making progress and reduce the load in working memory.

As outlined by Colman et al., (2017), fuzzy-trace theory can provide a plausible explanation of the empirical deviations from the sub-game perfect Nash equilibrium in the Centipede game. The players' possible gist representations at the outset of an increasing-sum Centipede game would be of the ordinal type (some/more). More specifically, STOP moves would be associated with the certainty of a small payoff, and GO moves with the possibility of a larger payoff. Based on the rational assumption that players prefer larger payoffs over smaller payoffs, this gist representation should lead them to cooperate until they reach later nodes in the game where all payoffs are generally larger, and the association of "STOP" with small payoffs no longer maintains. Consequently, fuzzy-trace theory would predict initial cooperation followed by a defection move before the game's natural end.

This theory can explain why players choose to cooperate in the game in the beginning of the game. However, it fails to account for the reliable finding that a substantial proportion of games reach the natural end.

6.2.6: Other-regarding preferences

While all the theories reviewed above could account for some cooperation in Centipede games, none of the theories offered a comprehensive explanation for repeated cooperation including the altruistic GO move at the final decision node. Instead, an explanation in terms of irrationality seems more likely—at least, the narrow conception of irrationality in behavioural game theory, where payoffs are taken as given. Assuming that players are not motivated solely to maximise their own payoffs but are driven by other-regarding preferences, and that they expect their co-players to be similarly motivated, then one can understand not only the empirical evidence of cooperative play but also the almost irresistible intuition that it makes sense to cooperate in a Centipede game. Almost a century and a half ago, Edgeworth (1881, pp. 102–104) introduced the idea of other-regarding payoff transformations. If the objective payoffs (monetary values, for example, or payoffs as displayed in an experimental game) to Player 1 and Player 2 in any particular outcome are v_1 and v_2 respectively, and if u_1 and u_2 are the players' actual utilities, representing their true preferences, then a simple mathematical model of Player 1's other-regarding utility is the linear equation $u_1 = \alpha v_1 + (1 - \alpha)v_2$, and Player 2's is $u_2 = \beta v_1 + (1 - \beta)v_2$. Here, α and β are parameters determined by the nature of the players' other-regarding preferences. In the simplest possible case, if a player has a utility function that weights both objective payoffs equally—the player cares equally about both players' objective payoffs, and nothing else matters—then the parameters are equal to 1/2 and leading to the cooperative SVO of interdependence theory (Rusbult & Van Lange, 2003). As an example, consider the first terminal node in the game depicted in Figure 1.1. Player A will be called "Player 1" and Player B "Player 2", to match the notation previously used. The objective payoffs are 2 to Player 1 and 1 to Player 2, and under the cooperative SVO, Player 1's utility for that outcome is $u_1 = 2/2 + 1/2 = 1.5$. Player 1's utility for the second terminal node in the same game is $u_1 = 1/2 + 6/2 = 3.5$, and so on. In any linear or exponential Centipede game with social gains—that is, one in which the joint payoff or pot increases from one terminal node to the next— if both or all players have cooperative utility functions, then it is rational for them to cooperate at every decision node, because cooperation can only yield a higher utility than defecting, each successive terminal node being preferred to its predecessor, and the BI argument is simply irrelevant. The interpretation is that we are dealing with collectively rational players who care about the joint payoff of the players or social gains rather than just their own personal payoffs, and it is rational for them to cooperate at every decision node. A cooperative move provides a benefit b at some cost c to the player pair, and this is always nonnegative, because $c \leq b$. If players are to some degree motivated in this way, then that would explain the evidence that has been reviewed for cooperative moves in linear and exponential Centipede games, and it would also explain why far fewer cooperative moves and much earlier defections are observed in constant-sum Centipede games, because players with a cooperative utility function prefer every terminal node in a constant-sum game equally.

This is not to suggest that human decision makers necessarily have such simple other-regarding preferences as the cooperative SVO. In reality, other-regarding preferences seem likely to weight a player's own payoff more than the co-player's, and there are other considerations, such as inequality aversion and altruism that are frequently associated with cooperativeness, leading to the identification of the hybrid prosocial SVO (Van Lange, 1999). Nonetheless, there is a substantial body of evidence suggesting that the cooperative SVO is predominant in about 57% of people (Au & Kwong, 2004; Murphy, Ackermann, & Handgraaf, 2011). In the light of such findings, it seems naive to assume that all experimental participants are predominantly individualistic, and hence that the objective payoffs as presented to them in experimental games necessarily reflect their actual utilities.

6.2.7: Conclusions

Based on the above review of theories for cooperation and the combined research presented in this thesis, it appears likely that human participants' strategies are influenced by a variety of factors, which may change flexibly across the course of the game.

The first question to be answered is why players do not follow BI reasoning. Importantly, it seems that BI reasoning is one of the least important factors in determining decision making in the Centipede game. This is likely due to four different reasons outlined in the previous section: (a) the questionable validity of the mathematical argument that is based on the assumption that players keep their beliefs of their co-players' BI rationality even after observing evidence contradicting it, (b) the cognitive burden imposed by iterated reasoning combined with counterfactual conditionals, (c) the likely breakdown of common knowledge of rationality which relies on participants doubting their co-players' rationality, (d) the unlikely event that two players would agree on the BI reasoning outcome if they were given the opportunity for an open bargain.

Instead, it seems more likely that participants deal with the difficult decision context by forming simplified gist representations of the game which offer quick and intuitively easy strategies for game play without impairing working memory or slowing the decision process. It is possible that virtual bargaining solutions could explain particular exit points in the game but due to a lack of research at this point, this is pure speculation.

The most important reason for cooperation in the Centipede game (and in repeated interactions overall) appear to be other-regarding preferences. As identified by Study 1 of this thesis, a qualitative investigation of motivations in the Centipede game, participants' reasoning and motives in the decision task are highly varied. Furthermore, data suggested that certain considerations may be more salient in the beginning compared to the end of the game. Whereas initial GO moves were most frequently explained with activity bias, curiosity about the game and the probing of the co-player, particular SVOs were most influential towards the end of the game, with cooperative and altruistic SVOs contributing to later defection or no defection at all.

6.3: Future research directions

In the light of the findings presented in this thesis, future research in the field of Centipede games and other experimental games should continue to use a wide range of both quantitative and qualitative methods to explore and formalise reasons for human cooperation and ways to promote reciprocity. Study 1 employed verbal protocols to study decision making, and the data provided rich, intelligible results. Future research could adopt similar methods to gain more insights into the complex reasoning and motivational processes underlying decision making.

Likewise, a greater effort should be made to increase applicability of experimental decision contexts by studying particular framing effects, or varying the amount of information provided to participants. Chapters 4 and 5 manipulated the task information available to participants, and both yielded interesting, yet complex, new results. While Studies 3 and 4 evidenced the influence of uncertainty and risk with regards to termination rules, Study 6 suggested that cooperation was affected by quality and quantity of payoff information.

Furthermore, in an increasingly global world with cross-cultural decision making being an important theme in international politics and economics, additional studies need to be conducted on cross-cultural differences in cooperativeness and in social norms surrounding cooperation and reciprocity. Particularly the comparison of industrialised nations with traditionally strong differences in culture and religion could be of interest.

Finally, as identified in this final chapter, novel research designs could be developed to test for the applicability of virtual bargaining theory to the Centipede. It would be interesting to test what exit point game participants would agree on, if they were given the opportunity for an open bargain. Future studies could compare the negotiated exit points from a treatment conditions with open participant bargaining to the actual exit points from a standard experimental treatment condition. If the results of the bargaining treatment matched those of the standard treatment, virtual bargaining might play in important role in determining choices and cooperation levels in the Centipede game.

6.4: General conclusions

This thesis set out to investigate repeated, cooperative behaviour in human decision makers, and how it can be maintained and promoted in society. The in-depth empirical study of varying types of Centipede games provided a more comprehensive understanding of decision making in repeated, reciprocal interactions. In this thesis, a systematic literature review and findings from six new empirical studies identified a number of factors that were shown to influence cooperation in repeated dyadic interactions. Intrinsically competitive payoff functions including constant-sum, Take-it-or-leave-it and zero-end payoffs were found to lead to earlier defection, while exponentially or linearly increasing-sum payoff functions—especially if combined with long game length— generally encouraged cooperation. A high number of players, or decision making in groups were shown to decrease cooperation, while particular cultural and personality variables such as high levels of assurance-based trust and cooperative or altruistic SVO were found to increase cooperation.

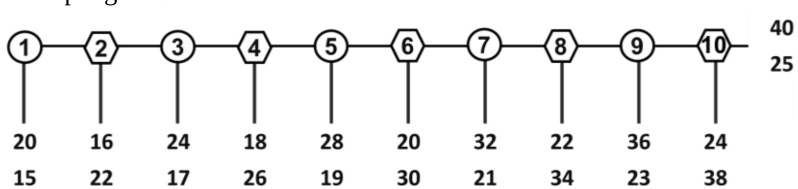
After reviewing six possible explanations for cooperation in Centipede games including the possible invalidity of the BI argument, cognitive burden hypothesis, common knowledge breakdown, virtual bargaining theory, fuzzy-trace theory and other-regarding preferences, it appears that a combination of different theories might be most successful in explaining the decision making observed in experimental studies of the Centipede game. It became evident that BI reasoning plays—at best—a very minor role in the decision process. Instead participants might form simplified gist representations of the game to lift the cognitive burden, and act upon a large and varying number of other-regarding preferences. Initial choices of cooperation may be mostly based on activity bias and probing while cooperation towards the end of the game is typically associated with cooperative and altruistic SVOs.

The crucial importance of individual differences economically irrational preferences was supported by all studies reported in this thesis. The qualitative study reported in Chapter 1 confirmed the influence of SVO, particularly on choices at later decision nodes in the game. It further showed that many participants struggled with the cognitive burden of iterated reasoning, but those participants with the highest reasoning skills were the ones to cooperate most consistently. In Study 2, the competitive framing of the game, for example by introducing zero payoffs as a highly undesirable outcome of unconditional cooperation, decreased cooperation, which also pointed to an influence of other-regarding preferences. Similarly, Study 3 found that high risk levels of random computer termination were necessary to override existing cooperative preferences for cooperativeness. Finally, Studies 5 and 6 indicated that other-regarding preferences, for example based on culturally-specific variations in trust, could have a strong impact on cooperative choices.

Furthermore, the research presented in this thesis suggested possibilities for enhancing cooperation. Study 3, for example, demonstrated that extending the likely time frame given for an interaction and increasing the chances for reciprocity could improve cooperativeness between individuals. Additionally, the use of commitment-enhancing tools in the form of social contracts (e.g., marriage contracts, business agreements, etc.) might promote cooperation, but these benefits might be culture-specific. Future research should continue to increase the real-life applicability of decision contexts, and employ a variety of research methods including qualitative approaches such as verbal protocol analysis to investigate decision making in social situations.

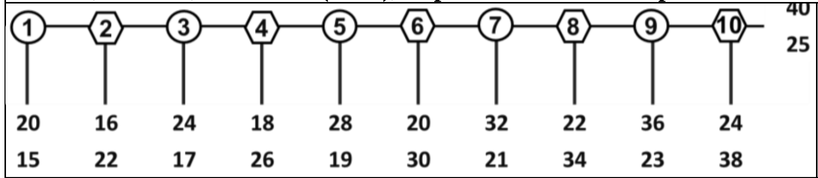
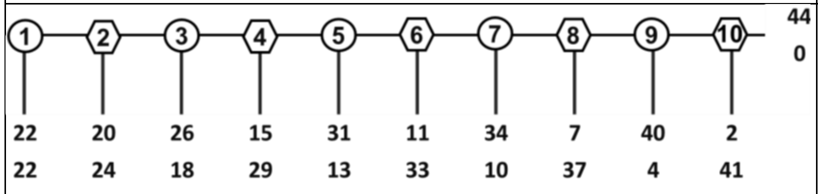
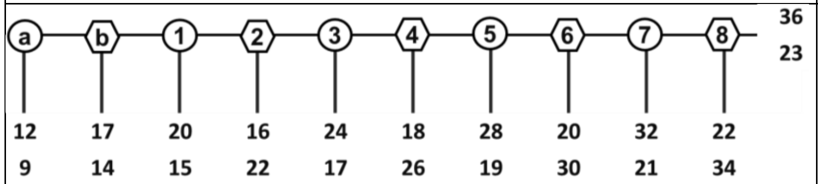
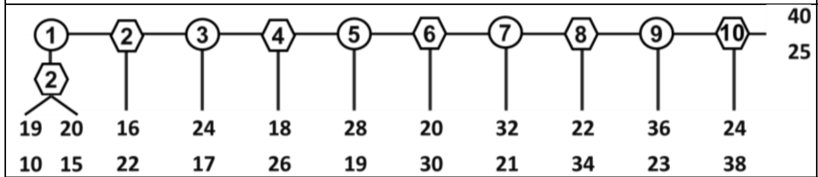
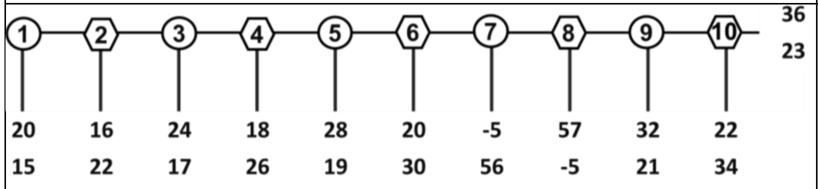
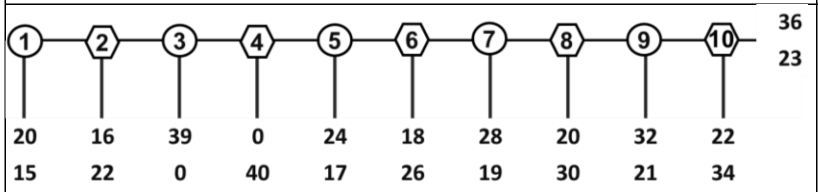
Appendices

Appendix A: Synopsis of Experiments Included in the Review

Game tree	Payoff function	Rounds	Treatment conditions	Elicitation method	% stopping at SPE[1]	% reaching last exit node	Mean exit node[2]
Atiker (2012), unpublished manuscript retrieved online							
Example game: 	Mixed	12	N/A	Strategy method	See results reported by Atiker et al. (2012)	See results reported by Atiker et al. (2012)	See results reporte d by Atiker et al. (2012)
This experiment investigated the influence of personality traits on play in the Centipede game. Participants completed a personality questionnaire (the International Personality Item Pool) and then engaged in 12 different Centipede games (drawn from of a pool of 17 Centipede games with different payoff functions), using the strategy method. The Centipede data reported in this study are identical to those presented by Atiker, Neilson, and Price (2011), (see below). However, instead of focusing on differences between the 17 different Centipede games used, this manuscript examined the relationships between personality and game play. A significant correlation was found between the personality variable "performance motivation" and the choice at Node 1, indicating that highly motivated individuals adhered to the game-theoretic solution more frequently than others. High self-esteem and intellectuality also yielded a more frequent use of BI reasoning and, thus, lower cooperation levels. Risk-takers and assertive personalities, on the other hand, were shown to cooperate longer than others.							

[1] SPE is the abbreviation of "subgame-perfect equilibrium".

[2] The first figure displays the mean exit node for the respective game. The second figure displays the standardised mean exit point of the game tree where the games ended. It provides a standardised measure of the exit node to increase comparability across studies. The standardised figure was obtained by dividing the mean exit node by the game length (i.e., the number of terminal nodes).

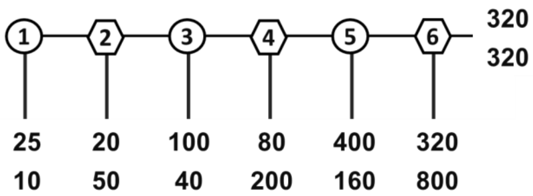
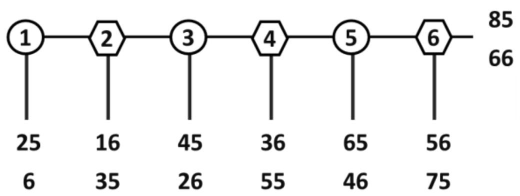
Atiker, Neilson, and Price (2011), unpublished manuscript retrieved online							
	Increasing sum (linear)	12	**C1:** Standard Centipede game	Strategy method	4.0	7.9	6.15/ 0.51
	Constant-sum		**C2:** Constant-sum Centipede game		16.8	0	6.06/ 0.50
	Increasing sum (linear)		**C3:** Early moves games (7 variations)		0	5.9	6.06/ 0.51
	Increasing sum (linear)		**C4:** Activity bias game (2 variations)		24.8	0.2	5.83/ 0.49
	Increasing sum (linear)		**C5:** “Beliefs about co-player’s rationality” games (4 variations)		13.7	0	4.06/ 0.34
	Increasing sum (linear)		**C6:** Focal point games (2 variations)		34.7	0.8	1.94/ 0.16

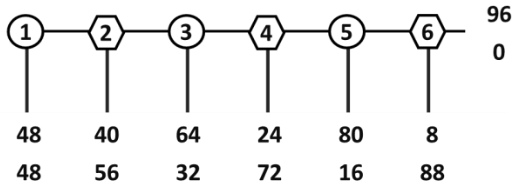
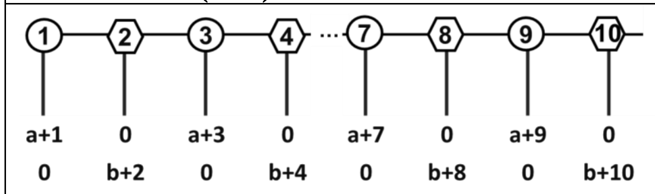
This study aimed to test a number of possible reasons that could explain the recurrent deviations from the Centipede's sub-game perfect Nash equilibrium. These reasons included (1) joint payoff maximization, (2) lack of common knowledge of rationality, (3) activity bias, and (4) lack of focal points in the standard game. Using a within-participants design, all participants played 12 Centipede games (drawn from a pool of 17) with slightly different, carefully manipulated payoff functions designed to isolate and measure the influence of the four possible reasons that could explain deviations from the equilibrium. Due to limited space, only six example treatment conditions (out of 17) are displayed in this summary. Participants were randomly re-matched after each of the 12 game rounds and game order varied across testing sessions. The strategy method was used to yield a richer data set. The Centipede data reported in this study are identical to those presented by Atiker (2012). However, instead of focusing on personality traits, this manuscript examined the differences between the 17 variations of Centipede. The results suggested that activity bias (i.e. the wish for the co-player to also have an influence on the payoffs) had an impact on decision making. The most important factor, however, was found to be the existence of focal points: Terminal nodes with payoffs breaking the game's regular payoff pattern were found to elicit disproportionately high numbers of exit moves.

