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Association between decisions: experiments with coupled two-person games

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ABSTRACT
Actors making public decisions about a certain policy issue in one particular arena also meet in other arenas where they will have to make decisions on other issues. By incorporating information from across coevolving arenas, actors make associations between the decisions in the different arenas. To understand the dynamics of associations, we deployed a formal game-theoretic approach and run an experiment. Subjects played two different games, each representing a different decision-making arena. The results show that history builds-up and that subjects made associations between the two games, partly explaining the behaviour of decision-makers interacting in multilevel decision-making settings.

KEYWORDS Decision-making; experiment; game theory; association; arena

1. Introduction

Inspired by the successes of the Japanese Shinkansen trains in the 1960s and the French and German high-speed trains later, the Dutch government decided that they also wanted high-speed rail (Gerrits and Marks 2014; Gerrits et al. 2014; Marks and Gerrits 2017). In the early 1990s, the plans developed into the HSL-Zuid high-speed project. The planning and construction lasted for about 20 years before becoming operational. One persistent issue in the decision-making was the track alignment across the border between Belgium and the Netherlands. The Dutch preferred a crossing point that would be more cost efficient for them than for the Belgians. Naturally, the Belgians demanded a crossing point that would be cheaper for them but more expensive for the Dutch. The decision-making in this arena concerning the cross-border alignment lasted about a decade.

These two governments were also entangled in long-lasting dispute about an unrelated issue; deepening of the Dutch Westerschelde estuary. The Belgian port of Antwerp cannot be reached by ships because the estuary's shallow depth. Dredging could solve the problem but the Belgians would need permission for this from the Dutch, who are reluctant to give that permission out of fears of environmental damage as well as not being eager to give Antwerp a competitive advantage over

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Dutch ports. The decision-making in the arena concerning the Westerschelde lasted for about 15 years (Meijerink 1999; Gerrits 2012).

These two unrelated decision-making processes become coupled because the representatives of both governments met each other in both arenas and took with them the history build-up from one arena to the other. The decision-making was concluded when the Belgian minister Van den Brande agreed about the Dutch preferred crossing point at the Belgian border in exchange for a Dutch permission to deepen the Westerschelde. Both complex decision-making processes become coupled due to actors acting and interacting in one arena, then meeting again in the other one. Naturally, they carry over the dynamics from the one arena to the other one. In other words: actors making collective decisions about a certain issue in one particular arena also meet in other arenas where they have to make collective decisions on other issues. This history and the associations these actors can make when moving between the different arenas helped lifting the deadlock.

We investigate the relationship between the actors' internal models, history build-up and the decision-making in coupled arenas. We develop and test a complexity-informed game-theoretic model that tests the relationship between actors interacting over time in different arenas in an experimental setting as a succinct proxy for collective decision-making in multiple arenas. The research question is: how do interacting actors make associations between their decisions in two coupled arenas and how does that association influence the outcomes?

Following Holland's work (1995, 2012), but also e.g. Knott, Miller, and Verkuilen (2003), Henry, Lubell, and McCoyy (2011), and Lavertu and Moynihan (2013), we first develop a formal game theoretic model, the so-called associative approach (Marks 2002). The associative approach is a mathematical model that structures the ways in which actors interacting in one arena, and the history associated with that interaction, influence the decisions made in other coupled arenas. Second, we carry out an experiment to test the associative approach (cf. e.g. Axelrod 1984, 1997; on the merits of game theoretical models in studying complex systems, and e.g. Molm 1990, Lavertu and Moynihan 2013; for a discussion of the merits of experimental approaches in social sciences and in public administration in particular). Controlled experiments allow comparison of players' decisions in equivalent conditions, holding other factors constant making it possible to disentangle the effects of associations between decisions in coupled arenas (cf. Molm, Takahashi, and Peterson 2000). The use of experimental methods in understanding complex decision-making processes may form 'a useful part of the apparatus for moving from the level of the individual actor to the behaviour of the system, ultimately yielding testable theories to explain the endogenous generation of macro behaviour from the microstructure of human systems.' (Sterman 1989, 228).

We acknowledge that some readers unfamiliar with mathematics and game theory will find the model quite abstract and possibly difficult to understand. We have therefore put a description of the model in the main text with limited references to mathematics. The full mathematical model is presented in the Appendix. The text is structured into five sections: (1) the formal game theoretic model of associations between decisions, (2) the experimental design and laboratory setting, (3) the results of the experiment, (4) a discussion about the implications of the results to collective decision-making, and (5) the main conclusions regarding decision-making in complex coupled arena's.

2. Associations between decisions

The perception of what other actors want to achieve, and how they want to achieve it, influences actor decisions. Naturally, decision-makers such as politicians and administrators want to push through their preferred problem and solution definitions. However, conflicts between the various problem-solution combinations mean that not all wishes can be fulfilled and certain combinations will prevail over others. Decision-makers will seek alignment with some partners, and increase distances with opponents if they think this will help further their particular problem-solution combination for that issue. As Knott, Miller and Verkuilen state in the realm of public policy:

> ‘There has been much literature written on decision-making in decentralized environments with limited information. Decision-makers are limited in both what they can control in the decision domain and what information they can obtain. Under these circumstances, decision-makers adapt to decisions made by others in a decision process, not a singular event. The overall outcome of the decision process is the collective result of the interactions among decision-makers.’ (2003, 341)

The above quote is our starting point for expansion on the complexity of decision-making process in multiple arenas. Actors not only have to deal with limited information (Simon 1955), they also have to act in various different decision-making arenas where they encounter people from different public organizations as well as stakeholders (Koppenjan and Klijn 2004; Klijn and Koppenjan 2015). This establishes coupling between arenas.

