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Abstract

This study introduces the concept of "compound games" and investigates whether the decomposition of a game – when implemented – influences behaviour. For example, we investigate whether separating battle of the sexes games into a pure coordination component and the remaining battle of the sexes component changes coordination success. The literature attributes high coordination rates in pure coordination games with focal points to team reasoning and low coordination rates in related battle of the sexes games to level-k reasoning. We find that coordination success in compound games depends on the decomposition and order of component games.

Keywords: Compound games, focal points, framing, collective interest

JEL Codes: C72, C91, D90

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1 Introduction

Consider the battle of the sexes game between a Bach admirer and a Stravinsky enthusiast regarding the evening entertainment on 21 March 2021. "Their main concern is to go out together, but one person prefers Bach and the other person prefers Stravinsky" (Osborne and Rubinstein, 1994, p. 15). It is common knowledge that the evening happens to be on Bach's 336th birthday, which makes the Bach event salient. In experiments, such saliency enables high levels of coordination in pure coordination games (PC), however, its effectiveness is severely reduced in battle of the sexes games. In this paper, we ask whether the coordination success of the two music devotees can be increased by emphasising the pure coordination element of the game "to go out together"?

We investigate this question with the help of the new concept of "compound games", which formalises the implementation of games in their decomposed state. A decomposition splits a simple game into multiple additive component games with strategy spaces identical to the simple game's strategy space. A compound game consists of these multiple component games and additional rules needed to study behaviour in its implementation. Specifically, across component games, players have to choose identical strategies so that, theoretically, a compound game and its original game are equivalent. Because of its different framing, compound games might elicit different behaviour and can offer insights beyond the study of standard games.

In contrast to a compound game, we call "Cartesian game" the implementation of multiple component games without the mentioned choice restrictions. They thus reflect the simultaneous engagement of players in multiple independent games.

In recent years, various game decompositions have been introduced to the literature (Candogan, Menache, Ozdaglar and Parrilo, 2011; Kalai and Kalai, 2013; Jessie and Saari, 2016; Demuynck, Seel and Tran, 2019). These decompositions have been mostly used for theoretical and diagnostical purposes, such as quantifying the competitiveness of a game (Demuynck et al., 2019). To our knowledge, we are the first to empirically study behaviour in what we call compound games. Closest to our study, Jessie and Kendall (2020) experimentally investigate behaviour in individual component games. We investigate behaviour in compound games in which, by contrast, all component games of a decomposition are implemented.

Table 1 shows one of many possible decompositions of a battle of the sexes game (BS) into a compound game $pc + bs$ consisting of a pure coordination component (pc) and the remaining battle of the sexes component (bs). For this "mixed-motive game", as Schelling (1960, p. 89) calls a BS game, this decomposition formally separates the motive "to go out together" from the second motive that "one person prefers Bach and the other person prefers Stravinsky".

The type of decompositions we study here illustrates the ability of compound games to formally reflect and explicitly implement a game's set of motives and, hence, to relate to a game's verbal

1

	B	S			B	S			B	S
B	11, 10	0, 0	=	B	4, 4	0, 0	+	B	7, 6	0, 0
S	0, 0	10, 11		S	0, 0	4, 4		S	0, 0	6, 7

Table 1: Decomposition of *BS* game into compound game *pc* + *bs*.

and possibly mental representation. Compound games might help to identify individual motives or game components that are elementary in terms of behaviour and reasoning. Relatedly, compound games bear the potential to analyse the effect of game components or their ordering on behaviour. Generally, any decomposition implemented in a compound game – in practice a mere re-framing of the original game – raises the question of whether behaviour will be affected. Therefore, the implementation of further types of decompositions might be empirically interesting. For example, decompositions by strategies to study equilibrium selection or random decompositions to study the scope of decompositions' behavioural relevance.

In our application, the question is whether a more explicit framing of the two motives increases or decreases the coordination success. Also, given that the two motives are separated, does the order of presentation or a possible sequence of presentation matter? In other words, is the game play influenced by the nature of the first or second component game rather than the original simple game? Would it matter that the second component is only visible after a provisional choice in the first? Furthermore, given that the decomposition is not unique and that a different common interest component could be separated, does the size of the separated *pc* payoff influence the success of coordination?