Baghestanian and Frey (2014)

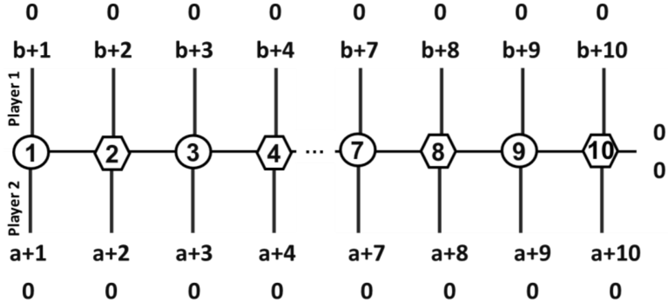
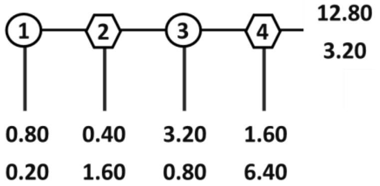
Smaller choice	Possible higher choices of opponents	Payoff of A	Payoff of B	Sum
1	{2, 4, 6, 8, 10, 12, 14}	40	10	50
2	{3, 5, 7, 9, 11, 13}	20	50	70
3	{4, 6, 8, 10, 12, 14}	80	20	100
4	{5, 7, 9, 11, 13}	30	110	140
5	{6, 8, 10, 12, 14}	160	40	200
6	{7, 9, 11, 13}	60	220	280
7	{8, 10, 12, 14}	320	80	400
8	{9, 11, 13}	110	450	560
9	{10, 12, 14}	640	160	800
10	{11, 13}	220	900	1120
11	{12, 14}	1280	320	1600
12	{13}	440	1800	2240
13	{14}	2560	640	3200

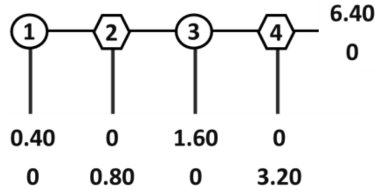
Increasing sum (exponential)	1	**C1:** Centipede game	Strategy method (game presented in normal form)	0	32.6	10.49 0.75
		C2: Traveller's dilemma		N/A	N/A	N/A
		C3: Kreps game		N/A	N/A	N/A
		C4: Matching Pennies game		N/A	N/A	N/A

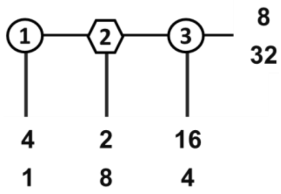
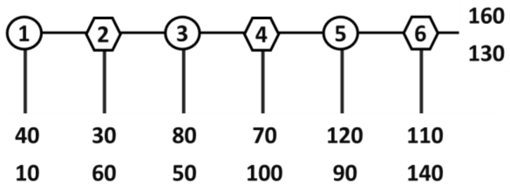
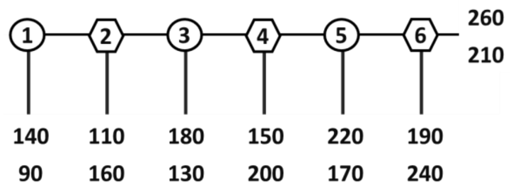
Using a sample of professional Go players, the authors compared decision making across four games – a normal form Centipede game, a Traveller's dilemma, a Kreps game and a Matching Pennies game, the former two of which are characterised by inefficient equilibrium solutions. They further measured strategic reasoning skills by assessing the participants' Go Elo scores and analytic reasoning skills with the help of the Frederick cognitive reflection test. Participants were found to deviate from the Nash equilibria in Centipede games and Traveller's dilemmas but not in the other two, suggesting that those deviations were less likely caused by a lack of cognitive ability. However, decision making in those two games correlated with the two different reasoning measures, with higher Elo scores related to lower cooperation levels and higher CRT scores related to higher cooperation levels. These findings suggest that different types of reasoning may affect decision making in the Centipede game.							
Basu, Mitra, and Gupti (2013)							
	Increasing sum (exponential)	15	**C1:** Random pairing across income groups	Direct response method	17.8	0	2.62/ 0.37
			C2: Pairing with participant from same income group		20	0	2.40/ 0.34
			C3: Pairing with participant from different income group		17.8	0	2.18/ 0.31
This study investigated the impact of wealth on decision making in the Centipede game. Prior to the experiment, participants were ranked according to their income and subsequently categorised as "high income", "medium income" or "low income". Then, they completed 15 rounds of the Centipede game. The first five were played with randomly changing co-players. The second lot were played with co-players from the same income group, and the last rounds were completed with co-players from different income groups. In treatment conditions 2 and 3, participants were informed about the income groups of their respective co-player before the start of the game. Following their analyses, the authors reported significant differences in the decision-making patterns across treatment conditions.							
Bornstein, Kugler, and Ziegelmeyer (2004)							
	Increasing sum (linear)	1	**C1:** Linear game; individual players	Direct response method	0	16.7	5.22/ 0.75
			C2: Linear game; group players		0	0	4.44/ 0.63

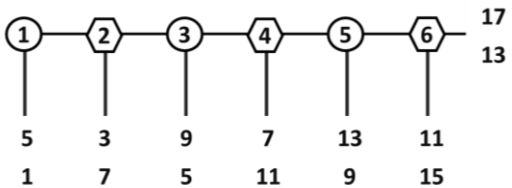
	Constant-sum		**C3:** Constant-sum game; individual players		16.7	0	2.56/ 0.37
			C4: Constant-sum game; group players		22.2	0	2.00/ 0.29
The experiment compared decision making of group players and individual players in linearly increasing and constant-sum Centipede games. In both games, groups showed less cooperation than individuals. This finding was explained with lower levels of pro-social orientation and less reasoning mistakes in groups. Furthermore, a main effect of payoff function was reported, with constant-sum games eliciting less GO moves than linearly increasing games. This finding was attributed to the lack of social gains in constant-sum games.							
Cox and James (2012)							
	"Take-it-or-leave-it"	3 rounds of 10 games from different condition s	**C1:** Tree format with sequential moves	Direct response method Direct response method	55.7	0	1.79/ 0.16
			C2: Clock format with sequential moves		86.2	0	1.15/ 0.10

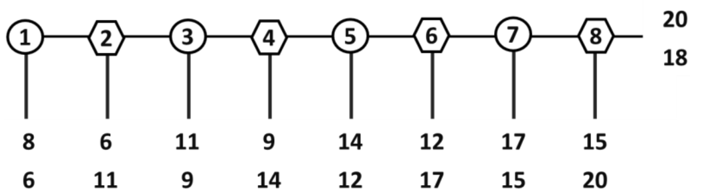
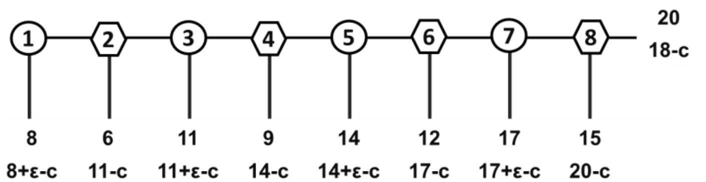
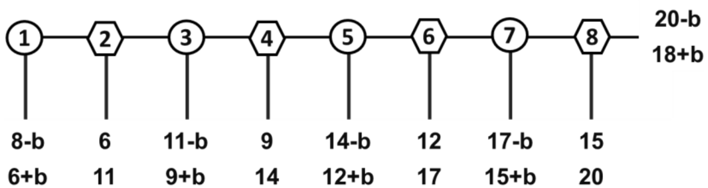
Player \ Clock reading	1	2	3	...	7	8	9	10
P1	a+2	0	a+4	...	0	a+10	0	a+12
P2	0	b+2	0	...	b+8	0	b+10	0

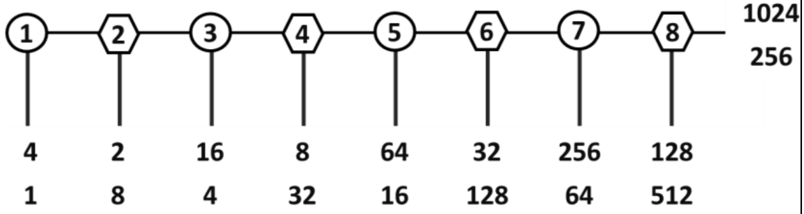
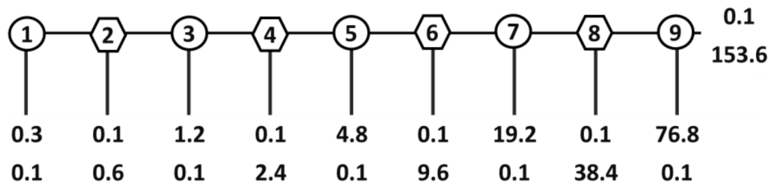
<table>
<tr><td>
</td><td rowspan="2"></td><td rowspan="2"></td><td>C3: Tree format with simultaneous moves</td><td rowspan="2">Direct response method (with simultaneous moves at each node)</td><td>72.6</td><td>0</td><td>1.45/ 0.13</td></tr>
<tr><td><table>
<tr><th>Player \ Clock reading</th><th>1</th><th>2</th><th>3</th><th>…</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td>If P1 decides to STOP first</td><td>a+2
0</td><td>a+3
0</td><td>a+4
0</td><td>…</td><td>a+9
0</td><td>a+10
0</td><td>a+11
0</td><td>a+12
0</td></tr>
<tr><td>If P2 decides to STOP first</td><td>0
b+1</td><td>0
b+2</td><td>0
b+3</td><td>…</td><td>0
b+8</td><td>0
b + 9</td><td>0
b+10</td><td>0
b+11</td></tr>
</table></td><td>C4: Clock format with simultaneous moves</td><td>96.4</td><td>0</td><td>1.06/ 0.10</td></tr>
<tr><td colspan="8">This study merged aspects of the Centipede game with those of Dutch auctions. The authors used a 2x2x2 design and manipulated the game type (Centipede game/Dutch auction), the institutional format it was presented in (clock/tree) and the move order (sequential/simultaneous moves). For the purpose of this review, the conditions using Dutch auctions have been omitted. The study found that presenting the Centipede games in clock format produced significantly different results from presenting it in the standard tree format; participants made decisions closer to the game theoretical solution. The earliest STOP moves were reported for the condition which combined clock format with simultaneous move structure.</td></tr>
<tr><td colspan="8">Cox and James (2015)</td></tr>
<tr><td>
</td><td>Increasing sum (exponential)</td><td>10</td><td>C1: Replication of McKelvey and Palfrey’s (1992) low-stake 4-node game, adjusted for inflation</td><td>Direct response method</td><td>21.0</td><td>0</td><td>2.19/ 0.44</td></tr>
</table>

<table>
<tr>
<td>
</td>
<td>Increasing sum (exponential)</td>
<td rowspan="4">3x10 rounds of different Centiped e games</td>
<td>C2: Replication of McKelvey and Palfrey’s (1992) low-stake 4-node game</td>
<td rowspan="4"></td>
<td>24.3</td>
<td>6.0</td>
<td>2.62/ 0.52</td>
</tr>
<tr>
<td>
</td>
<td>“Take-it-or-leave-it”</td>
<td>C3: Take it or leave it payoff function</td>
<td>54.3</td>
<td>0.7</td>
<td>2.13/ 0.43</td>
</tr>
<tr>
<td>
</td>
<td>“Take-it-or-leave-it”</td>
<td>C4: Take-it-or-leave-it payoff function with 10 second time limit for decisions</td>
<td>58.7</td>
<td>0.7</td>
<td>1.98/ 0.40</td>
</tr>
<tr>
<td><table>
<tr><td>Clock reading / Player</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>P1</td><td>0.40</td><td>0</td><td>1.60</td><td>0</td><td>6.40</td></tr>
<tr><td>P2</td><td>0</td><td>0.80</td><td>0</td><td>3.20</td><td>0</td></tr>
</table></td>
<td>“Take-it-or-leave-it”</td>
<td>C5: Take-it-or-leave-it payoff function with 10 second time limit for decisions; clock format</td>
<td>50.0</td>
<td>0</td>
<td>2.17/ 0.43</td>
</tr>
<tr>
<td colspan="8">This experiment included a replication of one of McKelvey and Palfrey’s (1992) original Centipede games as well as four other game conditions that differed in stake size, payoffs to non-Takers (“Take-it-or-leave-it” game versus standard Centipede game), time pressure and the format presented in (clock versus tree format). The authors found that both higher stakes and the introduction of zero payoffs to non-takers (i.e., adhering to a “Take-it-or-leave-it” payoff function) led to earlier unravelling and lower overall cooperation compared to the standard Centipede game used. Interestingly, the conditions introducing time pressure and clock format did not yield lower cooperation levels compared to the “Take-it-or-leave-it” game without these additional design features, which is in contrast with the findings by Cox and James (2012), (see above).</td>
</tr>
</table>

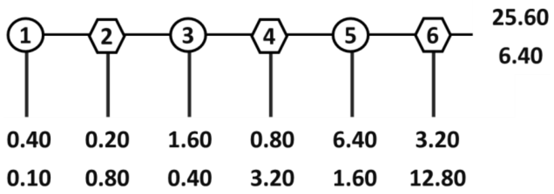
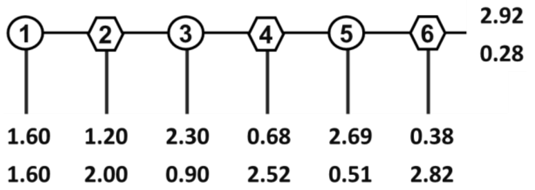
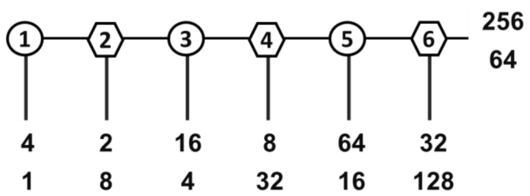
El-Gamal, McKelvey and Palfrey (1993)							
	Increasing sum (exponential)	2	N/A	Direct response method	31.6	14.5	2.24/ 0.56
This study investigated learning in a three-move Centipede game. The researchers applied two different models to the data to test whether reputation building (non-sequential model) or population learning (sequential model) could account for the findings. The authors found support for the second model, indicating that individuals learned about the population of players during each game they played and updated their strategies in response to previous experiences.							
Farina and Sbriglia (2008a)							
	Increasing sum (linear)	2	**C1**: Low-stake, homogeneous pairing	Direct response method	10.0	6.0	4.22/ 0.60
			C2: Low-stake, heterogeneous pairing		5.0	10.1	4.88/ 0.70
			**C3**: High-stake, homogeneous pairing		28.0	0	3.19/ 0.46
			C4: High-stake, heterogeneous pairing		10.0	2.0	3.76/ 0.54
This experiment (which was also discussed in a chapter by Farina & Sbriglia, 2008b) examined the effects of stake size and knowledge of the co-players strategic profile in a trust game on decision making in the Centipede game. Participants completed a two-stage trust game using the strategy method and then played two Centipede games with low and high stake sizes. Before engaging in the Centipede game, the players were informed about their co-players' choices in the trust game, identifying them as selfish, altruistic or reciprocating individuals. The results indicate that higher stake sizes significantly reduced cooperation levels. Overall, information about choices in the trust game decreased cooperation in the Centipede game, which was largely due to the very early game exits by homogenous pairings of selfish individuals.							

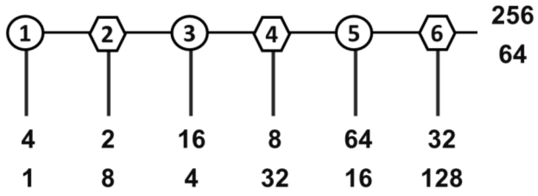
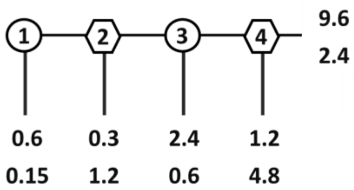
Fey, McKelvey, and Palfrey (1996)							
	Constant-sum	10	**C1:** Game length: 6 nodes	Direct response method	59.1	0	1.50/ 0.21
			**C2:** Game length: 10 nodes		45.1	0	1.93/ 0.18
The authors reported findings from two constant-sum Centipede games with varying lengths. Participants recurrently deviated from the unique Nash equilibrium but STOP probabilities tended to increase with every node passed. Furthermore, with increasing experience in the game, STOP moves were chosen earlier. The authors proposed the Quantal Response Equilibrium model, accounting for reasoning mistakes and learning, as the best match of their findings.							
Gamba and Regner (2015), unpublished manuscript retrieved online							
	Increasing sum (linear)	40	**C1:** Personal-direct information	Direct response method	0.6	5.0	4.51/ 0.64
			C2: Public-direct information		0.2	29.1	5.84/ 0.83
			C3: Personal-strategy information	Strategy method (variation)	0.7	7.0	4.51/ 0.64
			C4: Public-strategy information		0.2	22.8	5.59/ 0.80
This experiment manipulated the type of information about the co-player's behaviour (personal information about own game outcome only vs. public information about all game outcomes from previous round) and the elicitation method in the games (direct response method vs. strategy method). Additionally, SVO was measured using a combination of questionnaire data from an SVO scale and behavioural data from a simple trust game; participants were subsequently categorised as either proselfs or pro-socials. Finally, the authors assessed beliefs about the co-players' likely choices at different stages in the experiment. The results suggested that differences in the beliefs about the co-players and in consequent decision making are based on individual differences in prosocial preferences with pro-socials displaying higher initial cooperation							

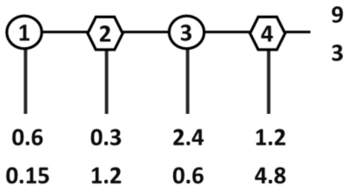
rates than proselfs. The authors further reported that proselfs cooperated more frequently in games with public information (particularly when combined with the strategy method) compared to games with personal information only. This was explained by the fact that the additional information about choices of all players of opposite participant role (rather than just of the own co-player) led them to adapt their initially non-cooperative strategies in order to increase payoffs.							
Gerber and Wichardt (2010)							
	Increasing sum (linear)	10	**C1:** Standard Centipede (control)	Direct response method	0	12.0	6.73/ 0.75
 Payoffs for the case where Player B has chosen the insurance option.			**C2:** Option to choose insurance tool: ε=0.5; c=2.5		1.5	11.5	6.84/ 0.76
 Payoffs for the case where Player A has chosen the bonus option.			**C3:** Option to choose bonus tool: b=2.5		0	56.0	8.07/ 0.90
The authors compared two treatment conditions where participants could choose to purchase one of two tools to improve their payoff certainty in a linearly increasing Centipede game. The insurance tool at cost c offered a higher personal payoff in case the other person chose to STOP. The bonus tool involved offering the co-player an incentive of b for not ending the game. Even though both instruments should have been equally effective, only the bonus tool was frequently used by the participants, leading to a significant delay in game termination. The authors explained this with a lower level of iterated reasoning ability required to understand the benefits of the bonus option. The findings demonstrated the challenges imposed by iterated reasoning processes and indicated that insufficient cognitive abilities could be a reason for deviation from Nash equilibrium in the Centipede game.							