The coupling can be strong when most of the actors from arena 1 (such as the HSL-Zuid arena) also meet in arena 2 (such as the Westerschelde arena), or weak when there is little overlap between the actors in arena 1 and 2. Due to the connections between actors and the decisions they make, a history of collective decision-making is built up. For example, certain actors may find it easier to cooperate now due to the fact that they have done so successfully in the past; or, conversely, more difficult because they carry negative experiences from the past. These history build-ups influence collective decision-making processes in various arenas. By *incorporating information* from *history build-up* in the collective decision-making process, actors construct *internal models* (Holland 1995; Allen, Strathern, and Varga 2010). As such, they make *associations* between the decisions in the different arenas that have become coupled (Marks 2002).

The internal model forms the basic building block that drives that emergence of complexity (Holland 1995). The continuous interaction between actors on the basis of their internal models within and across arenas builds a complex situation over time, as well as cements their behavioural rules if they return acceptable results. The actions of individuals are guided by an interpretative framework that includes both beliefs about the functioning of system and its components, but also the values or goals that are aimed for (Allen, Strathern, and Varga 2010, 55). As another complexity scholar puts it:

> ‘Our information processing capacity is limited and that humans employ biases and heuristics (e.g. anchoring and adjustment, the representativeness heuristic, and the availability heuristic) in order to reduce mental effort.’ (Vennix 1999, 381)

The actors make sense of the world by making associations between different decision settings. This helps them handling the complexity of coupled arenas. At the same time, the same associations and subsequent coupledness appear to increase the complexity of decision-making considerably in comparison to situations were all arenas are fully isolated. As such, associations lower the individual perception of complexity as well as drive the complexity on the macro-level. Naturally, it sometimes pays off to pursue a complexity absorptive response to a complex environment (cf. Ashmos, Duchon, and McDaniel 2000) because complexity needs to be mirrored with complexity as per Ashby's law of requisite variety. The counter-argument is that the associations help actors in dealing with the complexity of different settings by providing a focal point, i.e. the associations reduce the complexity of the situations for the actors. This is inevitable when working within complex adaptive systems (e.g. Lefebure and Letiche 1999; Boisot 2000; Cooksey 2000), even if it risks over-simplification (Beahrs 1992; Strand 2002; Morçöl 2002). In short, the complexity of situation leads actors to respond in ways that allow them to deal with that complexity within an arena, while simultaneously contributing to that complexity across arenas. In Holland's own words:

> '[…] agents are defined by an enclosing boundary that accepts some signals and ignores others, a "program" inside the boundary for processing and sending signals, and mechanisms for changing (adapting) this program in response to the agents' accumulating experience. Once the signal/boundary agents have been defined, they must be situated to allow for positioning of the relevant signals and boundaries.' (2012, 24).

2.1. *Decision-making dynamics from a game-theoretic perspective*

One of the main methods of inquiry in the complexity sciences is modelling using behavioural rules derived from game theory. Game theoretical models have been proven to be especially helpful when studying complex systems in terms of interactions and emergent properties. For example Axelrod (1984, 1997) and Holland (1995) used the prisoner's dilemma to demonstrate the mechanisms of complex systems, and Kauffman (1993) needed game theory to make his fitness landscape models work. Game theory concerns the formal modelling of strategic interaction between individuals and many social phenomenon can be presented in terms of games (cf. Hargreaves Heap and Varoufakis 1995, 1). As such, it is a tool that helps to clarify issues relating to human behaviour and social institutions.

For the present purpose, game theory gives us a device with which we can investigate how interactions between decision-makers can build complex situations across decision-making arenas. When two decision-makers try to reach a collective decision, they will have to interact. Such a situation can be modelled as a particular two-person game. Games can vary from dominated strategy to coordination games, or from prisoner dilemma to zero-sum games, depending on the payoff structure associated with the possible choices for these decision-makers. However, as we said above, decision-makers don't operate in a vacuum. They may meet again in other arenas where they have to decide on another policy issue. In game-theoretical terms, it may be that the new interaction setting will have the same payoff structure as in the first game, but hardly ever are two games exactly the same (cf. Sugden 1986, 50). When decision-making in one arena is followed by decision-making in another coupled arena, the decision-makers play different kinds of games after each other.

Model building inevitably means reducing some of the complexity associated with the messy character of real-world collective decision-making. However, simplifications in a model help focusing on the core-mechanics of decision-making in coupled arenas (cf. e.g. Friedman 1953; Sober 1994). Our model assumes that only two players will make a decision (cf. Knott, Miller, and Verkuilen 2003). History is introduced by letting these two players play two games in a row, the second game being completely different from the previous one, as if they were making collective decisions in two different but coupled arenas. The essential point is that the history that two players create together through their interaction in the first game or arena provides information for the decision in the second game or arena, i.e. the results from the previous game build an internal model (Holland 1995) and create a focal point for the latter game (see Schelling 1960). Rational players will use the asymmetries created through their interactions to formulate their strategies (Bacharach 1993; Janssen 2001).