Experimental evidence shows that in pure coordination games payoff-irrelevant salient features – such as Bach's birthday – allow players to coordinate with a success rate higher than predicted by random choice (Mehta et al., 1994; Bardsley et al., 2010; Isoni et al., 2013; Sitzia and Zheng, 2019). This success is commonly explained with the theory of team reasoning, which is based on Schelling's (1960) theory of focal points, and postulates that players look for a selection rule that maximises the chances of coordination when all act in line with that rule (Sugden, 1995; Bacharach, 2006). In recent years, this literature has furthermore established that this success is severely reduced in battle of the sexes games due to the players' conflicts of interest. The frequent mis-coordination is attributed to level-*k* reasoning, in which label or payoff salience shape level-0 players' behaviour (Crawford et al., 2008; van Elten and Penczynski, 2020; Isoni et al., 2020).

Our results show that the game decomposition has an influence on behaviour. Coordination success in compound games increases if a *pc* component game is presented first and decreases when the first game is a *bs*. Decomposing a simple *PC* game into two *bs* components reduces coordination success significantly. Even in Cartesian games, a *bs* component game reduces the coordination success in the subsequent *pc* component game.

2

In terms of concepts and results, some analogies exist between compound games and compound lotteries. The nature of our results relates our study to the literature on narrow bracketing and behavioural spillovers. Decomposing a game gives rise to the possibility that players narrow bracket if they consider component games in isolation and fail to see the compound game as a whole (Read, Loewenstein, Rabin, Keren and Laibson, 1999). Like the literature finds narrow bracketing in independent lottery choices (Tversky and Kahneman, 1981; Rabin and Weizsäcker, 2009), we find narrow bracketing in strategy choices in Cartesian games. Surprisingly, while the compound games' strategy space highlights the simultaneous relevance of the two component games, the effects of narrow bracketing are even stronger than in the Cartesian games. Behavioural spillovers imply that the adoption of one behaviour causes another related behaviour (Bednar et al., 2012). We see interesting asymmetric spillovers as a *bs* component influences a following *pc* component much more than vice versa.

While simple games can summarise concisely multiple aspects of strategic situations, compound games formally capture aspects of a framing that might arise naturally in the interaction. For example, complex negotiations such as the Brexit negotiations or the US-China trade negotiations will naturally be considered by topic before parties come to an overall agreement. The behavioural consequences of this framing are shown to be significant and relevant.

2 Cartesian, compound and reduced games

Our study requires a new and suitable terminology to describe details of the implementation of a decomposition. Due to the analogies with compound and reduced lotteries we align our terms where possible.

In line with the literature, we consider a decomposition to be the expression of a game's payoff matrix g as the sum of component game payoff matrices of the same size, $g = c_1 + c_2 + c_3 + \ldots + c_k$. As a starting point, we establish the simple game[1] as the elementary basis for further manipulations.

Definition 1 (Simple game). *A simple game G consists of a finite set of players $i \in N$ and a strategy space $S = \bigtimes_i S_i$. The preferences of player i are represented by a payoff function $\pi_i : S \rightarrow \mathbb{R}$.*

	$\underline{A}$	A
$\underline{A}$	11, 10	0, 0
A	0, 0	10, 11

Table 2: A simple 2-player $BS(11, 10)$ with $S_i = \{\underline{A}, A\}$.

---

[1]In cooperative game theory, games that feature only payoffs of 0 or 1 are called simple games. Here, we merely want to distinguish a game from a compound game.