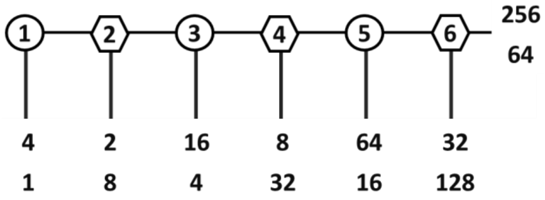
Horng and Chou (2012)							
Example game: 	Increasing sum (exponential)	51	Medium risk-cost payoff function	Direct response method	No information	No information	No information
This study investigated the effects of risk cost, payoff symmetry and stake size on decision making in the Centipede game. The authors manipulated the risk associated with each GO move (personal payoff decreased by 90%, 50% or 20%) and found that high-risk games were stopped significantly earlier than low-risk games but only when combined with big stakes sizes. The study further examined the effects of the inherently unequal player roles and of games with either symmetrically or asymmetrically increasing payoffs to the two players. The disadvantaged players stopped significantly earlier than the advantaged players, indicating inequality aversion and a concern with fairness in the participants.							
Huck and Jehiel (2004), unpublished manuscript retrieved online							
	"Take-it-or-leave-it"	50	**C1:** Information about other player's pass rates aggregated over all nodes from all rounds	Direct response method	No information	No information	No information
			C2: Information about other player's pass rates at specific nodes; information was aggregated over all nodes		No information	No information	No information

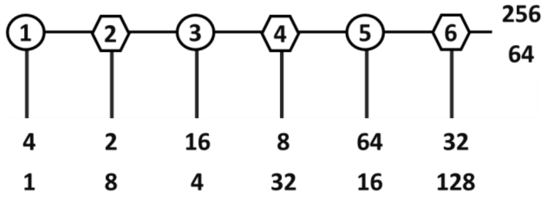
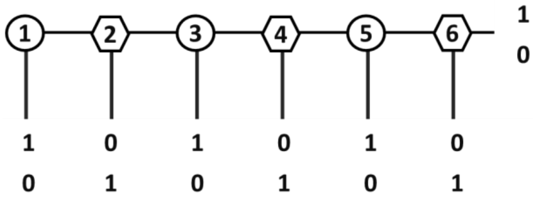
			from all rounds				
			C3: Information about other player’s pass rates aggregated over all nodes from past five rounds		No information	No information	No information
			C4: Information about other player’s pass rates at specific nodes; information was aggregated over all nodes from the past five rounds		No information	No information	No information
			C5: No information about other player’s previous play		No information	No information	No information
This article reported findings on decision making in a competitive Take-it-or-leave it version of the Centipede game. The authors manipulated the amount of public information available about the co-player. Participants were found to use both personal experience as well as public information (when available) for decision making. However, when stakes were very high, coarse public information was no longer taken into account. Finally, the provision of precise information on players’ pass rates at specific nodes during the most recent trials (Condition 4) led to an increase of participants using private and public information for their decision making. Learning rates were accordingly high in this condition, and the authors reported continuous unravelling up until the end of the experiment.							

Kawagoe and Takizawa (2012)							
	Increasing sum (exponential)	1	**C1:** Payoff function: exponential	Direct response method	2.3	6.8	5.09/ 0.73
	Constant-sum		**C2:** Payoff function: Constant-sum		34.1	0	1.95/ 0.28
The authors studied decision making in exponentially increasing and constant-sum Centipede games, merging their data with results from McKelvey and Palfrey (1992), Palacios-Huerta and Volij (2009) and Levitt et al. (2011), who all used games with the same payoff function. A level-k model, assuming that that all players are selfishly motivated but differ in their levels of reasoning abilities, provided the best match of findings in the exponential Centipede game.							
Le Coq, Tremewan, and Wager (2015)							
	Increasing sum (exponential)	1	**C1:** Participants playing against ingroup member	Strategy method	4.2	22.9	5.29/ 0.66
			C2: Participants playing against outgroup member		4.2	41.7	5.83/ 0.73
The study investigated whether group membership affected play in the Centipede game. After manipulating group identity, participants either played against an ingroup member or an outgroup member. The participants were further asked to indicate their beliefs about the other player's stop probabilities at different nodes. No significant differences were found between the conditions. In fact, the outgroup condition even produced higher cooperation levels. A possible explanation by the authors							

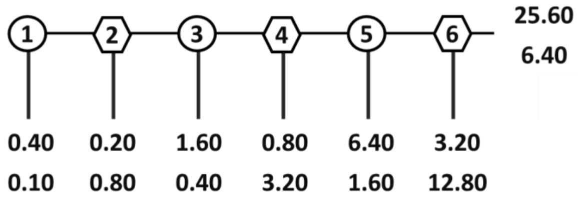
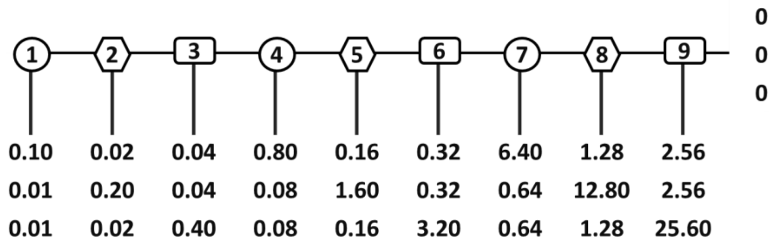
was that members of the same social group perceived each other as more similar and therefore predicted likely exit nodes with greater certainty. These beliefs, in turn, could have led to lower (albeit not significantly lower) levels of cooperation.							
Levitt, List, and Sadoff (2011)							
	Increasing sum (exponential)	1	**C1:** Type of Game: Centipede	Direct response method	3.9	6.9	4.23/ 0.60
			C2: Type of Game: Race to 100		N/A	N/A	N/A
The experiment compared decision making of expert chess players in the Centipede game and the “Race to 100” game. The latter was used to measure pure BI reasoning skill since its constant-sum winner-takes-it-all structure eliminates any social preferences. The chess players adhered to the game theoretical solution in only 3.9 percent of all games (compared to 69% reported in a similar study by Palacios-Huerta & Volij, 2009). Furthermore, not a single chess player with perfect performance in the Race to 100 game stopped the Centipede game at the first decision node. These findings indicated that cooperation in the Centipede game cannot fully be accounted for by limited cognitive abilities.							
Maniadis (2011), unpublished manuscript, retrieved online							
	Increasing sum (exponential)	13-15 + three practice trials	**C1:** Standard game with no information about previous fractions of STOP moves at each node	Direct response method	26.6	2.9	2.25/ 0.45

			C2: Standard game with full information about previous fractions of STOP moves at each node		30.2	0.7	2.18/ 0.44
			C3: Standard game with partial information about previous fractions of STOP moves at each node (moves of other player group only)		27.1	0.8	2.18/ 0.44
			**C4:** Modified game with no information about previous fractions of STOP moves at each node		6.3	4.6	2.89/ 0.58
			C5: Modified game with full information about previous fractions of STOP moves at each node		10.1	9.2	2.85/ 0.57
The author investigated the effects of aggregate information about previous game outcomes (no information, full information and partial information about other player group only) on decision making in two different Centipede games (standard and modified). Contrary to the author’s predictions, there was little evidence for the use of signalling to increase overall cooperation in the full information conditions. Instead, the article provided descriptive and tentative evidence that previous play decreased levels of cooperation. The modified Centipede game with a lower payoff difference between players at the final exit node of the game appeared to produce higher							

cooperation levels than the standard Centipede game, suggesting the participants' preferences for equality and their sensitivity to small payoff differences. Overall, more testing sessions with aggregate information are needed to establish statistical significance.							
McIntosh, Shogren, and Moravec (2009)							
	Increasing sum (exponential)	1	**E1C1:** Payoffs determined by tournament using ranking scheme based on total points earned	Strategy method	11.9	0.7	3.60/ 0.51
			E1C2: Payoffs determined by linear function based on total points earned (high base, low piece rate)		16.7	0.2	3.33/ 0.48
			E1C3: Payoffs determined by linear function based on total points earned (medium base and piece rate)		14.3	0.7	3.35/ 0.48
			E1C4: Payoffs determined by linear function based on total points earned (low base, high piece rate)		7.1	1.7	3.86/ 0.55

			E1C5: Payoffs determined by non-linear step function based on ranges of total points earned		9.5	0.6	3.54/ 0.51
 After applying tallies (in E2C1 only), this is equivalent to:  	Increasing sum (exponential)/ Take-it-or-leave it		**E2C1:** Payoffs determined by tournament using ranking scheme based on tally reward system		38.1	1.1	2.37/ 0.34
			E2C2: Payoffs determined by linear function based on total points earned (high base, low piece rate)		16.7	1.2	3.62/ 0.52
			E2C3: Payoffs determined by linear function based on total points earned (medium base and piece rate)		11.9	0.2	3.44/ 0.49
			E2C4: Payoffs determined by linear function based on total points earned (low base, high piece rate)		11.9	1.4	3.72/ 0.53

			E2C5: Payoffs determined by non-linear step function based on ranges of total points earned		2.3	1.0	4.17/ 0.60
Across two experiments, participants completed five Centipede games each using the strategy method, and their strategies were subsequently matched with every other participant's strategy twice (with different combinations of player roles). All games had identical point trees but different rules on how to convert points earned in the game into monetary payoffs. Most conversion rules were based on linear functions where the total number of points earned in the experiment was multiplied by a fixed rate. However, both experiments also included one competitive treatment condition each where the participants' strategies got entered into tournaments, and monetary rewards were determined based on relative ranking schemes. In the tournament of Experiment 1, the strategies were ranked according to the total number of points earned. In the tournament of Experiment 2, "tallies" were awarded to the "winner" of each game, essentially turning the original Centipede game into a constant-sum, Take-it-or-leave-it game. The participant with the highest number of tallies overall, received the highest financial reward. In Experiment 1, only 11.9% of tournament games ended at the first decision node, and no significant differences were found between the tournament treatment condition and the treatments using other (less competitive) conversion rules. After adding the tallies in Experiment 2, the tournament treatment yielded an exit percentage of 38% at Node 1 which significantly differed from the four treatments with less competitive monetary conversion rules. These results indicated that the binary Take-it-or-leave-it incentive structure significantly decreased cooperation levels. The quantitative results reported here are based on the game outcomes resulting from the strategy matches between players. Since this computational method differed from all other studies included in this review, the results are not included in the comparative figures.							
McKelvey and Palfrey (1992)							
	Increasing sum (exponential)	10	**C1:** 4 nodes, low stake	Direct response method	7.1	5.0	2.75/ 0.55
			**C2:** 4 nodes, high stake		15.0	5.0	2.54/ 0.51

			**C3:** 6 nodes low stake		0.7	1.4	4.10/ 0.59
The authors studied decision making in two Centipede games of different lengths. Additionally, they ran one testing session with a high payoff version of the shorter length game. In all versions of the game, the participants deviated from the Nash equilibrium solution. Participants stopped earlier in shorter games - particularly in the high payoff version. Furthermore, their play became less cooperative with increasing experience. The authors attributed the deviation from the game theoretic solution to incomplete information about the utilities involved in the game. They further assumed 5% of participants to be motivated by altruistic preferences.							
Murphy, Rapoport, and Parco (2004)							
	Increasing sum (exponential)	90	**C1:** 21 genuine participants	Direct response method	3.0	0.1	4.24/ 0.42
			C2: 15 genuine participants, 6 cooperative robots		3.9	0.7	5.80/ 0.58
			C3: 18 genuine participants, 3 non-cooperative robots		3.2	0.1	4.80/ 0.48
			C4: 15 genuine participants, 6 non-cooperative robots		13.9	0.3	4.54/ 0.45
This experiment examined the influences of players with programmed strategies (robots) on cooperation levels in real participants. Very cooperative robots were shown to increase overall cooperation, whereas the inclusion of non-cooperative players did not have a significant effect. Across all conditions, the researchers found individual differences in the natural disposition to cooperate and suggested that the play of altruistic players was not affected by the cooperation levels of their co-players.							

<table>
<tr><td colspan="8">Murphy, Rapoport, and Parco (2006)</td></tr>
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in sec's</th><th>0</th><th>1</th><th>5</th><th>10</th><th>20</th><th>30</th><th>40</th><th>45-ε</th><th>45</th></tr>
<tr><td>Winner</td><td>5</td><td>6</td><td>10</td><td>20</td><td>80</td><td>320</td><td>1280</td><td>2560-ε</td><td>0</td></tr>
<tr><td>Loser 1</td><td>3</td><td>3</td><td>5</td><td>10</td><td>40</td><td>160</td><td>640</td><td>1280-ε</td><td>0</td></tr>
<tr><td>Loser 2</td><td>3</td><td>3</td><td>5</td><td>10</td><td>40</td><td>160</td><td>640</td><td>1280-ε</td><td>0</td></tr>
</table>
</td>
<td rowspan="3">Increasing sum (exponential)</td>
<td rowspan="3">90</td>
<td>C1: Low payoff difference; 3 players</td>
<td rowspan="3">Direct response method (with simultaneous moves)</td>
<td>1.7</td>
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<td>7.52/ 0.75</td>
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in sec's</th><th>0</th><th>1</th><th>5</th><th>10</th><th>20</th><th>30</th><th>40</th><th>45-ε</th><th>45</th></tr>
<tr><td>Winner</td><td>5</td><td>6</td><td>10</td><td>20</td><td>80</td><td>320</td><td>1280</td><td>2560-ε</td><td>0</td></tr>
<tr><td>Loser 1</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 2</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
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<td>C2: High payoff difference; 3 players</td>
<td>3.3</td>
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<td>5.52/ 0.55</td>
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in sec's</th><th>0</th><th>1</th><th>5</th><th>10</th><th>20</th><th>30</th><th>40</th><th>45-ε</th><th>45</th></tr>
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<tr><td>Loser 1</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 2</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 3</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 4</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 5</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
<tr><td>Loser 6</td><td>1</td><td>1</td><td>1</td><td>2</td><td>8</td><td>32</td><td>128</td><td>256-ε</td><td>0</td></tr>
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</td>
<td>C3: High payoff difference; 7 players</td>
<td>43.6</td>
<td>0</td>
<td>2.51/ 0.25</td>
</tr>
<tr><td colspan="8">The authors reported findings from an iterative real-time trust dilemma, which was based on the payoff function of exponentially increasing, multi-player Centipede games. The game did not have discrete decision nodes but was characterised by a continuous payoff function over a period of 45 seconds. The first person to stop the game, the "winner", received a payoff associated with the respective stop-time. The losers received a small proportion of the winner's payoff. All the scores reported here were calculated by dividing the raw data of exit times ranging between 0 and 44 seconds into nine bins of five seconds each. A tenth bin was added for games reaching the natural end (after 45 seconds) Each bin thus corresponds to a decision node of a regular Centipede game. The authors manipulated two factors: number of players (3 or 7) and loser's payoff (either 50% or 10% of the winner's payoff). Across all conditions, participants stopped earlier with increasing experience in the game. Both larger payoff differences and larger group sizes accelerated the breakdown of trust.</td></tr>
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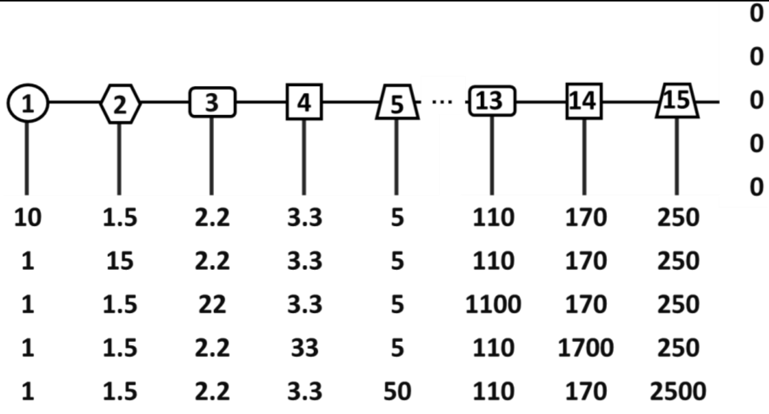
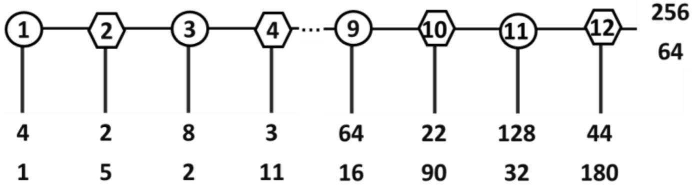
Nachbar (2014), unpublished manuscript retrieved online							
	Increasing sum	60	N/A	Direct response method	36.3	0	2.76/ 0.17
This study investigated learning across 60 rounds in 5-player, high-stake Centipede games with randomly changing co-players. Whilst some learning effects were reported, no convergence towards equilibrium play was found. This was partly due to the high number of individuals, who consistently employed cooperative/altruistic strategies throughout the experiment.							