2.2. *The associative approach*

Naturally, players see a resemblance between the former and latter game. By incorporating information from the first game into the second, players make an association between the decisions in the two games, i.e. the games become coupled through this association. There are many different ways players can make associations between multiple games, of which some are more prominent than others (cf. Mehta, Starmer, and Sugden 1994a, 1994b). That is, every player conceives the game being played differently, which then becomes a variable in the two-person decision problem (cf. Bacharach 1993; Bacharach and Bernasconi 1997). Given the limited cognitive capacities of players, a preceding but different game can be more prominent than a repeated (same) game for helping them solve the latter games. The external information of the preceding different game can be more prominent because it is more readily accessible (cf. Young 1996, 1998). This information can break the symmetry of a second game and thus raise the chance of coordination (cf. Bhaskar 1997). The associations between games as made by the players induce asymmetries between strategies. That is, the former game can create a focal point in the latter. Players can make many different associations depending on what external information they process and in which manner they do so. Prominence is ‘created’ by players having certain associations in their frame, while not having others. In short, when players or actors move from one arena to the other, they can negotiate the complexity of doing so by relying on prominence.

We will present the model here as narrative; see Appendix for the full formal model. Players have a given set of possible actions they can undertake. Based on the connection with a previous different game, players make associations for the decisions they can make in the current game. The association means that the initial set of possible actions becomes partitioned, i.e. the decisions can be categorized using the associations the players make. Not all associations will help a player in categorizing the decision set, or certain associations come to mind easier (cf. bounded rationality, Simon 1955). The different associations may be thought of as the frame through which a player looks at the problem. (Bacharach 1993). This frame F is a subset of the partitioned set of possible actions. Naturally, players believe that they consider all possible associations because they are not capable of thinking of associations existing outside their frame F. In other words, players optimize their behaviour on the actions they think are possible and that are always restricted to their frame *F*. Of course a player has beliefs about the possible associations the other player can use. Players tend to think that their strategy is more sophisticated than the strategy of the other player (Camerer, Ho, and Chong 2004). As such, a player believes that the other player holds the same associations as himself, or less, i.e. the other player is said to be type G, $G \subseteq F$. Given that the player is of type F, the conditional probability that the other player is of type G is denoted by $V(G \mid F)$. The availability of association β is denoted by v_β, hence an association β that is not available is denoted by $(1\ v_\beta)$. Players will try to maximize their returns by making the decision from the set of possible actions that is partitioned due to the associations the players has and beliefs of associations the other player has. This is the model in a nutshell.

3. Design of the experiment

We carried out an experiment mimicking actors operating in two different arenas. The experiment consists of two different games played after each other, each game being a proxy for a decision-making arena of a *different type* with the *same actors* engaging in collective decision-making. The first game was the hash-mark game, the second a distribution game.

The hash-mark game consists of 17 vertical hash-marks. Starting players are randomly assigned for each play of the game. Each player must on each, turn alternating with the other player, cross out 1, 2, 3, or 4 hash-marks. The game continues until all hash-marks have been crossed out. The person who crosses out the last hash-mark loses the game.

The second game is the distribution game, also called battle-of-the-sexes game (BOS-game). In the BOS-game, participants choose between two alternatives without being able to communicate with each other. If both participants choose mutually consistent alternatives, i.e. distributing the reward in the same way between them, they will get the amount prescribed by their chosen alternative. This amount will then be added up to their individual total earnings for the experiment. The alternatives they can choose differ in the two versions of the experiment. In the first version there is only a financial reward in the last game of the two, while in the second version both games have a financial reward. In both versions, 48 first year students from different faculties of the [university name blanked for review purposes] participated, distributed over four different sessions. Only students with no knowledge about game theory or theories of decision-making could participate to create a level playing field. Student anonymity was guaranteed and it was also promised that all the money they would make by playing the games would be paid in cash right after the experiment in private to prevent the other participants from feeling envious regarding how others played.

Each subject was randomly and anonymously drawn and were of type A_i or type B_i (i = 1,. . ., 7). The type A players were put in one room and the type B-players in the other. Each type A player would play another type B player exactly once. As the opponents were in different rooms they have no way of communicating with each other. In total, the participants played the combination five or six times in one session. The randomization is done to break up any groups of friends, and to make sure all the participants know that they are playing a real but unknown opponent. The subjects were informed that the subject pool consists of volunteers from various faculties. They were told that the experiment concerns the study of behaviour in interaction situations. This statement of purpose is necessary because it satisfies their curiosity about why someone is willing to pay them money for playing games. The statement is specific enough, yet, broad enough to avoid any 'demand effects'. The experiment starts with a test to see whether the participants understand the rules of the games, and thus lowering the opportunities for confusion during the experiment.

In both versions of the experiment, the outcome of the first game is common knowledge for both players. However, the subjects do not know whom they are playing. They only know that they are playing an opponent in the other room. Also in both versions, the outcome of the second game in the combination is privately revealed to every player, because the payment of the subjects is based on this outcome.

3.1. *Experiment 1*

No matter whether you are the winner or the loser of the hash-mark game the financial gain is zero. The money that has to be agreed upon for distribution in the second game is 10 euro, specified in two alternatives:

Alt 1. You get € 3.- and your co player gets € 7.-.
Alt 2. You get € 7.- and your co player gets € 3.-.