The most basic way of formalising play of multiple games is to represent the simultaneous play of a number of simple games in what we call a Cartesian game. Cartesian games have occasionally been implemented in the experimental literature but not formally defined (e.g. Bland, 2019); they are natural auxiliary games in this study of compound games.[2]

Definition 2 (Cartesian game). *A Cartesian game Γ consists of a totally ordered set of k simultaneously played simple component games, all of which feature the same finite set of players $i \in N$. Each component game c features a strategy space S^c and payoff functions for player i, $\pi_i^c : S^c \to \mathbb{R}$.*

Table 3 presents an example of a Cartesian game. Generally, we denote component games in lowercase as pc and bs, respectively. A Cartesian game with two pc component games is denoted by $pc \times pc$, where the first term refers to component 1 and the second to component 2. In order to be able to distinguish a $pc \times bs$ game from a $bs \times pc$ game with identical component games – as is necessary in any implementation – the definition uses a totally ordered set of c components.

$$
\begin{array}{c|cc}
 & a & b \\
\hline
a & 7,6 & 0,0 \\
b & 0,0 & 6,7
\end{array}
\quad\times\quad
\begin{array}{c|cc}
 & \alpha & \beta \\
\hline
\alpha & 4,4 & 0,0 \\
\beta & 0,0 & 4,4
\end{array}
$$

Table 3: Cartesian game $bs \times pc$ $(7,6 \times 4,4)$.

The reduction of a Cartesian game generates a simple game with the eponymous strategy space $\Sigma = \bigtimes_c \bigtimes_i S_i^c$ and a payoff function for player i, $\sum_c \pi_i^c = \Pi_i^\Gamma : \Sigma \to \mathbb{R}$, as table 4 illustrates.

$$
\begin{array}{c|cccc}
 & a\alpha & a\beta & b\alpha & b\beta \\
\hline
a\alpha & 11,10 & 7,6 & 4,4 & 0,0 \\
a\beta & 7,6 & 11,10 & 0,0 & 4,4 \\
b\alpha & 4,4 & 0,0 & 10,11 & 6,7 \\
b\beta & 0,0 & 4,4 & 6,7 & 10,11
\end{array}
$$

Table 4: Reduced form of Cartesian game $bs \times pc$ $(7,6 \times 4,4)$.

In contrast to the way in which a Cartesian game relates to its component games, all decompositions in the literature as well as our experimental design feature the same strategy space in the component games as in the reduced game. Furthermore, the strategies for the different component

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[2]Our concept of Cartesian game nests two concepts commonly referred to as "supergame". In the study of repeated games, a "supergame" refers to a possibly infinite number of sequential repetitions of a simple stage game, which is a sequential version of a Cartesian game with identical component games. In experimental economics, the term "supergame" is often used to emphasise the ensemble of games in an experimental session, in which participants play more than one game – be it simultaneously or sequentially – and which might therefore feature additional unintended strategic considerations beyond the individual component games.

games are not meant to be chosen independently by players, but rather are set to be the same across all component games. It is therefore useful to define a compound game as follows.

Definition 3 (Compound game). *A compound game C consists of a totally ordered set of k simultaneously played simple component games, all of which feature identical sets of players N and strategy spaces S. The chosen strategy s ∈ S is constrained to be the same across all component games. Each component game c features payoff functions for player i, $\pi_i^c : S \to \mathbb{R}$.*

Table 5 gives an example of a compound game. A compound game with two *pc* component games is denoted *pc + pc*. In the reduced form of a compound game, for each player and each outcome $s \in S$ the payoff is equal to the sum of payoffs of the component games: $\pi_i^C = \sum_c \pi_i^c$. Table 6 shows the exemplary reduced compound game.

$$
\begin{array}{c|cc}
 & a & b \\
\hline
a & 7,6 & 0,0 \\
b & 0,0 & 6,7
\end{array}
\quad + \quad
\begin{array}{c|cc}
 & a & b \\
\hline
a & 4,4 & 0,0 \\
b & 0,0 & 4,4
\end{array}
$$

Table 5: Compound game $bs + pc$ $(7, 6 + 4, 4)$.

$$
\begin{array}{c|cc}
 & aa & bb \\
\hline
aa & 11,10 & 0,0 \\
bb & 0,0 & 10,11
\end{array}
$$

Table 6: Reduced form of the compound game $bs + pc$ $(7, 6 + 4, 4)$.