Nagel and Tang (1998)

Smaller choice	Possible higher choices of opponents	Payoff of A	Payoff of B	Sum
1	{2, 4, 6, 8, 10, 12, 14}	4	1	5
2	{3, 5, 7, 9, 11, 13}	2	5	7
3	{4, 6, 8, 10, 12, 14}	8	2	10
4	{5, 7, 9, 11, 13}	3	11	14
5	{6, 8, 10, 12, 14}	16	4	20
6	{7, 9, 11, 13}	6	22	28
7	{8, 10, 12, 14}	32	8	40
8	{9, 11, 13}	11	45	56
9	{10, 12, 14}	64	16	80
10	{11, 13}	22	90	112
11	{12, 14}	128	32	160
12	{13}	44	180	224
13	{14}	256	64	320

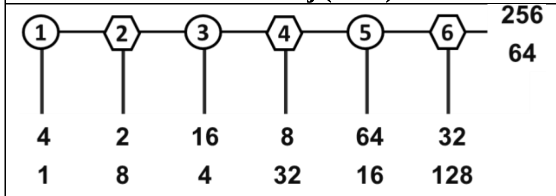
Strategically equivalent to:



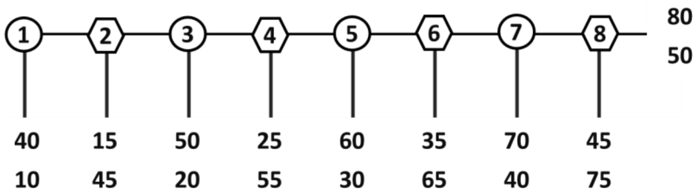
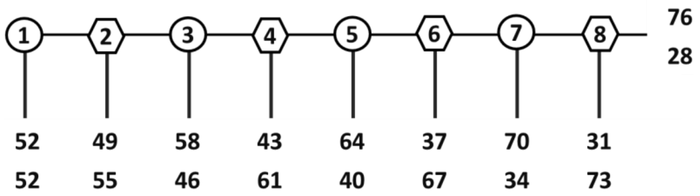
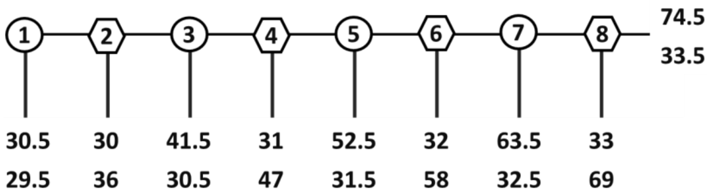
Increasing sum (exponential)	100	N/A	Strategy method (variation), game presented in normal form	0.5	9.3	9.16/ 0.65

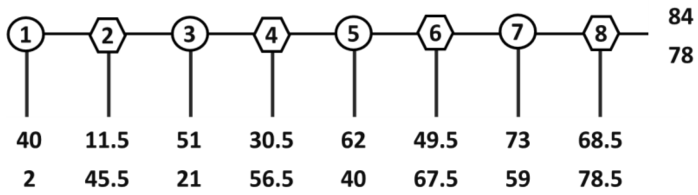
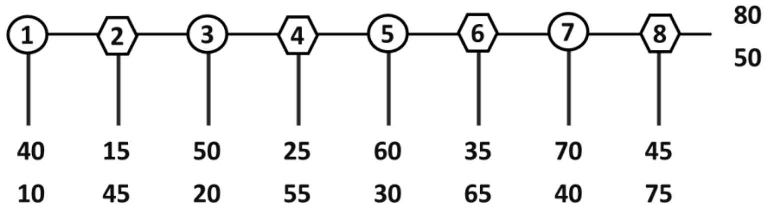
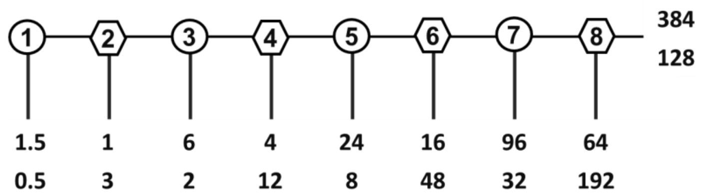
This experiment tested for learning effects in a normal-form Centipede game over a period of 100 game iterations. No convergence towards equilibrium play was found. In earlier rounds, players seemed to be influenced by the immediately preceding moves. In later rounds, some fixed strategies were adopted. However, these were not in line with equilibrium play.

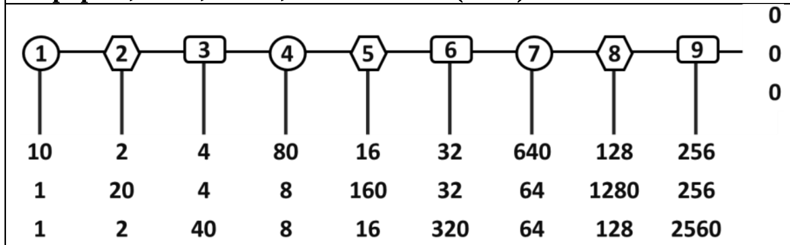
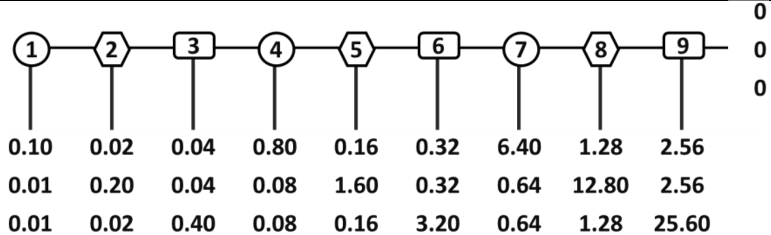
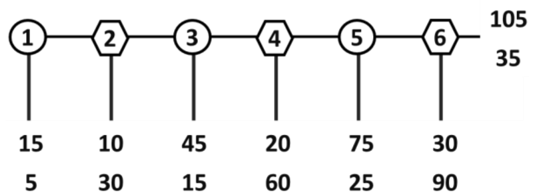
Palacios-Huerta and Volij (2009)

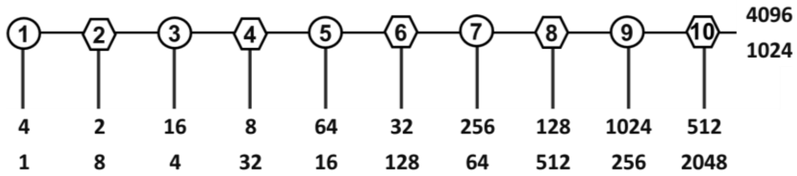
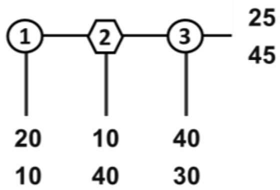
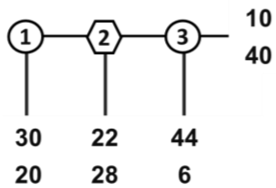
	Increasing sum (exponential)	1	**C1:** Chess players (field)	Direct response method	68.7	0	1.44/ 0.21
		1	**C2:** Students (field)		7.5	0	3.28/ 0.47
		10	**C3:** Chess players (lab)		72.5	0	1.39/ 0.20
		10	**C4:** Students (lab)		3.0	0.5	3.44/ 0.49
		10	**C5:** PA=chess player, PB=student (lab)		37.5	0	2.19/ 0.31
		10	**C6:** PA=student, PB=chess player (lab)		30	0	2.21/ 0.32

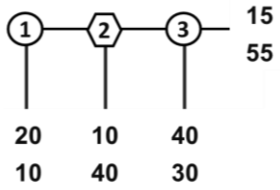
This article reported findings from Centipede studies using chess experts and students in field and laboratory settings. Overall, the chess players' decisions were much closer to the Nash equilibrium solution than the students'. Only a third of the chess players and none of the chess Grandmasters in the field study decided to continue at

the first decision node. When matching students and chess players in lab experiments of the Centipede game, cooperation levels differed depending on the sample composition. Pure student samples were most cooperative; pure samples of chess players were least cooperative and mixed groups scored in between. The findings indicated that decision making in the Centipede game was significantly influenced by cognitive abilities, and that individuals adapted their strategies depending on the type of co-player (and their expected reasoning skills).							
Pulford, Colman, Lawrence, and Krockow (2017)							
	Increasing sum (linear)	20	**C1:** Constant payoff difference; fixed pairing	Direct response method	13.3	9.6	4.63/ 0.51
	Increasing sum (linear)		**C2:** Constant payoff difference; random pairing		20.8	0.8	3.40/ 0.38
	Constant-sum		**C3:** Constant-sum; fixed pairing		17.1	0.4	3.10/ 0.34
	Constant-sum		**C4:** Constant-sum; random pairing		27.1	0	2.53/ 0.28
	Increasing sum (linear)		**C5:** Increasing payoff difference; fixed pairing		0.9	9.3	5.01/ 0.57
	Increasing sum (linear)		**C6:** Increasing payoff difference; random pairing		2.5	0	3.95/ 0.45
	Increasing sum (linear)		**C7:** Decreasing payoff differences; fixed pairing		17.3	30.0	5.72/ 0.64

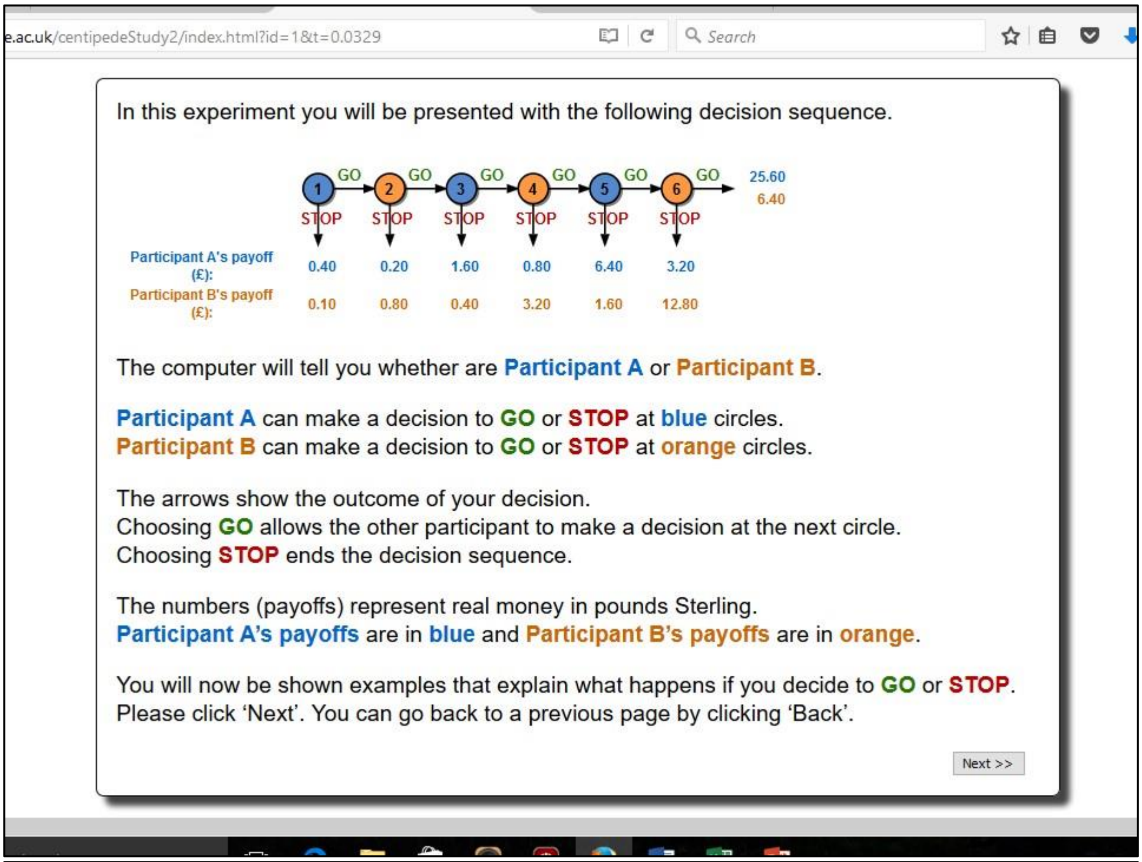
	Increasing sum (linear)		**C8:** Decreasing payoff differences; random pairing		11.4	37.7	5.88/ 0.65
	Increasing sum (linear)		**C9:** Constant payoff difference with strategy method, random pairing	Strategy method (variation)	23.3	1.3	3.47/ 0.39
This study tested different theories explaining cooperation in the Centipede game. The authors compared decision making in games with subtly different payoff functions and found that cooperation was highest in Centipede games with linearly increasing payoffs where payoff differences between the two players decreased throughout the game. Comparing conditions of fixed pairing with the same co-player and conditions of random pairing, the former produced higher levels of cooperation. Play was found to be similarly cooperative when omitting sequential play by using the strategy method compared to standard conditions where the direct response method was used. Taken together, these findings suggest a strong impact of pro-social interests (including inequity-aversion), influences of fuzzy traces (mental gist representations), and reputation effects across games when repeatedly playing with the same co-player.							
Pulford, Krockow, Colman, and Lawrence (2016)							
	Increasing sum (exponential)	20	**C1:** Individualistic SVO	Direct response method	1.0	18.0	6.72/ 0.75
			C2: Competitive SVO		1.5	7.5	5.98/ 0.66
			C3: Cooperative SVO		0	10.0	6.30/ 0.70
			C4: Neutral SVO		2.5	5.5	6.32/ 0.70
Using framed task instructions, this study including two experiments induced different types of social value orientations (cooperative, competitive and individualistic) to test for influences of other-regarding preferences on decision making in the Centipede game. To keep this summary concise, on the results of Experiment 2 are reported. The manipulations produced significantly different cooperation levels, with competitively framed players stopping earlier than individualistically framed players.							

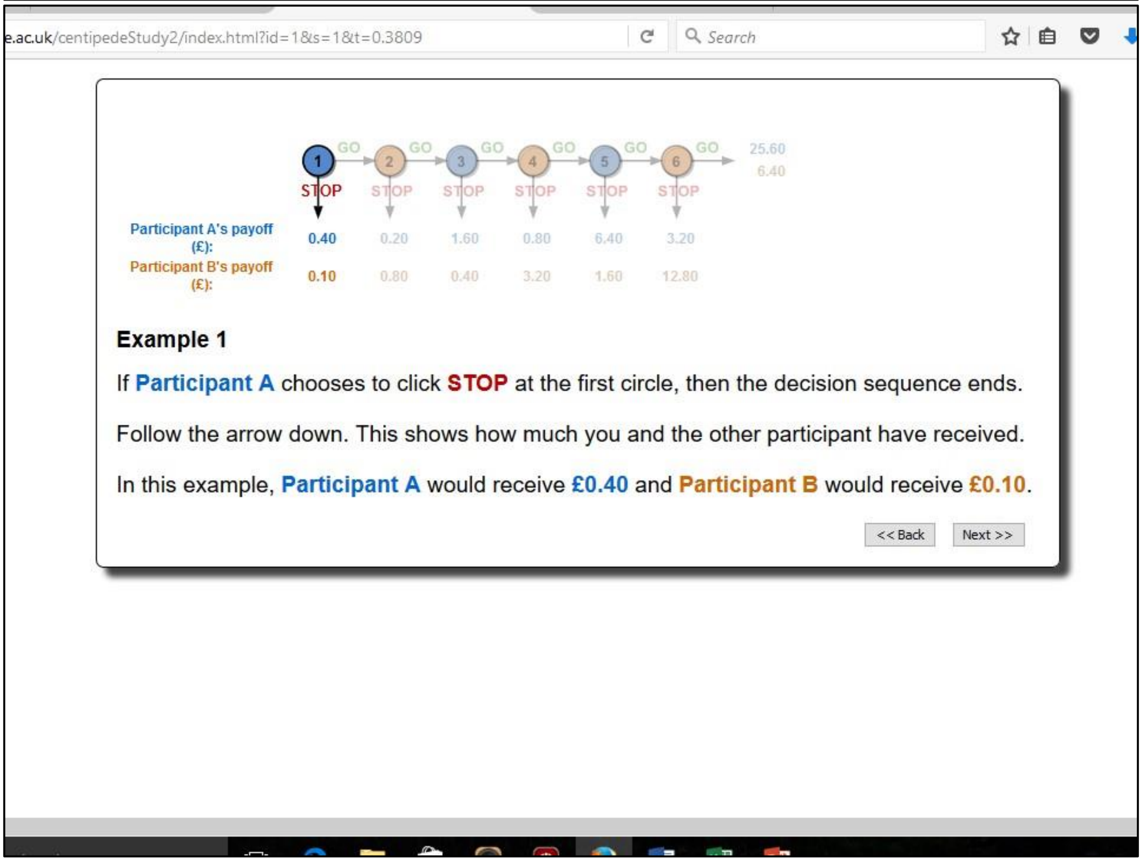
Additionally, a questionnaire measure of trait SVO showed interactions with the experimental manipulations. Interestingly, decision making in the neutral control condition was found to be significantly different from the individualistic condition. This refuted the game-theoretical assumption that randomly sampled participants may hold selfish preferences by default.							
Rapoport, Stein, Parco, and Nicholas (2003)							
	Increasing sum (exponential)	60	**C1:** High stake	Direct response method	39.2	0	2.30/ 0.23
			**C2:** Low stake		2.6	0	5.31/ 0.53
The experiment compared decision making in high stake and low stake three player Centipede games. The data obtained in Condition 2 were also reported in a shorter article by Parco, Rapoport, and Stein (2002). The authors found convergence towards equilibrium play in the high stake version. The low stake version produced very different results which yielded similar cooperation patterns as previously observed in McKelvey and Palfrey's (1992) 6-node Centipede game.							
Sheldon and Fishbach (2011)							
	Increasing sum (linear)	1	**C1:** Strong barrier to success	Strategy method (variation)	No informati on	No informati on	2.00/ 0.67
			C2: Weak barrier to success		No informati on	No informati on	1.50/ 0.50
The authors investigated the effects of self-control on mixed-motive interactions such as the Centipede game, arguing that the short-term temptation to defect requires self-control in order to achieve higher outcomes in the long run. They manipulated the amount of interpersonal control in a game's context as well as the perceived "barrier to success" in the game, and compared decision making across the Centipede game, a Prisoner's Dilemma game and a Union-management negotiation. In the Centipede experiment, all participants were assigned the role of Player A which the authors argued to be a position of high interpersonal control. They manipulated the perceived barrier to success by having the participants engage in thoughts about risk/insecurity about the task (strong barrier to success) or in thoughts about why they							