If players have no extra information available, they have no conclusive reason to choose one alternative over another, because they know their opponent has the same problem and this is then common knowledge. In a large population, the expected outcome by traditional game theory will be that the players mix their strategies: alternative 1 will be played in 30 per cent of the cases, and alternative 2 in 70 per cent of the cases, resulting in matching and mismatching of alternatives as given in Table 1.

The associative approach predicts that players will make different choices due to their framing based on the information from playing the hash-mark game prior to the BOS-game. This extra information may cause players to attribute a dominant position to the winner and a subservient position to the loser of the hash-mark game in the distribution game, based on the so-called Lockean principle of distributive justice (see Locke [1690] 1986; Hoffman and Spitzer 1985). Players frame the winner as more entitled to a larger share. That is, players in such settings think it is 'normal' for the winner to claim the larger share in the distribution game, and that it is 'normal' for the loser to agree with this. If the players see this *convention* as being relevant to the play of the game they make the entitlement association. This means the winner of the hash-mark game will choose alternative 2 much more often than the loser, and vice versa. This results in a much higher matching percentage in the left bottom cell of Table 1 (for a mathematical proof of the calculations see Appendix).

Table 1. Fractions of expected outcomes.

		Player B	
		Alt. 1	Alt. 2
Player A	Alt. 1	0.09	0.21
	Alt. 2	0.21	0.49

3.2. *Experiment 2*

In this version, the winner of the hash-mark game receives 4 euro, the loser still receives nothing, and the money that the players can share in the distribution game is 7 euro in total, instead of 10.

Alt 1. You get € 3.- and your co-player gets € 4.-.

Alt 2. You get € 4.- and your co-player gets € 3.-.

Again, in a large population, the expected outcome by traditional game theory will be that the players mix their strategies: alternative 1 will be played in 43 per cent of the cases, and alternative 2 in 57 per cent of the cases, resulting in Table 2 that shows the fractions for the different possible outcomes in the distribution game.

The possible financial rewards for both games show that the difference in payoff in the second game is smaller than the difference in payoff in the first. In line with the Lockean principle of distributive justice, people think that overall the winner of the hash-mark game should still receive more than the loser. However, in the combination of the hash-mark and the distribution game the total payoff to both players can be more equal (Hobbes 1996). This has also shown up in many experiments (e.g. Fehr and Schmidt 1999; Huck and Oechssler 1999; Levine 1998). According to the associative approach, if players use the labels of winner and loser (of the hash-mark game) the winner will choose alternative 1 much more than the loser, and vice versa, resulting in a much higher matching percentage in the right top cell in the table

4. Experimental results

The a-priori assumed relations that need to be analysed are shown in Figure 1.

To analyse whether players do make associations between games, the focus variables of the experiment should be on the outcome of the hash-mark game and the outcome of the distribution game, without other interfering variables. Data on a range of possible intervening variables (*Sex, Faculty, Cultural background*, and *Risk-averse behaviour*) was collected and none of these had a significant impact on the outcomes recorded in both versions of the experiment (see Appendix). Therefore, two a-priori relations remain:

> *HM start* → *HM result*: the player that starts the hash-mark game can always win (please try it yourself to find out how), while the second player can only win if the starting player makes a mistake. Given the coding of the variables the expected relation between the two is negative, because if the *hash-mark game start* variable goes up – from the starting to the second player – the *result of the hash-mark* game goes down – from winning to losing.
>
> *HM result* → *distribution alternative*: subjects will claim the larger share when they have won the hash-mark game, and settle for the smaller share if they lost in version 1, i.e. a positive relation, and vice versa in version 2, i.e. a negative relation.

We will now discuss the results of the two versions of the experiment.

Table 2. Fractions of expected outcomes.

		Player B	
		Alt. 1	Alt. 2
Player A	Alt. 1	0.184	0.245
	Alt. 2	0.245	0.327

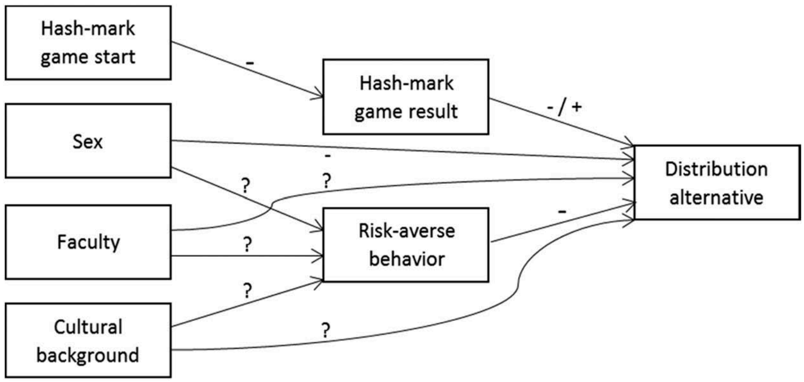

Figure 1. A-priori assumed relations between all variables.

4.1. *Version 1*

The participants did not figure out that they could always win if they started (see Appendix), eliminating the possibility of the random device deciding who will be winner or loser of the game. As such, the winner of the hash-mark game is indeed recognized as having to put in the effort to win. The participants also did not learn how to win the hash-mark game, or did not learn to take advantage of the no-learning situation of the starters (see Appendix). That is, the relation of the starting position in the hash-mark game and the winning position does not influence the possible association that players can make between the hash-mark result and the distribution alternative.