3 Literature

3.1 Decompositions

The last 10 years have seen the emergence of a sizeable set of theoretical studies that propose decompositions of games mostly for theoretical and diagnostical purposes. With two exceptions, these have not been used for empirical investigations of behaviour as we propose here.

Candogan et al. (2011) introduce a flow representation of finite games in strategic form, which is used to decompose an arbitrary game into its potential, harmonic and nonstrategic components. A game is said to be a "potential" game if the incentive of all players to change their strategy can be expressed with a single global function called the potential function (Monderer and Shapley, 1996).

In a prominent contribution, Kalai and Kalai (2013) decompose any 2-player game with finitely many strategies into a competitive zero-sum game and a cooperative common-interest game. They

use the decomposition to define a semi-cooperative solution, the coco value, for games with transferable utility.

Demuynck et al. (2019) extend this decomposition to games with an arbitrary number of players and an infinite strategy space. With an appropriate metric, they define the normed distance between any game and its cooperative component as the competitiveness-cooperativeness index (CCI). In the empirical part of the paper, they show that the competitiveness of behaviour in experimental games is on average in line with the CCI.

Jessie and Saari (2016, 2019) introduce a unique decomposition of n-player, binary strategy games into three parts, a Nash, a behavioural and a Kernel (non-strategic) part, see figure 7 for an example.[3] One main contribution of this decomposition is the reduction of complexity in the analysis of a game. Building on this decomposition, Jessie and Kendall (2020) show experimentally that the invariance to the behavioural and non-strategic part – which many equilibrium concepts and models of strategic thinking feature – is not observed empirically. Kendall (2020) uses the behavioural part of the decomposition to improve predictions for one-shot and repeated stag-hunt games.

$$
\begin{array}{c|cc}
 & B & S \\
\hline
B & 8,4 & 0,0 \\
S & 0,0 & 4,8
\end{array}
=
\begin{array}{c|cc}
 & B & S \\
\hline
B & 4,2 & -2,-2 \\
S & -4,-4 & 2,4
\end{array}
+
\begin{array}{c|cc}
 & B & S \\
\hline
B & 1,-1 & -1,-1 \\
S & 1,1 & -1,1
\end{array}
+
\begin{array}{c|cc}
 & B & S \\
\hline
B & 3,3 & 3,3 \\
S & 3,3 & 3,3
\end{array}
$$

Table 7: Decomposition of *BS* game into Nash, behavioural and Kernel part according to Jessie and Saari (2019).

3.2   Coordination games with focal points and modes of reasoning

To investigate behaviour in compound games we employ pure coordination and battle of the sexes games with focal points. These games present interesting case studies because observed behaviour is found to be sensitive to whether players' preferences are aligned or conflicting with respect to which equilibria to coordinate on. No theory, as of yet, is able to fully organise the experimental evidence of this literature.

Coordination games present a problematic class of games for standard game theory because of its inability to select one equilibrium out of many. In his seminal work, Schelling (1960) proposes a theory of focal points in which players are able to concert their expectations on some salient features of the game (e.g. salient labels attached to strategies) and coordinate on one particular equilibrium, the focal point of the game. Schelling's theory has been further developed by Sugden

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[3]The Nash part contains all information to determine a strategic outcome while the behavioural part captures the game's aspects that can lead to other kinds of analysis, such as side payments, social preferences, etc.

(1993) and Bacharach (2006) under the name of team reasoning. These theories assume that players think of themselves as being part of a team (collective rationality). In Bacharach's theory, when players team-reason they ask the question "what should we do" and work out a strategy profile, the best rule in Sugden's theory, that leads to the best possible outcome for the team and dictates what each player should do.

Using a variety of pure coordination games, abundant experimental evidence consistent with team reasoning has been collected over the years. For example, Mehta et al. (1994) employ a series of matching games in which subjects are asked to name an object (flower, city, etc.) or to choose an object out of many. Crawford et al. (2008) find similar results employing a pie game and an allocation *XY*-game. The pie game is a two-player game with three pure Nash equilibria while the allocation game features two. Isoni et al. (2013) use a bargaining table in which players have to agree on how to share a monetary surplus by making claims on some valuable "discs".