<table>
<tr><td colspan="8">might feel secure regarding the task (weak barrier to success). Findings showed that participants, who expected strong barriers, cooperated significantly more frequently. According to the authors' interpretations, participants in the strong barrier condition increased their cooperation to counteract the anticipated difficulties in the task and the temptation to defect. Additional experiments reported in the article suggested that this effect only persisted if participants perceived themselves to be in a high-control position within the game.</td></tr>
<tr><td colspan="8">Thiele (2012)</td></tr>
<tr><td>
</td><td>Increasing sum (exponential)</td><td>6 (change of co-player after three games)</td><td>N/A</td><td>Direct response method</td><td>1.3</td><td>9.2</td><td>8.02/ 0.73</td></tr>
<tr><td colspan="8">In this experiment, all participants completed six Centipede games. Their co-players remained the same for the first three games. Then, random re-matching took place and they completed another three rounds with a different co-player. Overall, the results showed reliable deviations from the subgame-perfect Nash equilibrium solution, with participants exiting particularly late in the first round played with a new co-player (i.e., rounds 1 and 4). Cooperation then decreased in the following two rounds with the same co-player. These findings indicated that participants treated the three rounds of repeated matching with the same co-player as super games. The author suggested that sophisticated rationality and conscious deviations from the game-theoretic solution were used to establish a reciprocal relationship with the other player across rounds in order to ultimately maximise personal payoffs.</td></tr>
<tr><td colspan="8">Wang (2015), unpublished manuscript retrieved online</td></tr>
<tr><td>
</td><td>Increasing sum</td><td rowspan="2">1 (Strategy method); then the strategies were matched across 15 game rounds</td><td>C1: Baseline game</td><td rowspan="2">Strategy method</td><td>No information</td><td>No information</td><td>No information</td></tr>
<tr><td>
</td><td>Constant-sum</td><td>C2: Constant-sum game</td><td>No information</td><td>No information</td><td>No information</td></tr>
</table>

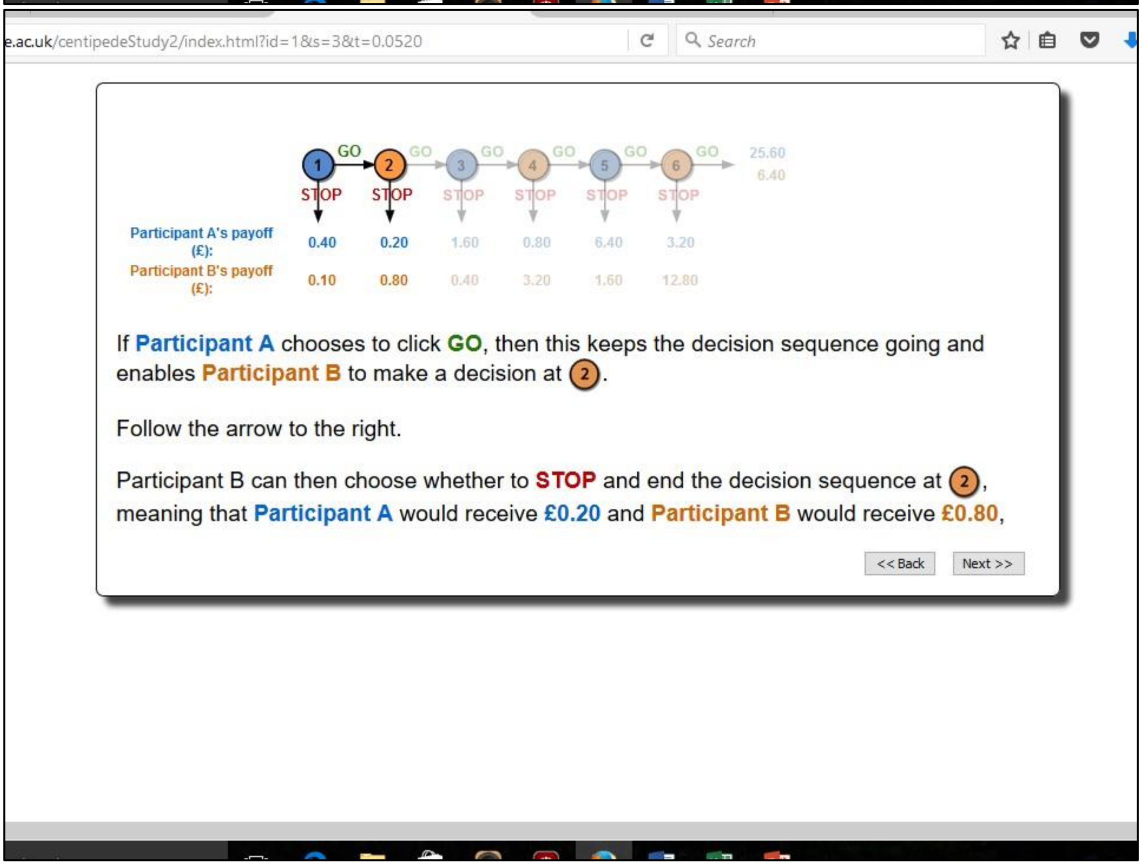
	Increasing sum		**C3:** “No-mutual benefit” game (low payoff for Player A at natural end)		No information	No information	No information
This experiment explored rationality in the Centipede game which was defined as best response to the co-player’s expected beliefs and consequent decisions. Using a between-subjects design, the participants completed one out of three Centipede games (baseline game with increasing sum and mutual benefits at final node; constant-sum game and increasing sum game with no mutual benefits at final node) using the strategy method. The strategy profiles were subsequently matched across 15 rounds of games. Afterwards, the participants had to make predictions about their co-players’ strategy profiles. All treatment conditions showed reliable deviations from the Nash equilibrium solution. The baseline condition produced the highest levels of cooperation, followed by the “No-mutual-benefit” condition and the constant-sum condition. When matching the actual decision strategies with the predicted strategies of the co-players to test for rationality, the results showed that participants in the role of Player A overall were more rational than those in the role of Player B, and that the constant-sum game elicited higher levels of rationality than the other games.							

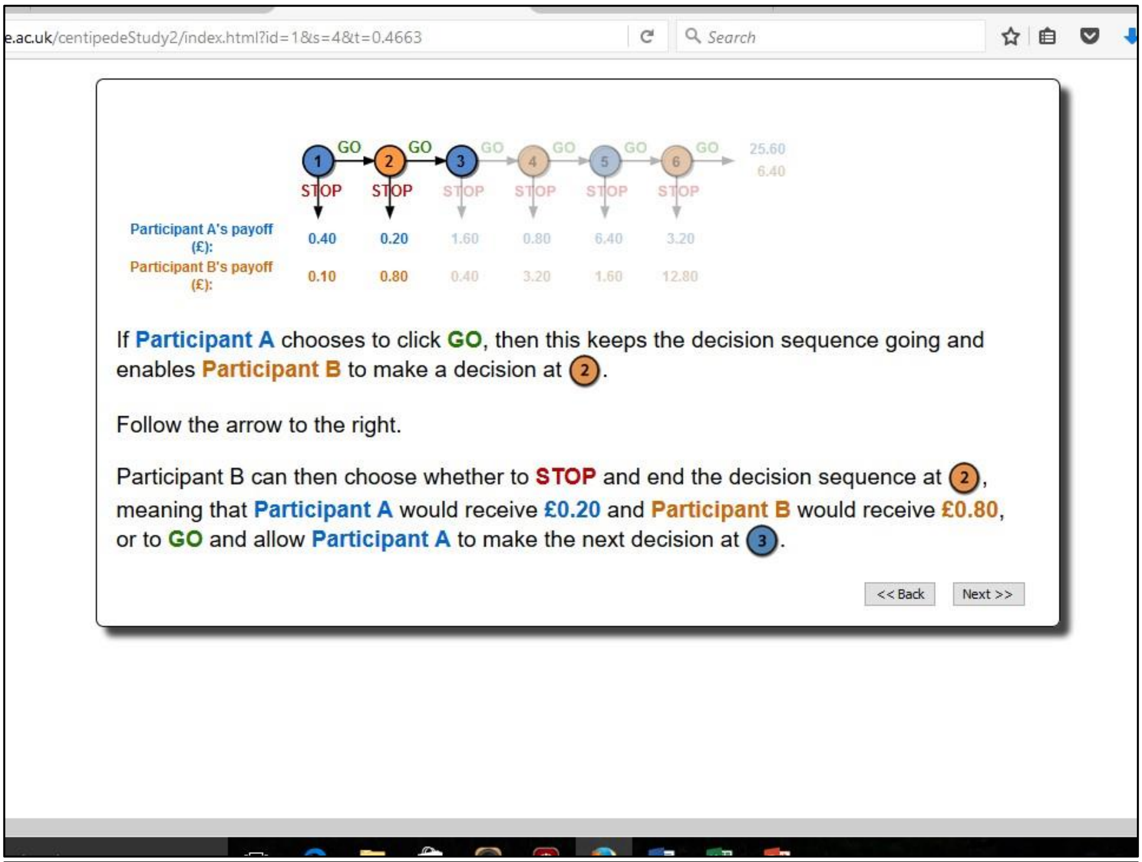
Appendix B: Screenshots of Web Application Used for Study 1 (Similar Versions were used for Studies 2, 3, 4, and 6)

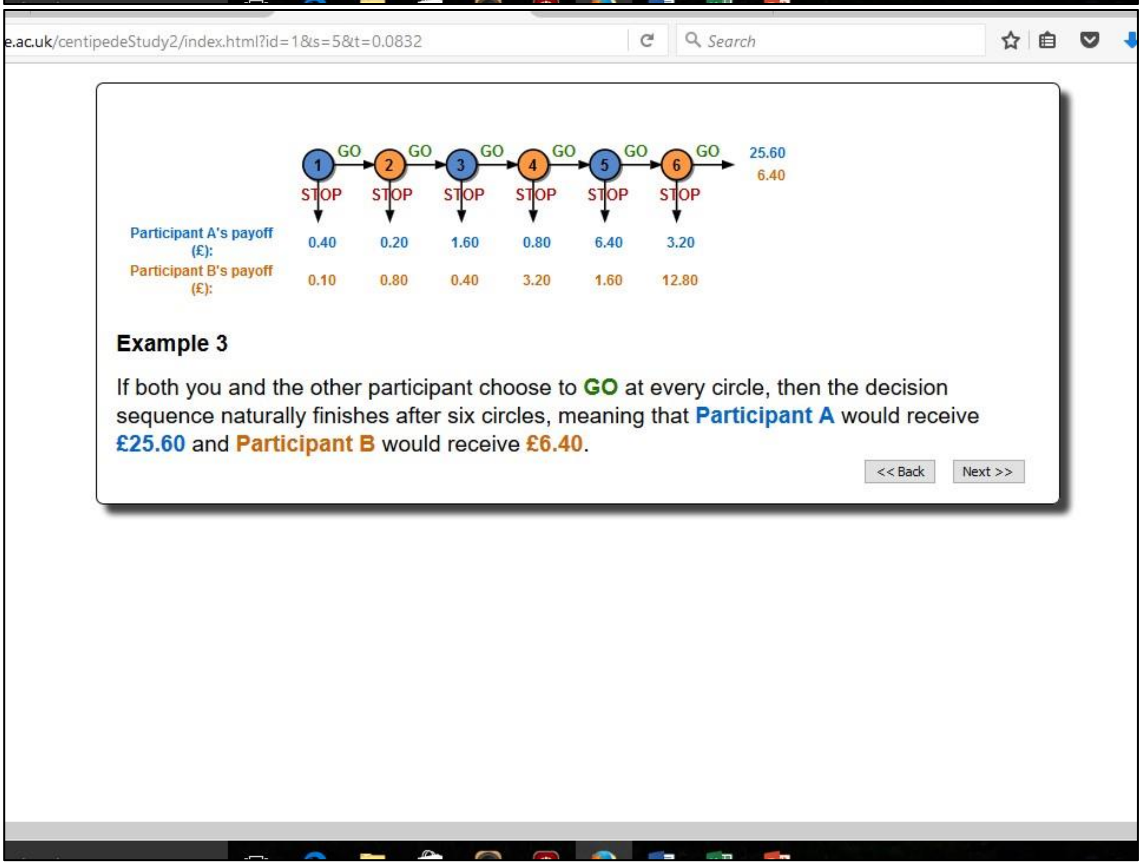


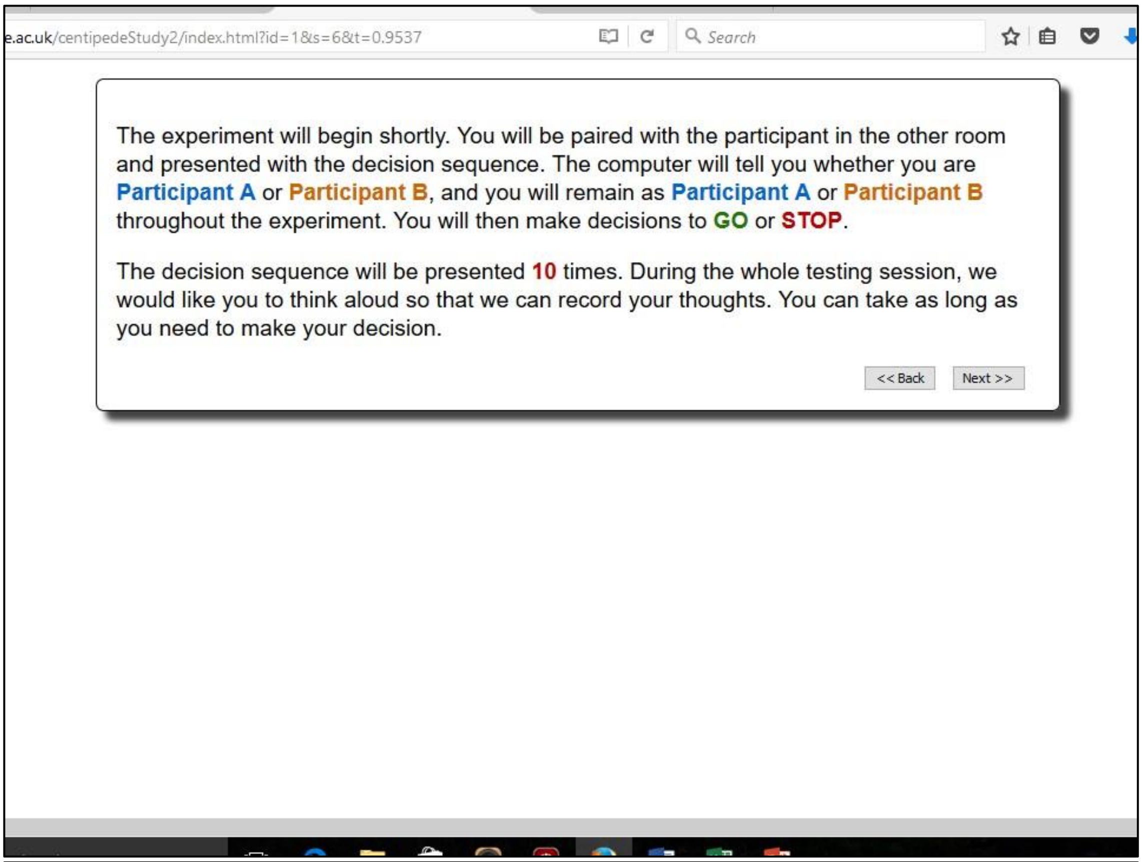


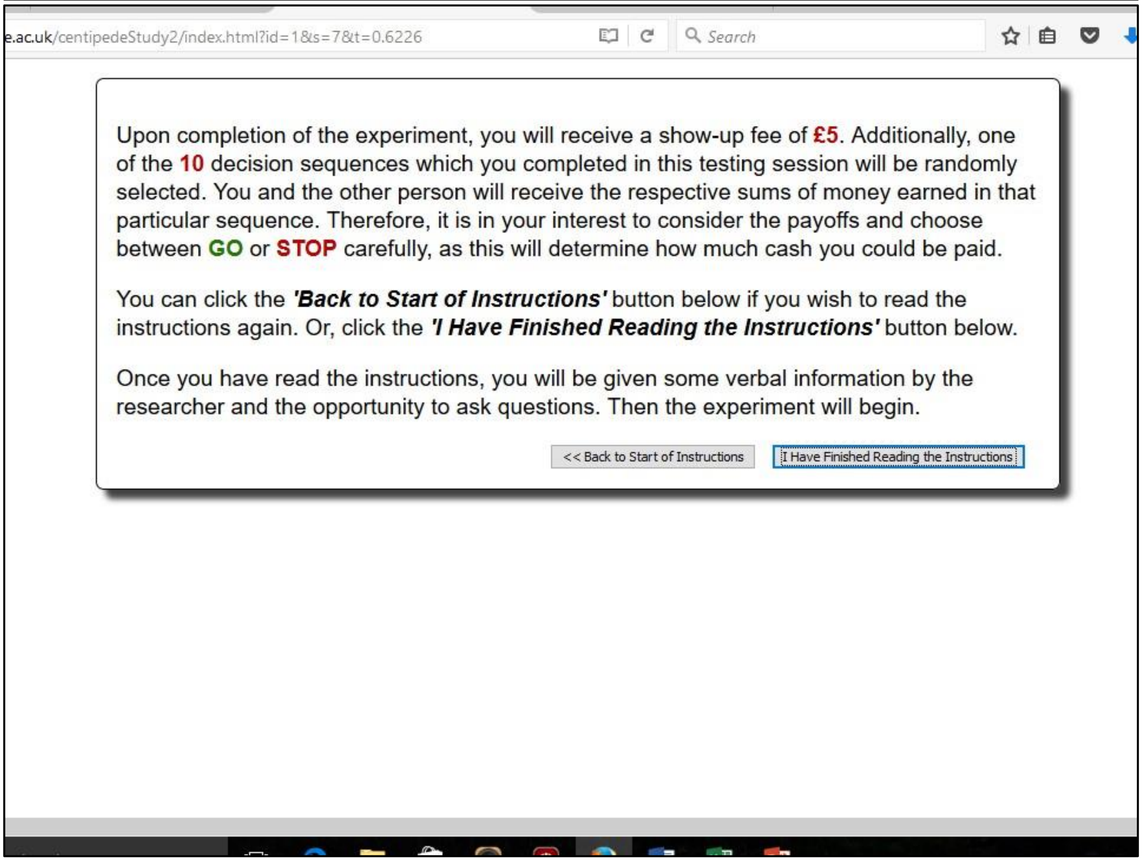

e.ac.uk/centipedeStudy2/index.html?id=1&s=2&t=0.3119
Search
GO
STOP
25.60
6.40
Participant A's payoff (£):
0.40
0.20
1.60
0.80
6.40
3.20
Participant B's payoff (£):
0.10
0.80
0.40
3.20
1.60
12.80
If Participant A chooses to click GO, then this keeps the decision sequence going and enables Participant B to make a decision at 2.
Follow the arrow to the right.
<< Back
Next >>