The entitlement association, i.e. the relation between *HM result* and *Distribution alternative*, has a significant positive coefficient (see Appendix). That is, winners of the hash-mark game chose the larger share almost 50 per cent more than losers, or, vice versa, losers chose the smaller share almost 50 per cent more than winners. The remaining significant relation is that the two groups, winners and losers, behave differently when choosing an alternative (see Table 3).

The total percentages of alternatives 1 and 2 are almost the same as traditional game theoretic prediction; i.e. winners (and losers) will choose alternative 1 in 30 per cent of the cases and alternative 2 in 70 per cent of the cases. However, the choices made by the different groups do differ from the total percentages. There is a 45.3 per cent difference in choosing alternatives 1 or 2 for the group of losers compared to the winners (respectively,

Table 3. Alternatives chosen based on losing/winning HM-game.

			Distribution alternative		
			Alternative 1	Alternative 2	Total
HM result	Lose	Count	79	60	139
		% within HM result	56.8%	43.2%	100%
	Win	Count	16	123	139
		% within HM result	11.5%	88.5%	100%
Total		Count	95	183	278
		% within HM result	34.2%	65.8%	100%

56.8–11.5 per cent and 88.5–43.2 per cent). To assess whether the group behaviour deviates from traditional game theory, the following hypotheses will be tested:

H_0: Winners and losers will play according to traditional game-theoretic prediction: $p_{W0} = p_{L0} = 0.7$.

H_1: According to the associative approach winners (losers) will claim the larger share a lot more: $p_{W1} \gg 0.7$ ($p_{L1} \ll 0.7$).

The observed proportion of winners (losers) choosing alternative two is 0.885 (0.432), which is outside the respective boundaries of 0.764 and 0.636. Stronger still: the correlation even holds if the confidence area is extended to 99 per cent (significance level of 1 per cent) making the boundaries 0.79 and 0.61, respectively. In other words, the null hypothesis is rejected and the alternative corroborated. This means that the decisions of the players, divided in losers and winners, in the second game based on the history build-up in the first game as predicted by the associative approach. Comments and remarks of participants in both the post-questionnaire and the comment sheets of the experiment made clear that some participants always claim seven when they win the hash-mark game and three when they lose.

A partial correlation check shows that participants do not use the association more frequently in later rounds ($\rho = -.031$; $p = .303$; $N = 275$). However, the post-questionnaire made clear that after a couple of rounds, or in hindsight, some participants changed (or thought they should have changed) their tactics from always claiming seven or three to basing their alternative on the result of the previous hash-mark game. The substantial amount of associating players helped to create a higher payoff in the subject pool. The result of the first game resonates in the second game creating a payoff that is 0.67 euro higher (32 per cent) than what the players would earn according to the expectations of the traditional game-theoretic perspective.

4.2. *Version 2*

As in the first version of the experiment, the participants did not figure out how to win the hash-mark game when playing (see Appendix). The winners of the hash-mark game were immediately rewarded with four euro, while the losers did not get anything. Putting in the effort for winning the hash-mark game is thus immediately rewarded, and does not undermine the possible egalitarian or entitlement position in the distribution game, where the players have to agree on distributing seven euro.

The relation between *HM result* and *Distribution alternative* is significant at a 1 per cent level. This means that being a winner or loser has a significant influence on the alternative chosen. The correlation between the two variables confirms that in this version the loser of the hash-mark game is more inclined to demand the larger compared to the winner. Table 4 shows the amount and percentages of participants who lost or won the hash-mark game and their respective alternatives chosen in the distribution game.

The total percentages of the chosen alternatives in this version of the experiment are close to the average outcome expected by traditional game theory, i.e. winners and loser will choose alternative 1 in approximately 43 per cent (3/7) of the cases and alternative 2 in approximately 57 per cent (4/7). However, there is a 20.8 per cent difference in choosing alternatives 1 or 2 for the group of losers compared to the winners, respectively 59.4–38.6 per cent, and 61.4–40.6 per cent. To see whether this

Table 4. Alternatives chosen based on losing/winning HM-game.

			Distribution alternative		
			Alternative 1	Alternative 2	Total
HM result	Lose	Count	39	62	101
		% within HM result	38.6%	61.4%	100%
	Win	Count	60	41	101
		% within HM result	59.4%	40.6%	100%
Total		Count	99	103	202
		%within HM result	49.0%	51.0%	100%

behaviour deviates significantly from traditional game theory for the winners (losers) the following hypotheses will be tested:

H0: Winners and loser will play according to traditional game theoretic prediction: $H_0 = p_{W1} = p_{L1} = 4/7$.

H1: According the associative approach winners (losers) will claim the larger share a lot less: $H_1 = p_{W1} \ll 4/7$ ($p_{L1} \gg 4/7$).