The promising success of team reasoning theories in explaining behaviour in pure coordination games however is greatly reduced when players' interests are not aligned, such as in the battle of the sexes games. Crawford et al. (2008) develop a model of level-*k* thinking that is able to explain the low coordination success observed in these games. This type of reasoning is fundamentally different and incompatible with team-reasoning, as it implies an individualistic type of reasoning in which players anchor their beliefs on the behaviour of a player that lacks strategic sophistication, a level-0 player, and best respond to that.

Since Crawford et al. (2008), attempts have failed to show that team reasoning is the prevalent mode of reasoning employed across the whole range of coordination games (e.g. Bardsley et al., 2010; Isoni et al., 2013; Faillo et al., 2017). Empirical evidence shows that individuals seem to be using both types of reasoning depending on the features of the coordination games. Specifically, conflicts of interest seem to inhibit team-reasoning and evoke individualistic reasoning while absence of conflict facilitate collective reasoning (Faillo et al., 2017; van Elten and Penczynski, 2020)

Compound games provide insights that are indicative of the extent to which modes of reasoning can be influenced and of whether one of the two modes of reasoning is more fragile.

3.3 Narrow bracketing and behavioural spillovers

When facing multiple choices at the same time, individuals often consider each choice in isolation and fail to appreciate the consequences of those choices collectively. Narrow bracketing is a well-documented phenomenon in the literature of individual decision-making under risk (Read et al., 1999). A clear instance is offered in the study by Tversky and Kahneman (1981), later replicated by Rabin and Weizsäcker (2009). Specifically, from choices between lotteries A and B as well as C

and D, only 3 percent choose combination BC. Yet, the majority chooses BC over AD when these lottery pairs are presented in aggregate.

Bland (2019) finds evidence of narrow bracketing in a Cartesian game of two Volunteer's dilemmata at the individual but not at the aggregate level. Our study, although not designed as a controlled test of narrow bracketing, adds clear evidence of this phenomenon in compound and Cartesian games. Most apparently, in a $bs + bs$ decomposition of a PC game, subjects do not integrate outcomes because the coordination success is lower than in the PC game.

While the concept of narrow bracketing focuses on the differences between the game and its decomposed equivalents, the concept of behavioural spillovers considers changes in behaviour in a game due to games played beforehand or simultaneously.

In an ensemble of games, behavioural spillovers might be the result of a positive transfer of a principle, rule or strategic behaviour from one game to another one (Knez and Camerer, 2000; Cooper and Kagel, 2005, 2008; Haruvy and Stahl, 2012; Mengel and Sciubba, 2014). For example, Cooper and Van Huyck (2018) provide experimental evidence of a transfer of the principle of dominance from stag-hunt games to order statistic games such as the weak-link or median games. In the absence of feedback, our study provides an example of asymmetric "rule spillover". Our results are in line with the explanation that the mode of strategic reasoning is carried over from bs to pc components, but not vice versa.

To the extent that these spillovers are inefficient, they can be seen as a type of behavioural inertia (Bednar et al., 2012; Liu et al., 2019). In these studies on inefficient spillovers, defection is observed more frequently when the Prisoner's Dilemma is played with a Self-Interest game than when it is played in isolation. This literature predominantly observes such inertia from games with clearly favoured actions to games with more distributed action profiles (Cason et al., 2012). Here, we see the opposite, as the inertia is most pronounced when moving from the low coordination bs components to the high coordination pc components.

Once a decomposition is implemented in a compound game, the presentation order of the component games has to be inevitably defined. This way, permutations of a given decomposition might lead to different behaviour. In psychology, order effects such as primacy and recency effects have been studied with respect to elementary cognitive operations such as recall and belief updating that influence decision-making (Murdock, 1962; Hogarth and Einhorn, 1992).