e.ac.uk/centipedeStudy2/index.html?id=1&s=3&t=0.0520
Search
GO
STOP
25.60
6.40
Participant A's payoff (£):
0.40
0.20
1.60
0.80
6.40
3.20
Participant B's payoff (£):
0.10
0.80
0.40
3.20
1.60
12.80
If Participant A chooses to click GO, then this keeps the decision sequence going and enables Participant B to make a decision at 2.
Follow the arrow to the right.
Participant B can then choose whether to STOP and end the decision sequence at 2, meaning that Participant A would receive £0.20 and Participant B would receive £0.80,
<< Back
Next >>


e.ac.uk/centipedeStudy2/index.html?id=1&s=4&t=0.4663
Search
GO GO GO GO GO GO
1 2 3 4 5 6
STOP STOP STOP STOP STOP STOP
25.60
6.40
Participant A's payoff (£):
0.40 0.20 1.60 0.80 6.40 3.20
Participant B's payoff (£):
0.10 0.80 0.40 3.20 1.60 12.80
If Participant A chooses to click GO, then this keeps the decision sequence going and enables Participant B to make a decision at 2.
Follow the arrow to the right.
Participant B can then choose whether to STOP and end the decision sequence at 2, meaning that Participant A would receive £0.20 and Participant B would receive £0.80, or to GO and allow Participant A to make the next decision at 3.
<< Back
Next >>

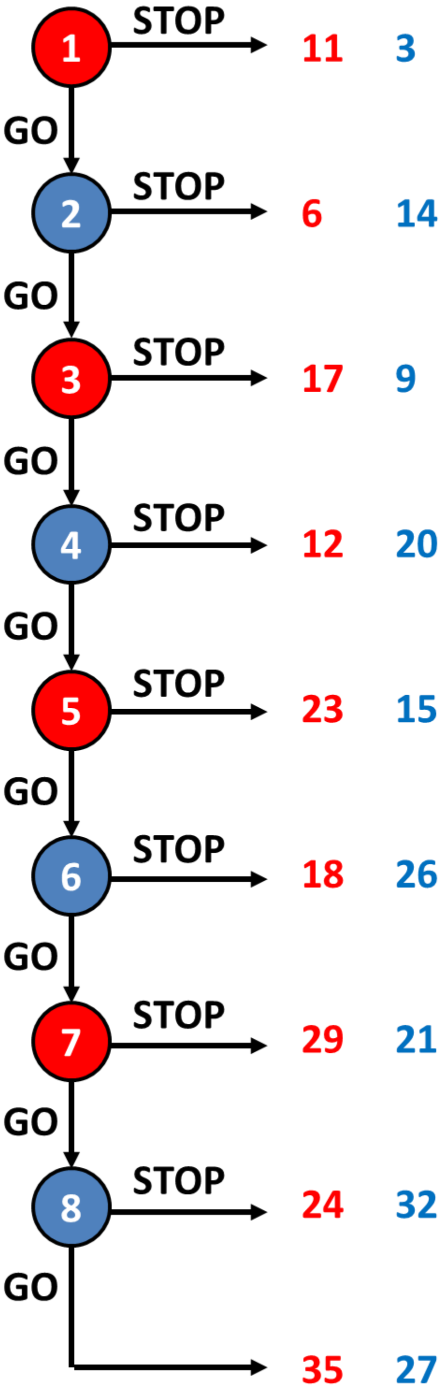

e.ac.uk/centipedeStudy2/index.html?id=1&s=5&t=0.0832
Search
GO GO GO GO GO GO
1 2 3 4 5 6
STOP STOP STOP STOP STOP STOP
25.60
6.40
Participant A's payoff (£):
0.40 0.20 1.60 0.80 6.40 3.20
Participant B's payoff (£):
0.10 0.80 0.40 3.20 1.60 12.80
Example 3
If both you and the other participant choose to GO at every circle, then the decision sequence naturally finishes after six circles, meaning that Participant A would receive £25.60 and Participant B would receive £6.40.
<< Back
Next >>


e.ac.uk/centipedeStudy2/index.html?id=1&s=6&t=0.9537
Search
The experiment will begin shortly. You will be paired with the participant in the other room and presented with the decision sequence. The computer will tell you whether you are Participant A or Participant B, and you will remain as Participant A or Participant B throughout the experiment. You will then make decisions to GO or STOP.
The decision sequence will be presented 10 times. During the whole testing session, we would like you to think aloud so that we can record your thoughts. You can take as long as you need to make your decision.
<< Back
Next >>


e.ac.uk/centipedeStudy2/index.html?id=1&s=7&t=0.6226
Search
Upon completion of the experiment, you will receive a show-up fee of £5. Additionally, one of the 10 decision sequences which you completed in this testing session will be randomly selected. You and the other person will receive the respective sums of money earned in that particular sequence. Therefore, it is in your interest to consider the payoffs and choose between GO or STOP carefully, as this will determine how much cash you could be paid.
You can click the 'Back to Start of Instructions' button below if you wish to read the instructions again. Or, click the 'I Have Finished Reading the Instructions' button below.
Once you have read the instructions, you will be given some verbal information by the researcher and the opportunity to ask questions. Then the experiment will begin.
<< Back to Start of Instructions
I Have Finished Reading the Instructions

Appendix C: Example Materials for Study 5 (Condition 2)

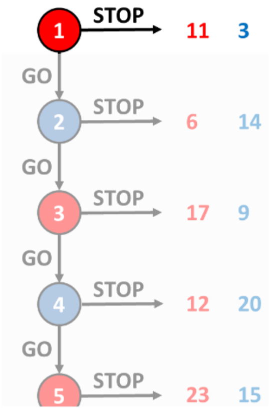
In this experiment you will be presented with the following decision sequence:



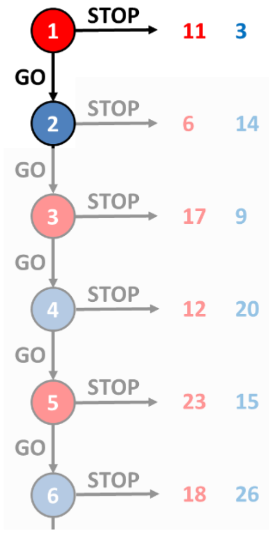
Participant Red can make a decision to **GO** or **STOP** at the **red** circles (decision points).
Participant Blue can make a decision to **GO** or **STOP** at **blue** circles (decision points).
The arrows show the outcome of your decision.
Choosing **GO** allows the other participant to make a decision at the next circle.
Choosing **STOP** ends the decision sequence.
The numbers (payoffs) are monetary units. **Participant Red**'s payoffs are in **red** and **Participant Blue**'s payoffs are in **blue**.
One monetary unit in the decision sequence equals £1.36. Hence, if you wanted to calculate the payoff in Pounds Sterling, you would have to multiply the number of monetary units by 1.36.
For example:
5 monetary units equal £6.80
10 monetary units equal £13.60
50 monetary units equal £68.

For your better understanding of the decision sequence, here are a few rules determining how the payoffs change from one circle to another:
If a participant chooses to **GO**, he/she decreases his/her own payoff by 5 monetary units and adds 11 to the other participant's payoff at the next circle.
If a participant chooses to **GO**, both participants' combined payoffs increase by 6 monetary units at the next circle.
If a participant chooses to **STOP**, the sequence finishes leading to an immediate payoff. The participant, who decides to **STOP** always receives 8 monetary units more compared to the other participant.

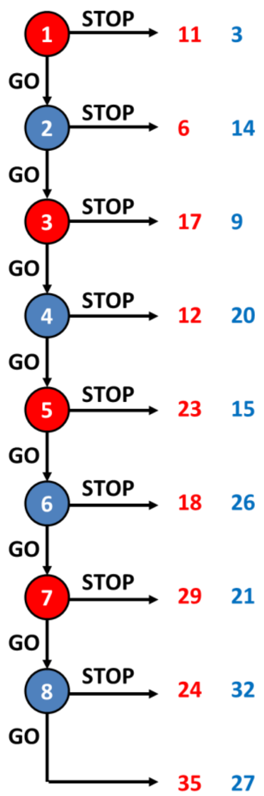
You will now be shown a few examples what happens when you choose GO or STOP:



Example 1
If **Participant Red** chooses to click **STOP** at the first decision point, then the decision sequence ends. Follow the arrow across. This shows how much you and the other participant have received.
In this example, **Participant Red** would receive **11** monetary units and **Participant Blue** would receive **3**.



Example 2
If **Participant Red** chooses to click **GO**, then this keeps the decision sequence going and enables **Participant Blue** to make a decision at the second decision point. Follow the arrow down.
Participant Blue can then choose whether to **STOP** and end the decision sequence at the second decision point, meaning that **Participant Red** would receive **6** monetary units and **Participant Blue** would receive **14**, or **Participant Blue** can choose to **GO** and allow **Participant Red** to make the decision at the third decision point.

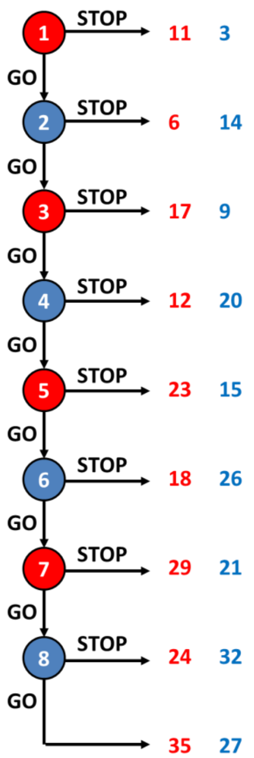


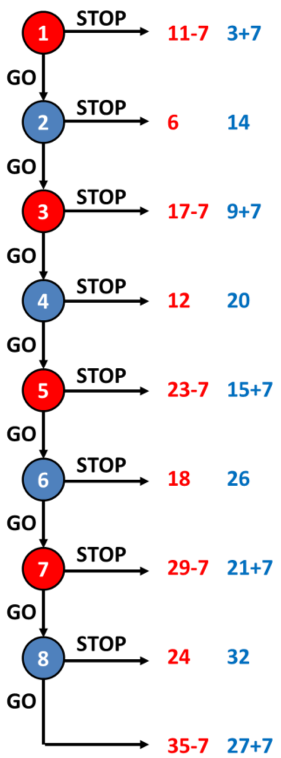
Example 3
If both you and the other participant choose to **GO** at every decision point, then the decision sequence naturally finishes when it passes the eighth decision point, meaning that
Participant Red would receive **35** monetary units and **Participant Blue** would receive **27**.

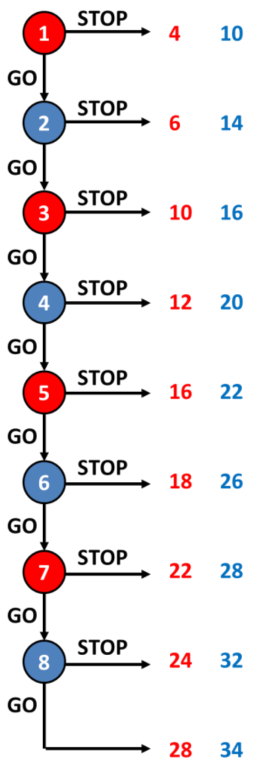
The previous pages described the standard version of the decision sequence to you. Before engaging in the sequence, however, you will be offered to purchase a tool that changes the payoffs to both participants.
If you choose to purchase the tool, 7 monetary units will be deducted from your own payoff and added to the other person's payoff ONLY if the other person does not STOP the decision sequence.
Please take a look at the different displays below to see how the payoffs change in the event that (1) only **Participant Red** purchases the tool, (2) only **Participant Blue** purchases the tool, or (3) both participants decide to purchase the tool.

Display 1: Only Participant Red decides to purchase the tool

Standard decision sequence	7 monetary units are deducted from Red's payoff and added to Blue's payoff ONLY if Blue does not STOP the decision sequence.	These are the final payoffs after taking into account the changes caused by the tool.

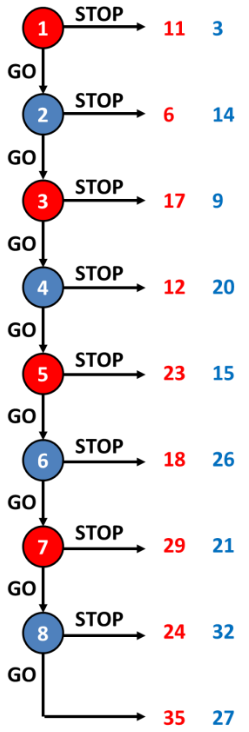


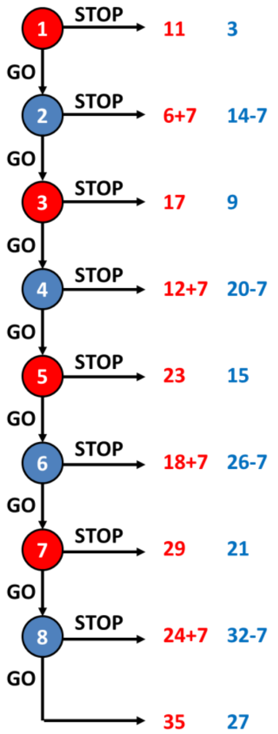


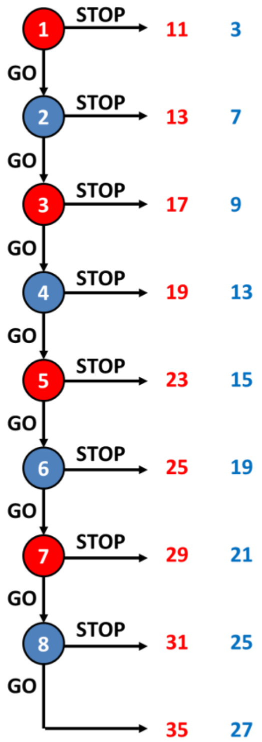


Display 2: Only Participant Blue decides to purchase the tool

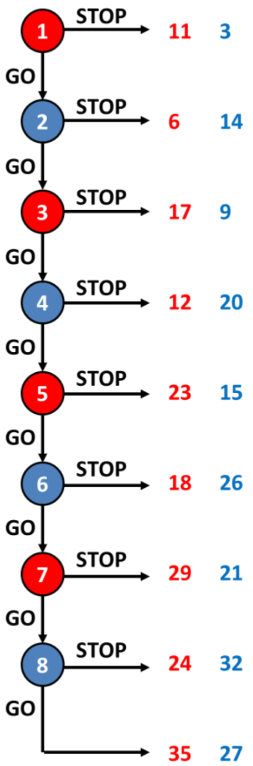
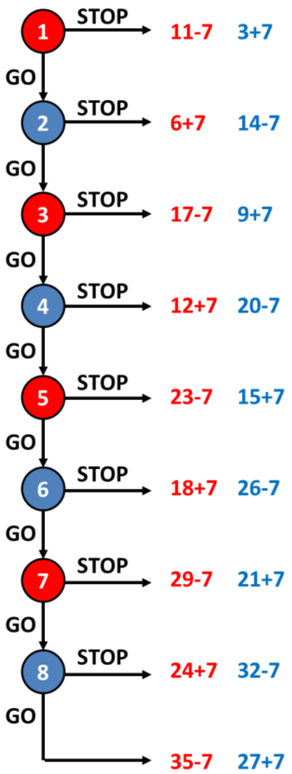
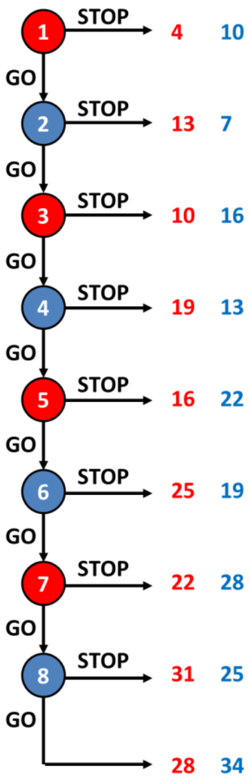
Standard decision sequence	7 monetary units are deducted from Blue's payoff and added to Red's payoff ONLY if Red does not STOP the decision sequence.	These are the final payoffs after taking into account the changes caused by the tool.