The winners of the hash-mark game chose alternative 2 only 40.6 per cent times compared to the boundary of 49 per cent. In other words, the frequency of winners choosing alternative 2 is outside the confidence area (even at the 1 per cent significance level), which means that the null hypothesis is rejected and the alternative hypothesis corroborated. The percentage of losers that chose alternative 2 is still within the boundary at a significance level of 5 per cent, which means that the 5 per cent difference between what traditional game theory and the associative approach predict about the behaviour of the losers is not large enough, or the experimental data is too small. This variance may be contributed to differences between behaviour of losers and winners as the winners are aware of the 4 euro they receive for winning the hash-mark game while the losers only know this subconsciously. Because the losers do not have this extra information (readily available) in their frame to help them solve the problem at hand, they tend to randomize between the two alternatives rather than opting for alternative two.

Similar to version 1, the individual participants did not start using the possible association more frequently in later combinations during play ($\rho = -0.000$; $p = .498$; $N = 199$). While not all participants make the egalitarian association, the total money amount generated in this version is significantly higher than the outcome expected by traditional game theory. That is, the group of associating players helps make the total financial earnings nearly 2 euro, 30 eurocents higher than when all participants would behave as expected by traditional game theory.

5. Implications and extensions

As example, March (1994) and many others have shown in the realm of organization, management and decision-making: history build-up between public actors is very real but the exact dynamics behind it need to be carefully researched. The experimental results show that players, as proxy for the decision-makers discussed in the introduction, consciously use information of the history build-up in the combination of the two games. That is, in the first version the players clearly couple the first and second game. Here, we see Holland's internal model as presented in Section 2 at work: the history build-up causes players to associate between the games, and provides them beliefs that their opponent has certain associations. These frames of the players, i.e. the possible decisions they can make and that they think the other player can make, helps them resolve the distribution problem much better. In other words: their refined internal models help them cope with the complexity of coupled arenas. Although slightly weaker than in the first version of the experiment, the players in the second version are also better in matching. However, this is mainly due to history build-up over the two games: the winners choose the lower share much more often than the larger share. In other words, the frame through which the winners looked at the second game builds on the association and coupling of the two. This results in an overall higher matching of alternatives, even though the decisions, rooted in a shared history, are not always in full alignment. Overall, the framing of the players and the beliefs of the frames of other players and the possible associations these players can make between the coupled games helps players focusing on particular outcomes in favour of randomization (cf. focal points by Schelling 1960) or it helps break a deadlock (cf. Gerrits and Marks 2017). As such, it demonstrates that players as actors develop internal models that help them to deal with two coupled arenas in which two very different decision-making processes take place.

Even though the formal model and the corresponding experiment seem to be a major reduction of the complexity of decision-making processes in real cases, it does help in understanding the intricacies of actors trying to find clues in order to help them reach (better) results. Let us return to the high-speed rail case from the introduction. The package deal – in the shape of a deeper estuary for the Belgians and track alignment favoured by the Dutch – is quite common in public administration and management literature. We can now understand such a package deal in terms of decision-making in coupled arenas. They have build-up history in the two separate arenas which helps them make associations between the possible problem and solution definitions for the respective issues and as such their framing. This partitions their set of action possibilities that helps them resolve the respective deadlocks. In other words: their refined internal models help them navigating the complexity of the two decision-making processes in the coupled arenas. Decision-making in the first arena shaped the structure in the second arena.

Naturally, the research presented here should be extended. The formal model can be tested in increasingly more realistic situations instead of controlled experimental situations. It is worth incorporating into the model the possibility of prior experience that contributes to the internal model of the actors. For example, there is a long history of bilateral negotiations about cross-boundary issues between the Netherlands and Belgium, so the decision-making in the two arenas didn't come out of the blue. Some (Belgian) civil servants would even refer to the treaty of 1848 between the two countries as a foundation for why they went for certain decision alternatives. This joint history influences the frames with which the respective actors enter the arena and as such predefines possible associations they can make. This, in turn, limits their action space. A shared background means that the decision-makers position themselves differently to other decision-makers, or that their frame is already predefined in comparison to a situation where this background is absent. The frame of reference also means decision-makers are likely to seek alignment with other decision-makers based on history build-up (cf. Henry, Lubell, and McCoyy 2011).

Another addition to the model that could be tested would be to incorporate communication prior to the actual decision-making. Prior communications would find their way in the frames that actors have at their disposal. Players will find out what possible associations others have due to communication, possibly enhancing their frame. After all, it is extremely unlikely that decision-makers would be able to enter the final decision-stage unbiased, uninformed, and uncoordinated. The testing of the model that incorporates prior communications would enhance understanding of the associations and the actions by the actors. Lastly, extending the amount of players, the number of options available and/or the diversity of interaction situations is needed to do justice to the empirical richness of collective decision-making (cf. Malatesta 2012). For example, the number of actors involved in the two arenas discussed here run into the double digits and the space of possible outcomes was also considerable and changeable as new options became available and others disappeared due to external forces.

6. Conclusion

We started this article with the observation that part of the complexity of collective decision-making comes from actors moving back and forth between coupled arenas and the updating of their internal model to become more effective in dealing with that complexity in order to reach their goals. To research this coupledness, we followed the game theoretical approach favoured in the complexity sciences and presented the associative approach. The associative approach was modelled and then tested in an experiment. In the last step, we discussed the implications of the experimental results for understanding complex coupled decision-making processes. The results show that the history build-up in the first setting between the decision-makers creates focal points for the next setting. This helps the actors in the decision-making process to better align choices. In other words: history is key. We have demonstrated that the associative approach in this model can explain at least a fraction of the behaviour of decision-makers interacting in complex situations.