4 Experimental design and procedures

4.1 The games

We employ 31 games (simple, compound, and Cartesian) inspired by the *XY*-game in Crawford et al. (2008). In this game, two players are required to choose one out of two strategies. Strategies are labelled by the resulting payoff allocation in the case of coordination. One of the strategies is made salient by underlining it. If players choose the same strategy then the allocation is enforced, otherwise they earn nothing. The two choices are presented as follows.

- You receive £a and the other receives £b

- You receive £b and the other receives £a

In a pilot experiment, underlining one of the strategies has proved to be a more powerful cue for coordination than using *X* and *Y*. As simple games, we implemented one *PC* game, in which $a = b$, and two *BS* games, in which $a > b$. The payoff matrices for these games are reported in table 8. In line with the experiment's framing, the strategies have been labelled as $\underline{A}$ and A.

	$\underline{A}$	A
$\underline{A}$	10, 10	0, 0
A	0, 0	10, 10

(a) *PC* (10, 10).

	$\underline{A}$	A
$\underline{A}$	11, 10	0, 0
A	0, 0	10, 11

(b) *BS* (11, 10)

	$\underline{A}$	A
$\underline{A}$	12, 9	0, 0
A	0, 0	9, 12

(c) *BS* (12, 9)

Table 8: Implemented simple games.

	$\underline{A}$	A			$\underline{A}$	A			$\underline{A}$	A
$\underline{A}$	11, 10	0, 0	=	$\underline{A}$	7, 6	0, 0	+	$\underline{A}$	4, 4	0, 0
A	0, 0	10, 11		A	0, 0	6, 7		A	0, 0	4, 4

Table 9: Decomposition of *BS* into compound game *bs+pc*.

For our purposes, a simple game is decomposed into $k = 2$ component games, component 1 and component 2. The simple *PC* game is decomposed either into two *PC* games ($pc + pc$) or two *BS* games ($bs + bs$). The simple *BS* games are decomposed into one *pc* game and one *bs* game (see table 9). Table 10 lists all simple, compound and Cartesian games that we employed.[4] We use

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[4]Due to a typo, instead of $(4, 4 \cdot 8, 5)$ our experiment implemented $(4, 4 \cdot 7, 5)$. Since behaviour in these games is not significantly different from other compound games reducing to the *BS* (12, 9) game, we expect that this would have been true for $(4, 4 \cdot 8, 5)$ as well.

the "·" notation to represent simultaneously the notation "+" and "×" employed for compound and Cartesian games.

For each simple game and any combination of component games (e.g. $pc \cdot bs$) there are at least four games featuring different payoffs. This range enables us to verify whether the size of the pc payoffs matter. This range also prevents any inference over time about the simple game from the first component game, a feature whose relevance will be clear below.

Simple Games	Compound/Cartesian games			
	$pc \cdot pc$	$bs \cdot bs$	$pc \cdot bs$	$bs \cdot pc$
	$0, 0 \cdot 10, 10$	$1, 0 \cdot 9, 10$		
	$4, 4 \cdot 6, 6$	$3, 0 \cdot 7, 10$		
	$7, 7 \cdot 3, 3$	$4, 3 \cdot 6, 7$		
$PC(10, 10)$	$9, 9 \cdot 1, 1$	$5, 2 \cdot 5, 8$		
	$10, 10 \cdot 0, 0$	$7, 5 \cdot 3, 5$		
		$7, 6 \cdot 3, 4$		
			$0, 0 \cdot 11, 10$	$11, 10 \cdot 0, 0$
$BS(11, 10)$			$4, 4 \cdot 7, 6$	$7, 6 \cdot 4, 4$
			$7, 7 \cdot 4, 3$	$4, 3 \cdot 7, 7$
			$10, 10 \cdot 1, 0$	$1, 0 \cdot 10, 10$
			$0, 0 \cdot 12, 9$	$12, 9 \cdot 0, 0$
$BS(12, 9)$			$4, 4 \cdot 7, 5$	$7, 5 \cdot 4, 4$
			$7, 7 \cdot 5, 2$	$5, 2 \cdot 7, 7$
			$9, 9 \cdot 3, 0$	$3, 0 \cdot 9, 9$

Notes: The games $pc(0, 0)$ and $bs(1, 0)$ have different equilibrium features than standard pc and bs games, respectively.