Display 3: Both participants decide to purchase the tool

Standard decision sequence	The payoff changes presented in the two previous tables are combined:	These are the final payoffs after taking into account the changes caused by the tool.
		

The experiment will begin shortly. Using a special computer programme, you will be randomly paired with another participant in the room and presented with the decision sequence. On the screen, the decision sequence will look like this. As you can see, even though the sequence is presented in a table, the decision points are still on the left and the payoffs to **Participant Red** and **Participant Blue** are displayed in the two columns on the right.

		Red's units	Blue's units
Decision Point 1	STOP	11	3
GO			
Decision Point 2	STOP	6	14
GO			
Decision Point 3	STOP	17	9
GO			
Decision Point 4	STOP	12	20
GO			
Decision Point 5	STOP	23	15
GO			
Decision Point 6	STOP	18	26
GO			
Decision Point 7	STOP	29	21
GO			
Decision Point 8	STOP	24	32
GO		35	27

The computer will randomly determine whether you are **Participant Red** or **Participant Blue**, and you will remain in that role throughout the experiment.
Before each decision sequence, both participants will be asked whether they would like to purchase the tool that changes the payoffs in the sequence. When both participants have made their decisions, they will be informed about the choice of the other person. Then the decision sequence starts and you will make decisions to **GO** or **STOP**.
Once the decision sequence has ended, you will be randomly paired with a different participant. Again, you will have to choose whether to purchase the tool and you will be asked to make decisions to **GO** or **STOP** on the decision sequence. The whole decision sequence will be presented **20 times** in total and you will be randomly paired with a different participant for each sequence. You will not know who you are paired with and for each new sequence you will have to decide again whether or not to purchase the tool.
At the end of the testing session today, the computer will randomly select one participant out of this group to win his or her payoff from one randomly chosen decision sequence he or she completed during the testing session. The monetary units earned in this sequence will be converted into Pounds Sterling through multiplying the number by 1.36. Therefore, it is in your interest to consider the payoffs and choose between **GO** or **STOP** carefully, as this will determine how much cash you could be paid.
Please do not talk to other participants during the experiment.
Once everyone has read through the instructions, you will be given some verbal information by the researcher and the opportunity to ask questions. Then the experiment will begin

Comprehension test (Conditions 2 and 3)

Please answer all the questions below. This will help us assess whether you have understood the instructions. Feel free to consult your handout while answering the questions.

1. Which participant can make a move at Decision Point 5 (the fifth circle)?

   ____

2. In the event that neither participant decides to purchase the tool, how many monetary units do both participants earn if the sequence is stopped at Decision Point 5?

   Participant Red: __________ monetary units

   Participant Blue: __________ monetary units

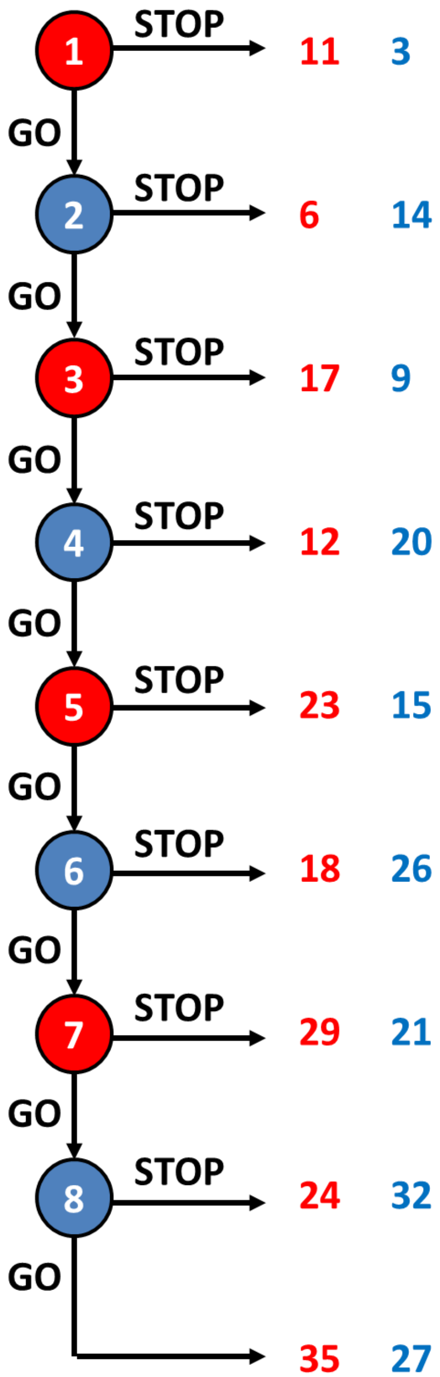
3. In the event that only Participant Red decides to purchase the tool, how many monetary units do both participants earn if the sequence is stopped at Decision Point 5?

   Participant Red: __________ monetary units

   Participant Blue: __________ monetary units

4. How often will you be presented with the decision sequence?

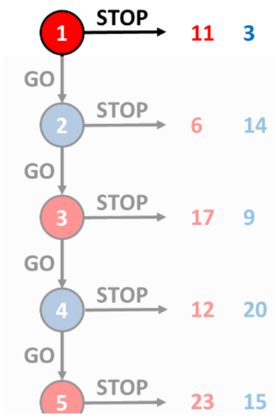
   ________ times



左図をみてください。やりとりは、上から下へと進んで行きます。
赤の参加者は赤い円で表現された決定地点に来たら、「**進む (GO)**」か「**止まる (STOP)**」か、どちらかを選択します。
同様に青の参加者は青い円で表現された決定地点に来たら、「**進む**」か「**止まる**」かどちらかを選びます。
参加者が決定すると、その決定に対応した方向の矢印に従って進みます。
「**進む**」を選ぶと、次の決定地点へ移動し、もう一方の参加者が決定をすることになります。
「**止まる**」を選ぶと、そこでやりとりは終了です。
数値は、報酬ポイントを表します。赤の参加者は赤い数値のポイントを、青の参加者は青い数値のポイントを得ます。
報酬ポイントは 1 点あたり￥242 に換算されます
例：
5 ポイント＝¥1,210
10 ポイント＝¥2,420
50 ポイント＝¥12,100

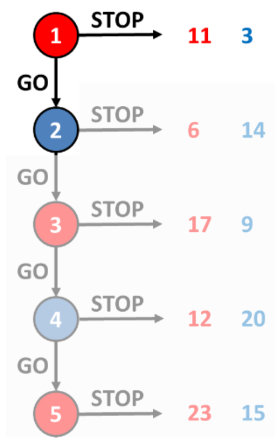
やり取りが進むに連れて、報酬ポイントは以下に記すルールに従って変化していきます:
参加者が「**進む**」を選択すると、決定した参加者のポイントが 5 単位減り、相手の参加者のポイントが 11 単位増えます。従って 2 人のポイントの合計は 6 単位増加します。
一方、参加者が「**止まる**」を選択すると、即座にやりとりは終了します。そして「**止まる**」を選択した参加者は常に相手よりも 8 単位多くのポイントを得ます。

次に具体例を使って説明します。



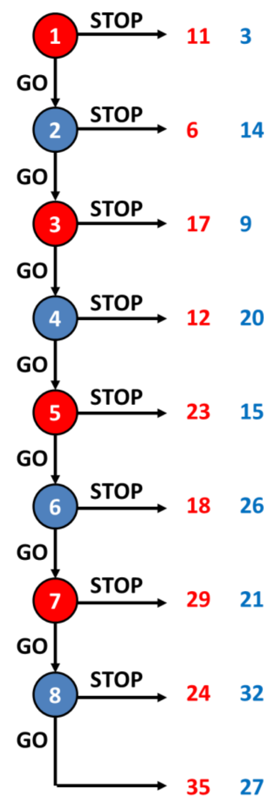
例 1

赤の参加者が最初の決定地点で「**止まる**」を選択した場合、そこでやり取りは終了します。
矢印に沿って右へ移動します。そこに二人が得る報酬ポイントが表示されています。
この例の場合、赤の参加者は **11** ポイント、青の参加者は **3** ポイントを得ます。



例 2

赤の参加者が「**進む**」を選択した場合、やりとりは継続され、次に青の参加者が決定をすることになります。矢印に沿って下へ進んでください。
次に 2 つ目の決定地点で青の参加者が「**止まる**」を選択すると、そこでやりとりは終了します。この場合赤の参加者は **6** ポイント、青の参加者は **14** ポイントを得ます。
青の参加者は「**進む**」を選択することもできます。その場合、赤の参加者は上から 3 つ目の決定地点で判断をすることになります。



例 3

もし参加者が全ての決定地点で「**進む**」を選んだならば、やりとりは 8 つ目の決定地点を通過し、赤の参加者は **35** ポイント、青の参加者は **27** ポイントを獲得します。

ここまでやりとりについて説明してきましたが、実験ではさらに、やりとりを開始する前にツールを購入して、2 人が得る報酬額を変化させることができます。**このツールを購入すると、相手が「止まる」を選ばない限り、あなたが得る報酬から 7 ポイントが差し引かれ、相手の参加者の得る報酬に加算されます。**
このツールを購入すると報酬ポイントがどのように変化するのか、下の表を見て確認して下さい。（1）**赤の参加者**のみがツールを購入した場合、（2）**青の参加者**のみがツールを購入した場合。（3）両参加者がツールを購入した場合。

表 1：赤の参加者のみがツールを購入決定した場合。

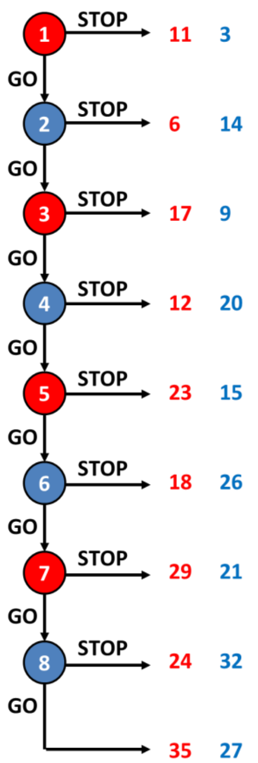
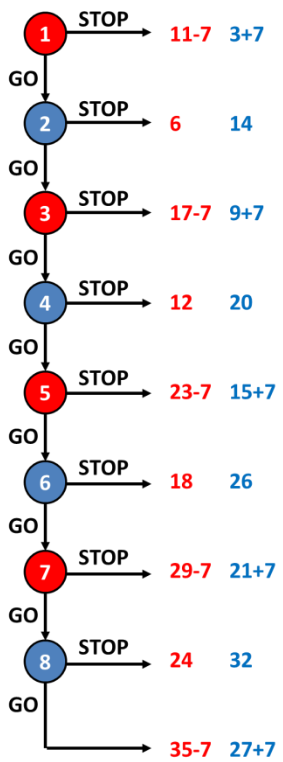
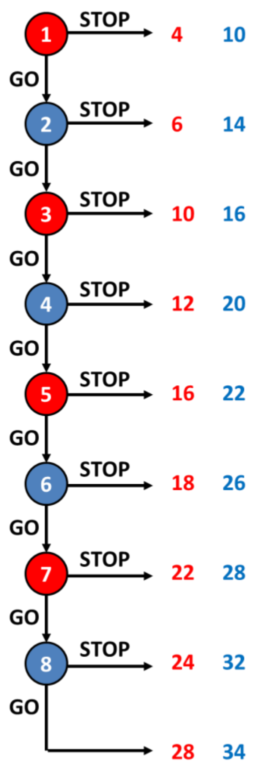
どちらもツールを購入しない場合の報酬ポイントを表示しています。	青の参加者が「止まる」を選ばない限り、赤の参加者から 7 ポイントが差し引かれ、それが青の参加者のポイントとして加算されます。	赤の参加者のみがツールを購入した場合、最終的にポイントはこのように変化します。
		

表 2： 青の参加者のみがツールを購入決定した場合。

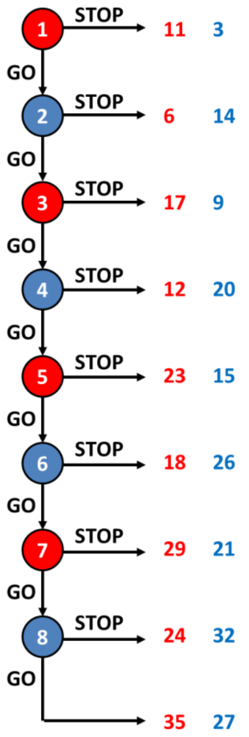
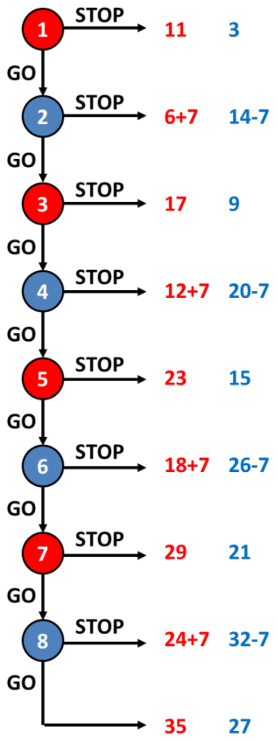
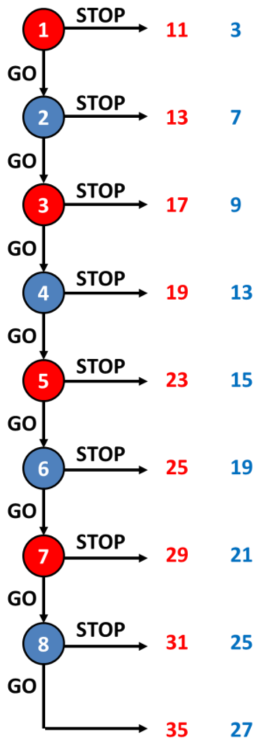
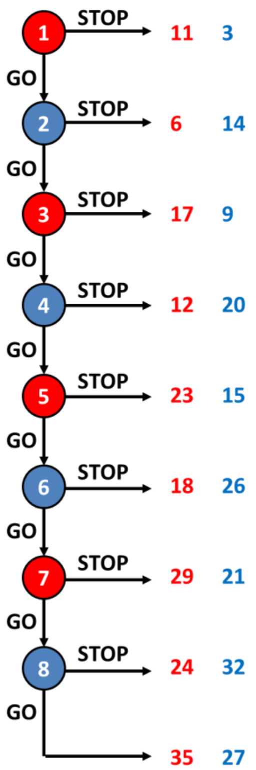
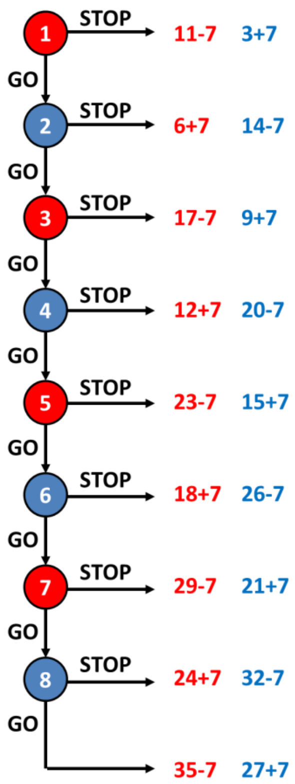
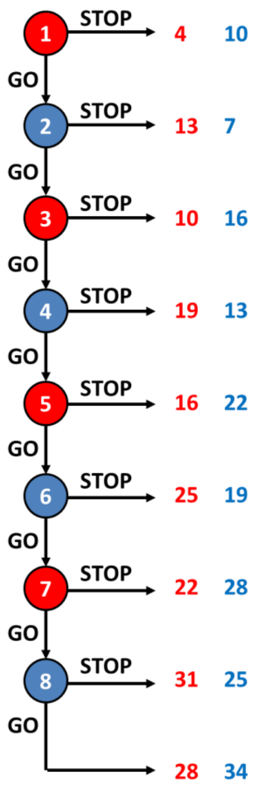
<table>
<tr>
<td>どちらもツールを購入しない場合の報酬ポイントを表示しています。</td>
<td>赤の参加者が「止まる」を選ばない限り、青の参加者から 7 ポイントが差し引かれ、それが赤の参加者のポイントとして加算されます。</td>
<td>青の参加者のみがツールを購入した場合、最終的にポイントはこのように変化します。</td>
</tr>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
</table>

表 3: 両参加者がツールを購入決定した場合。

どちらもツールを購入しない場合の報酬ポイントを表示しています。	上記の表 1、表 2 で表記されていたポイントを組み合わせるのでこのようになります。	両方の参加者がツールを購入した場合、最終的にポイントはこのように変化します。
		

これから皆さん自身でやり取りを行ってもらいます。コンピュータープログラムによって 2 人の参加者がランダムにペアとなり、やりとりを開始します。
やりとりは下図のような表でコンピュータ画面に表示されます。決定地点（説明書では丸で表されていました）が左に表示されています。**「止まる」**を選んだ場合に得られる報酬ポイントは右の列に表示されます。

		Red's units	Blue's units
Decision Point 1	STOP	11	3
GO			
Decision Point 2	STOP	6	14
GO			
Decision Point 3	STOP	17	9
GO			
Decision Point 4	STOP	12	20
GO			
Decision Point 5	STOP	23	15
GO			
Decision Point 6	STOP	18	26
GO			
Decision Point 7	STOP	29	21
GO			
Decision Point 8	STOP	24	32
GO		35	27