The formal model developed for this article helps conjecturing on what may be necessary, but does not yet provide full answers to all facets of decision-making in coupled arenas. Both theoretical and empirical research is needed in order to extend the initial model of the associative approach.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Formal model

Players have a possible set of actions they can undertake, which is finite and given by $\Sigma = \{1,\ldots, m\}$. Based on the connection with a previous different game, players make associations for the decisions they can make in the current game. Each of these associations induces a partition of Σ. A basic partition is a partition of Σ induced by a single association. B denotes the set of basic partitions. A typical element of B will be denoted β. 'Nature' predetermines the probabilities with which players see certain associations. Players may learn from playing previous games and incorporate this into their approach of later games. If players have learned that there is a possible association they can make between the games, this means that in a later combination – not necessarily between the same two players – nature assigns different availabilities to the players. The frame of a player is denoted by F, which is an arbitrary subset of B. The probability of all associations that are possible in F come to mind of player is denoted by $V(F)$: The availability of F. player believes that the other player holds the same associations as himself, or less, i.e. the other player is said to be type G, $G \subseteq F$. Given that the player is of type F, the conditional probability that the other player is of type G is denoted by $V(G \mid F)$. The availability of association β is denoted by v_β, hence an association β that is not available is denoted by $(1 - v_\beta)$. It is assumed that the availabilities of the different associations are not dependent on each other. The probabilities $V(F)$ and $V(G \mid F)$ can be stated if we write v_β for the availability of association β.

$$V(F) = \prod\nolimits_{\beta \in F} v_\beta \prod\nolimits_{\beta \in F \setminus G} (1 - v_\beta)$$

$$\mathrm{V}(G|F) \ = \prod\nolimits_{\beta \in F} v_\beta \prod\nolimits_{\beta \in F \setminus G} (1 - v_\beta) \ \textit{for}\ G \subseteq F$$

$$V(G|F) \ = \text{Undefined}\ \textit{for}\ G \not\subset F$$

"The expected payoff for a type F player is given by

$$\pi_i(p(\cdot)|F) = \sum\nolimits_{G \subseteq F} V(G|F) \cdot \pi(p_i(F), p_{-i}(G)),$$

where $p_i(F)$ denotes the randomization chosen by type F, $p_{-i}(G)$ denotes the randomization chosen by type G and $\pi(p_i(F), p_{-i}(G))$ denotes the players' expected payoff when these randomizations are chosen." (Janssen 2001, 127).

Do note that: Availabilities are defined between zero and one, which needs some explanation because an association is in the frame of a player, or not. However, the idea of availability can be seen as nature programming the player to 'assign' probabilities to other players having certain associations in their frame. In other words, nature determines the player's beliefs about the cognitive capacities of other players. For instance, nature determines the following thinking for a player: I think that there is a 70 per cent chance that the other player makes and uses this particular association. For this player it would mean that the availability of this particular association would be v = 0.7. Another way of looking at the idea of availability is that in a population the average probability of members of this population making a particular association is, for instance, 0.7. Given shared background, players have this particular association available with 0.7, and not available with 0.3. An association can be labelled, or be perceived as, more prominent when it is more available. However, when the availabilities of, for instance, two associations are 0.6 0.7, respectively, one cannot say that the second is more prominent than the first: They are both prominent. Intuitively thinking, when the difference in availability is large, one can say that one of the two is more prominent. But this does not prevent the possibility that players can coordinate/match by using a less available association.

Calculations of associative approach in experiment 1

The strategy a player will adopt depends on the associations in his frame and the conditional probabilities of the other player having (a subset of) his frame, i.e.:

• no association	→	$(1-v_1)(1-v_2)$	$0 \le v_1, v_2 \le 1$
• entitlement association	→	$v_1(1-v_2)$	
• egalitarian association	→	$v_2(1-v_1)$	
• both associations	→	$v_1 v_2$	

The calculation of the expected payoffs for both players when they claim either the larger or the smaller share of the money can be depicted in the following equations, where π^i is the expected payoff for player i ($i = w, l$), where w is the winner and l is the loser of the hash-mark game.

$$\pi^w(7) = (1-v_1)(1-v_2)\tfrac{21}{10} + v_1(1-v_2)7 + v_2(1-v_1)0 + v_1v_2X$$

$$\pi^w(3) = (1-v_1)(1-v_2)\tfrac{21}{10} + v_1(1-v_2)0 + v_2(1-v_1)3 + v_1v_2X$$

$$\pi^l(7) = (1-v_1)(1-v_2)\tfrac{21}{10} + v_1(1-v_2)0 + v_2(1-v_1)7 + v_1v_2X$$

$$\pi^l(3) = (1-v_1)(1-v_2)\tfrac{21}{10} + v_1(1-v_2)3 + v_2(1-v_1)0 + v_1v_2X$$