Table 10: Implemented simple, compound and Cartesian games (outcomes of the equilibrium $\underline{AA}$ in each component game reported). The dot "·" stands for "+/×".

4.2 The experiments

We have run two experiments, the experiment $COMP$ that features the basic framing of a compound game and the experiment $PART$ that is intended to further emphasise this framing. The emphasis is achieved by varying the amount of information subjects have when considering component 1.

In $COMP$ (*COMP*lete information) we implement simple and compound games.[5] In this ex-

---

[5]In order to identify games in the experiment, the instructions employ a more transparent terminology: "linked"

periment, the component games are presented on the screen at the same time (see figure 1). Players have therefore complete information of the entire compound game when deciding which strategy to select. Component 1 is always displayed at the top of the screen and component 2 at the bottom.

Figure 1: Screenshot of compound game in experiment *COMP*.

In *PART* (*PART*ial information) we implement simple, compound and Cartesian games. In this experiment, the framing of compound games is strengthened by presenting the component games on the screen one after the other and by requiring a decision in component 1 to be made before component 2 is shown.

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allocations for compound games, "unlinked" allocations for Cartesian games, and "allocations" for simple games. Instructions are reprinted in appendix A.1.

Scenario
1 out 31

Please select an allocation by clicking on the "Choose this allocation" button. Click OK to continue.

TASK 1

Choose this allocation   You receive €a and the other receives €b.

Choose this allocation   You receive €c and the other receives €d.

OK
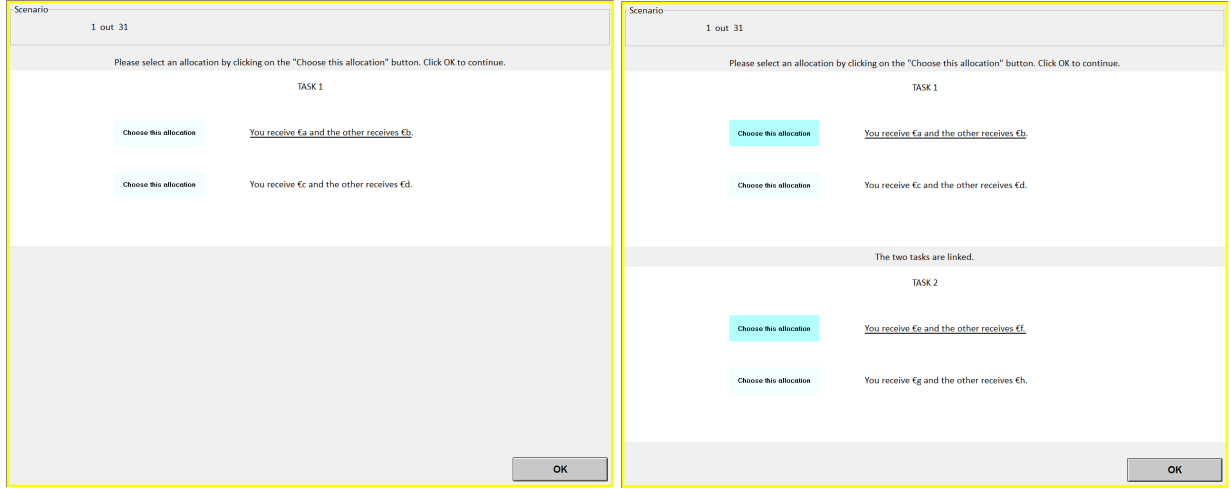
(a) Screen 1 with component 1.   (b) Screen 2 with components 1 and 2.

Figure 2: Screenshots of compound games in *PART*.