最初のやりとりが始まる前に、コンピュータがランダムに**赤の参加者**か**青の参加者**かどちらかの役割を決定します。一度あなたの役割が決まると、実験の間、最後までずっと代わることはありません。
やりとりを開始する前に、両方の参加者はツールを購入したいかどうか選択します。選択が終わると、自分の相手がツールを購入したか否かが画面に表示され、それからやりとりが始まります。
1 つのやりとりが終了すると、今度は別の参加者とランダムにペアが組みなおされます。そして新たなやりとりが始まります。実験では、このやりとりを合計で **20 回**行います。毎回ランダムに相手が選択されるので誰とやりとりするのか分からないようになっています。
全員が 20 回のやり取りを終了すると、1 人の参加者がランダムに選択されてボーナスを獲得します。さらに 20 回のやりとりの中から 1 つがランダムに選びだされ、この参加者がそのやりとりで得たポイント（に 242 円を掛けた額）が報酬に追加されます。どの参加者が選ばれるかは等確率なので、全員がボーナスを獲得するチャンスがあります。従って、全てのやり取りはよく考えて行ってください。あなたの決定によってあなたの得る報酬額が決まるのだと考えてください。
実験中は他の参加者との会話はしないでください。
全参加者が説明書を読み終えたら、実験者が口頭で追加説明をおこないます。何か質問があれば、その後に尋ねてください。その後で実験を開始します。

確認問題

実験内容を理解したことを確認するために、以下の質問に回答してください。計算のために余白を利用して構いません。

1. 5つ目の決定地点（上から5つめの円）で決定をするのは誰ですか？
____

2. 2人ともツールを購入しなかったと考えてください。もし5つ目の決定地点で「止まる」が選択されたならば、2人の参加者は何ポイントを獲得しますか？

赤の参加者：__________ ポイント

青の参加者：__________ ポイント

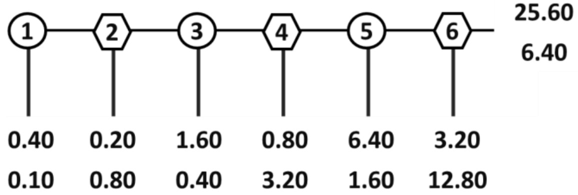
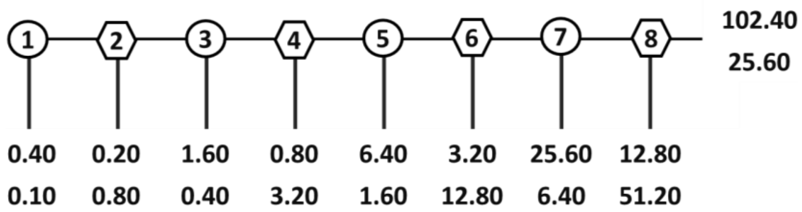
3. 赤の参加者だけがツールを購入したと考えてください。もし5つ目の決定地点で「止まる」が選択されたならば、2人の参加者は何ポイントを獲得しますか？

赤の参加者：__________ ポイント

青の参加者：__________ ポイント

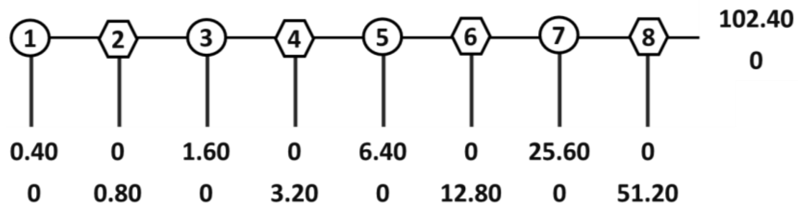
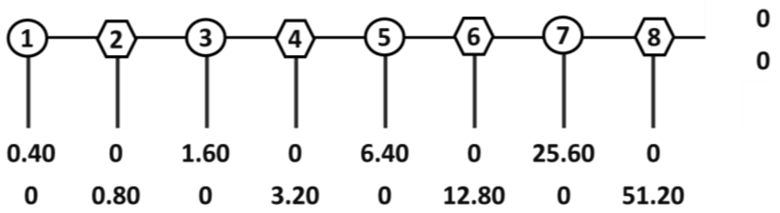
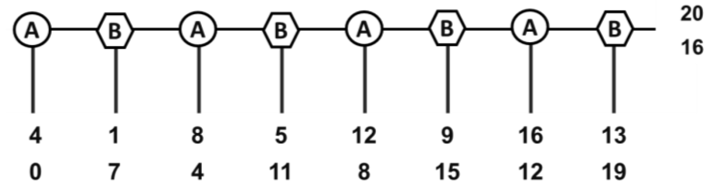
4. このやりとりを全部で何回行いますか？
________ 回

Appendix D: Synopsis of Experiments Reported in this Thesis

Game tree	Payoff function	Rounds	Treatment conditions	Elicitation method	% stopping at SPE[3]	% reaching last exit node	Mean exit node[4]
Study 1 (see also: Krockow, Colman, & Pulford, 2016b)							
	Increasing sum (exponential)	10	N/A	Direct response method	1.7	30	5.12/ 0.73
This study used a qualitative approach to investigate decision making in the Centipede game. Verbal protocol analysis revealed that only few participants employed sophisticated recursive reasoning in the game. Interestingly, however, the few sophisticated reasoners were the ones who cooperated most consistently. Additionally, a large number of motives for cooperation was found (32 motives); their respective importance changed with the stage of (or position) in the Centipede game. Initial cooperation in the game was largely associated with activity bias whereas cooperation towards the end of the game was more frequently linked to prosocial value orientations. Additionally, it was found that participants attached meaning to the response latencies of their co-players and interpreted delays as indicators of likely defection on the next move.							
Study 2 (see also: Krockow, Pulford & Colman, 2015)							
	Increasing sum (exponential)	20	**C1:** Standard exponential Centipede game	Direct response method	0.6	6.4	6.13/ 0.68

[3] SPE is the abbreviation of "subgame-perfect equilibrium".

[4] The first figure displays the mean exit node for the respective game. The second figure displays the standardised mean exit point of the game tree where the games ended. It provides a standardised measure of the exit node to increase comparability across studies. The standardised figure was obtained by dividing the mean exit node by the game length (i.e., the number of terminal nodes).

	Increasing sum (exponential), zero-end		**C2:** Exponential Centipede game with zero-end		5.0	0	4.29/ 0.48
	Take-it-or-leave-it		**C3:** Take-it-or-leave-it Centipede game		2.3	3.2	5.74/ 0.64
	Take-it-or-leave-it, zero-end		**C4:** Take-it-or-leave-it Centipede game with zero-end		0.1	1.0	5.12/ 0.57
This study investigated cooperation in four Centipede games differing in their payoffs at the games' ends (positive versus zero) and payoff differences between players (moderate versus high difference). All four games were characterised by identical subgame-perfect Nash equilibria and, thus, should have resulted in similar decision making across all treatment conditions. However, both zero-end payoffs and high payoff inequality led to significantly lower cooperation levels. Interestingly, combining these two competitive game aspects in a single game resulted in a weakening of their independent deterrent effects. These findings demonstrated the large influence that relatively small payoff changes can have on decision making. They further showed that the effects do not combine synergistically.							
Study 3 (see also Krockow, Colman, & Pulford, under review)							
	Increasing sum (linear)	20	Finite 8-node game with known end	Direct response method	4.4	9.4	5.40/ 0.60

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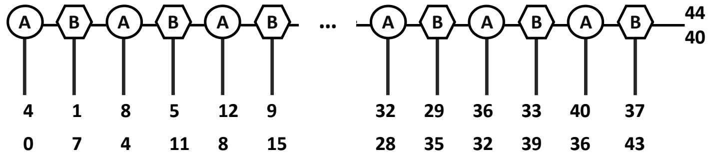
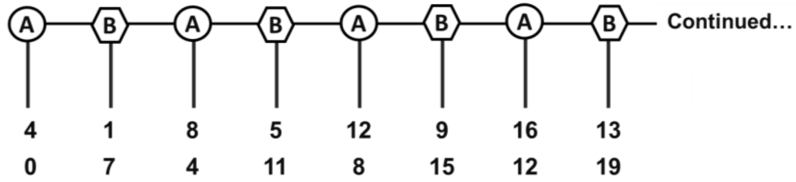
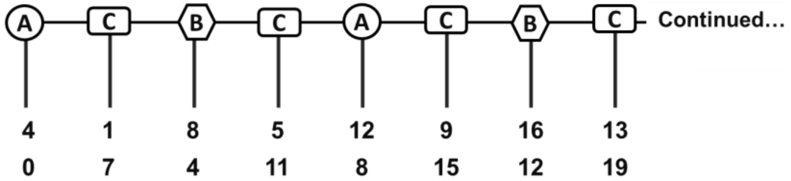
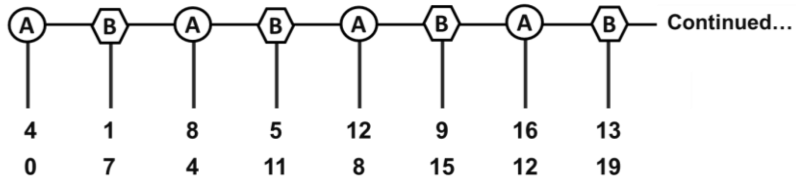
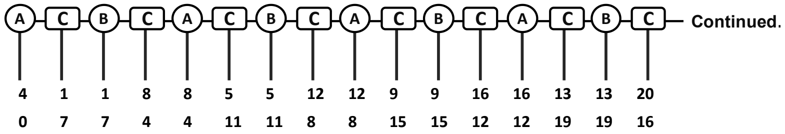
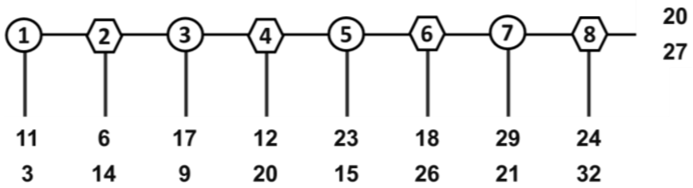
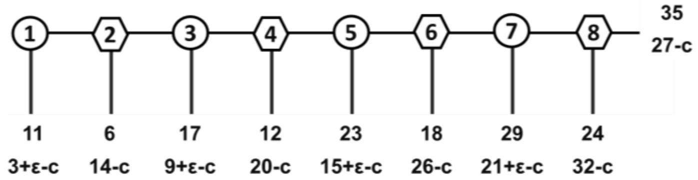
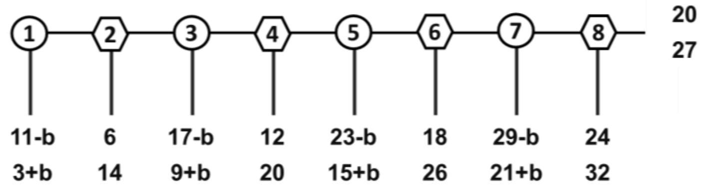
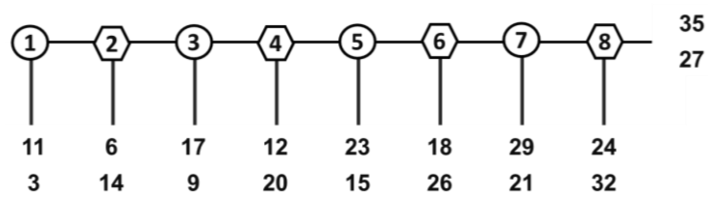
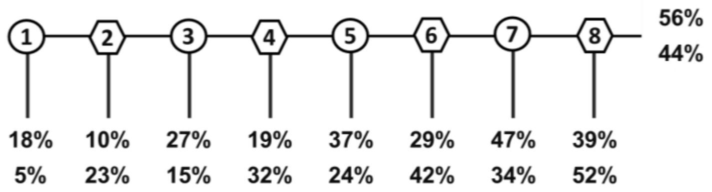
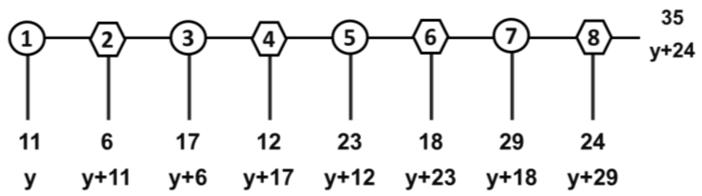
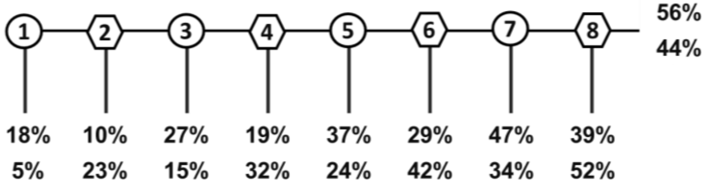
	Increasing sum (linear)		Finite 20-node game with known end		0	17.8	16.17/ 0.77
	Increasing sum (linear)		Finite 20-node game with unknown end		0.5	22.2	14.07/ 0.67
	Increasing sum (linear)		Indefinitely repeated game with random termination of 1/6		6	N/A	N/A
This study investigated the effects of game length and termination rules on cooperation in the Centipede game. It was found that increasing game length from 8 to 20 nodes increased cooperation but only if the game end was known to participants. While games with unknown ends may yield decreased endgame effects (i.e., higher defection rates just before the natural end), overall cooperation levels may be reduced—particularly if participants expect shorter game lengths. Random game termination through the computer appeared to increase the percentage of games adhering to the Nash equilibrium outcome, and generally lowered cooperation levels. This suggests that a long, but finite horizon of relationships encourages higher levels of reciprocity and cooperation, whereas the introduction of uncertainty or risk may lead to earlier defection.							
Study 4							
	Increasing sum (linear)	20	24-node Centipede game	Direct response method	4.8	9	15.84/ 0.63

	Increasing sum (linear)		24-node Centipede game with random STOP probability of 1/4		14.2	0	3.34/ 0.13
	Increasing sum (linear)		24-node Centipede game with increasing STOP probability		4.0	0	5.79/ 0.23
	Increasing sum (linear)		24-node Centipede game with decreasing STOP probability		39.8	0	2.24/ 0.09
This experiment investigated if and how different rules of random stopping by the computer (fixed, increasing and decreasing STOP probability) affected cooperation levels of participants in a linearly increasing, 24-node Centipede game. The findings showed that participants exited games earlier in treatment conditions with random game termination than in conditions without. However, using a new cooperation measure (the percentage of STOP moves per participant), it was found that only conditions with very high STOP probabilities may result in a significant decrease of individual cooperation levels.							
Study 5 (see also: Krockow, Takezawa, Pulford, Colman, Smithers, Kita, & Nakawake, under review)							
	Increasing sum (linear)	20	**C1:** Standard Centipede (control); Japanese sample	Direct response method	0	29.3	7.23/ 0.80
			C2: Standard Centipede (control); European sample		11.7	0	3.76/ 0.42

			**C3:** Option to choose insurance tool: ε=7; c=7; Japanese sample		2.3	3.5	5.92/ 0.66
			C4: Option to choose insurance tool: ε=7; c=7; European sample		6.1	1.7	5.12/ 0.57
			**C5:** Option to choose bonus tool: b=7; Japanese sample		2.5	62.5	7.27/ 0.81
			C6: Option to choose bonus tool: b=7; European sample		5.6	12.2	5.18/ 0.58
This study investigated European-Japanese differences in trust and cooperation in a linear version of the Centipede game with two treatment conditions offering similar insurance and bonus tools as Gerber and Wichardt (2011). Overall, Japanese subjects made significantly more cooperative choices in the standard Centipede game than Europeans. These cultural differences were explained with higher levels of assurance-based trust (as needed in committed, reciprocal relationships) in Japan. The Japanese also purchased significantly more tools than the Europeans, indicating their stronger preference for security and commitment in social interactions. The purchase of bonus and insurance tools significantly improved cooperativeness in both groups. However, the Japanese differed from the European participants as they interpreted refusal to purchase available tools as a signal of non-cooperative intent, causing a decrease in assurance-based trust and consequently also of cooperativeness.							

<table>
<tr><td colspan="8">Study 6 (see also: Krockow, Takezawa, Pulford, Colman, & Kita, under review)</td></tr>
<tr><td rowspan="2"></td><td rowspan="6">Increasing sum (linear)</td><td rowspan="6">20</td><td>C1: Standard Centipede (control); Japanese sample</td><td rowspan="6">Direct response method</td><td>1.5</td><td>7.0</td><td>5.78/ 0.64</td></tr>
<tr><td>C2: Standard Centipede (control); UK sample</td><td>6.0</td><td>0.5</td><td>4.35/ 0.48</td></tr>
<tr><td rowspan="2">
These payoffs represent percentages of a fixed pot containing 62 monetary units (£84.32).</td><td>C3: Complete information framed as %; Japanese sample</td><td>4.5</td><td>10.5</td><td>5.94/ 0.66</td></tr>
<tr><td>C4: Complete information framed as %; UK sample</td><td>6.5</td><td>3.5</td><td>4.75/ 0.53</td></tr>
<tr><td rowspan="2">
Perspective Player A: “y” is fixed and remains the same throughout the experiment. It was set at a number between 0 and 10. It is equally like to be any of those numbers.</td><td>C5: Absolute payoff information only; Japanese sample</td><td>1.0</td><td>12.0</td><td>6.55/ 0.73</td></tr>
<tr><td>C6: Absolute payoff information only; UK sample</td><td>4.0</td><td>8.0</td><td>5.04/ 0.56</td></tr>
</table>

 These payoffs represent percentages of a fixed pot containing an unknown number of monetary units.			**C7:** Relative payoff information only; Japanese sample		1.0	26.6	6.61/ 0.73
			C8: Relative payoff information only; UK sample		5.2	1.0	4.31/ 0.48
To achieve greater applicability of the Centipede game to real-life decision situations with uncertain prospects, this study introduced two game conditions with incomplete payoff information, providing either absolute or relative information only. Comparing Japanese and UK participants' decision making, the Japanese were found to cooperate significantly more frequently than the British. The amount of payoff information also affected decision making. In Japan, both treatment conditions with incomplete information yielded significantly higher cooperation levels compared to the control. In the UK, only the condition with absolute payoff information produced significantly higher cooperativeness. Overall, the findings suggested that the Japanese players cooperated more frequently than the British players in stable, Centipede-type partnerships. This might be due to the assurance-based trust elicited by reciprocal interactions, a typical feature of Japanese culture. In situations with incomplete information, expectations about the stake size might have guided decision making, with lower expectations resulting in higher cooperation levels.							

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