The last term denoted by X is unspecified, because one is not able to determine what the outcome will be: The outcome depends on what the player believes the probabilities of the other player having the associations are. To be able to specify the claims, the last term (X) of the equations can be specified by showing the cases in which the minimum of one claim (i.e. $X = 0$) exceeds the maximum of the other (X = claim maximum). In these cases it is always rational to act according to the claim, because the expected payoff of following it is always higher, i.e. it is a dominant strategy. It is rational for the winner to claim seven if the minimum expected payoff of claiming seven is equal to or exceeds the maximum expected payoff of claiming three. In formula: min $\pi^w(7) \geq$ max $\pi^w(3)$, which is satisfied if:

$$v_2 \leq \frac{7v_1}{3+7v_1}.$$

It is rational for the winner of the hash-mark game to claim the smaller share in the distribution game, if max $\pi^w(7) \leq$ min $\pi^w(3)$, which is satisfied if:

$$v_2 \leq \frac{7v_1}{3+7v_1}.$$

For the loser of the hash-mark game, it is rational to claim the smaller share when max $\pi^w(7) \leq$ min $\pi^w(3)$, and the larger share when min $\pi^w(7) \geq$ max $\pi^w(3)$, which are satisfied if $v_2 \leq \frac{3v_1}{7+3v_1}$, respectively, $v_2 \geq \frac{3v_1}{7-7v_1}$.

Coding variables

Start hash-mark game	1 =	Start
	2 =	Second
Result hash-mark game	0 =	Lose
	1 =	Win
Distribution alternative	1 =	Alternative 1
	2 =	Alternative 2
Distribution result	0 =	Non-matching offers
	1 =	Matching offers
Sex	0 =	Male
	1 =	Female
Cultural background	0 =	Dutch
	1 =	Non-native Dutch
Risk behaviour alternatives	0 =	€ 3.- for sure
	1 =	Toss of coin 20 vs. 0
Faculty	1 =	Economics
	2 =	Business administration
	3 =	Law
	4 =	History & Arts
	5 =	Economics & Law
	6 =	Philosophy
Possible association version 1	0 =	Lost HM & chose alternative 2
		Won HM & chose alternative 1
	1 =	Lost HM & chose alternative 1
		Won HM & chose alternative 2
Possible association version 2	0 =	Lost HM & chose alternative 1
		Won HM & chose alternative 2
	1 =	Lost HM & chose alternative 2
		Won HM & chose alternative 1

Results analyses variables version 1:

Correlation *HM start* and *HM result*: 278 (*N*) valid entries to test the correlation. Starting players win almost 8 per cent more than players that go second. The one-sided significance (*p*) is 0.094, and thus is the relation not significant in a 95 per cent confidence interval.

Correlation *results game* to each individual players: The relation for each individual player is not significant (ρ = −0.000; *p* = .499; *N* = 275). Starting players did not learn how to win the game (ρ = .089; *p* = .149; *N* = 136). And the players who go second in the hash-mark game did not learn how to take advantage of the no-learning situation of the starters (ρ = .091; *p* = .291; *N* = 136).

Correlation *HM result* and *Distribution alternative*. When the result of the hash-mark game goes up (the variable is coded as 0 = lost HM, and 1 = won HM) the alternative chosen in the distribution game goes up (coding: 1 = alternative 1, and 2 = alternative 2). The corrected coefficient is 0.482 (ρ = .000; *N* = 275).

Correlations

		Risk behaviour	Cultural background	HM start
Sex	Pearson Correlation	−.122	.195	.000
	Sig. (2-tailed)	.408	.183	1.000
	N	48	48	278
Risk behaviour	Pearson Correlation		−.209	.018
	Sig. (2-tailed)	n.a.	.155	.769
	N		48	278
Cultural background	Pearson Correlation			−.026
	Sig. (2-tailed)	n.a.	n.a.	.669
	N			278

One-way ANOVA test of Faculty

	F	Sig.	*N*
Sex	2.339	.087	46
Cultural background	1.769	.167	46
Risk behaviour	1.776	.166	46
HM start	1.059	.367	272

Correlations distribution alternative

		Distribution alternative
Cultural background	Pearson Correlation	−.045
	Sig. (1-tailed)	.229
	N	278
Risk behaviour	Pearson Correlation	.059
	Sig. (1-tailed)	.162
	N	278

One-way ANOVA test of Faculty

	F	Sig.	*N*
Distribution alternative	1.189	.314	272

Results analyses variables version 2:

Correlation *HM start* and *HM result*: starting players (ρ = .022; *p* = .412; *N* = 100) or the second player (ρ = .023; *p* = .821; *N* = 100)

Correlations

		Cultural background	HM start
Sex	Pearson Correlation	.130	−.077
	Sig. (2-tailed)	.379	.199
	N	36	278
Cultural Background	Pearson Correlation		−.042
	Sig. (2-tailed)	n.a.	.489
	N		278

One-way ANOVA test of Faculty

	F	Sig.	*N*
Sex	2.267	.141	35
Cultural background	0.110	.742	35
HM start	0.117	.733	208

Correlations

		Distribution alternative
Sex	Pearson Correlation	−.055
	Sig. (1-tailed)	.181
	N	274
Cultural background	Pearson Correlation	−.050
	Sig. (1-tailed)	.205
	N	274

Correlation *HM result* and *Distribution alternative*: Corrected correlation for the almost significant (p = .084) variable sex is – 0.228 (p = .001; N = 199), which means that when the result of the hash-mark game goes up, from 0 for losing to 1 for winning, the other variable goes down from alternative 2 to alternative 1 by almost 23%.

One-way ANOVA test of Faculty

	F	Sig.	N
Distribution alternative	.077	.781	207