In compound games, when the individual components are presented sequentially (see figure 2), decisions in component 1 are made under partial information, as payoffs of component 2 are not yet displayed. Of course, players are allowed to change the strategy they have selected in component 1 once they are presented with component 2. However, as players know that decisions in component 1 are not binding, to minimise the risk of players not engaging with those choices, *PART* also implements Cartesian games. Therefore, when facing a component 1, players do not know whether that is the component 1 of a compound game, the component 1 of a Cartesian game, or a simple game. They are informed of this after they select a strategy. Because of this uncertainty, decisions in this component will be treated as binding with some probability, as players will not be able to change it in Cartesian or simple games.[6] Even over time, subjects cannot guess the payoffs of the second component just by knowing what the first component payoffs are, because each first component game features in several games.

To have a similar number of games in both experiments, *PART* features two treatments: $PART_a$ and $PART_b$. Each treatment features only half of the compound games in *COMP* with the remaining half implemented as Cartesian games. The compound games in $PART_a$ are implemented as Cartesian games in $PART_b$, and vice versa. Component games are chosen so that in both $PART_a$ and $PART_b$ there is an equally numerous representation of $pc + pc$, $bs + bs$, $pc + bs$, and $bs + pc$ for each simple game employed.

---

[6]Later on we provide evidence that indeed subjects' behaviour in the first component of both compound and Cartesian games does not significantly differ.

4.3 Procedures

The experiments were run in the AWI laboratory at the University of Heidelberg (Germany) in July 2018. We recruited 148 subjects with the online system hRoot (Brock 2004): 46 subjects in *COMP* and 102 subjects in *PART$_a$* and *PART$_b$* treatments. Upon arrival, subjects were handed the experimental instructions that were read aloud by the experimenter. Subjects then answered a brief questionnaire to check their understanding of the experiment. When all participants were ready the experiment started. The order of the games was randomised across participants. Feedback was only provided at the end for one randomly selected game that was then used to determine the experimental earnings. In addition, subjects were given a participation fee of €5. Average earnings were about €10.38.

5   Hypotheses

The main objective of this study is to investigate the following general conjecture.

Conjecture. *Even though a simple game and all its derived compound games feature the same payoff consequences, the specific framing of a compound game can lead to significant changes in behaviour compared to the simple game or other compound games. Such changes will be caused by reactions to the specific nature of one or more component games as is conceivable, for example, under narrow bracketing.*

The experimental implementation of any simple game and some of its derived compound games can speak to this conjecture. The literature's results about the quite distinct reasoning generated by pure coordination games and battle of the sexes games motivates our choice of combinations of component games. In this section, we will therefore derive detailed hypotheses for our games using a combination of team reasoning (Bacharach, 2006; Schelling, 1960; Sugden, 1995) and level-*k* thinking (Crawford et al., 2008). Following Isoni et al. (2019), we will assume that players are capable of using both modes of reasoning, although only one at a time.

The simple games feature two players $i = \{1, 2\}$ and two strategies $s = \{\underline{A}, A\}$. Strategies are uniquely labelled with one label per strategy, one of which is salient ($\underline{A}$). By virtue of this labelling, one strategy stands out. If players choose the same strategy, which is equivalent to choosing the same label, their payoffs are $\pi_{is} \in \{a, b\}$ (with $a \geq b > 0$) and zero otherwise. The simple games are used to derive compound and Cartesian games. These games consist of two component games $c = \{1, 2\}$, each with two strategies $s(c) \in \{\underline{A}, A\}$. In compound games, players are required to choose the same strategy in both component games. In Cartesian games, players are not constrained in their strategy choice.

We say that two players team-reason if they independently look for a uniquely optimal rule which, if followed by both players, maximises the chances of coordination leading to the best possible outcome for the team. In coordination games in which labels are common knowledge the best rule for the team is to choose the label salient strategy, i.e. $s = \underline{A}$.

The version of the level-k model in Crawford et al. (2008) assumes that players differ in their level of strategic sophistication. Level-0 players ($L0$) have a payoff bias, in that they choose, with a probability $p > 0.5$, the strategies whose equilibria have a higher own-payoff. If both equilibria have the same own-payoff, $L0$ choose according to label salience with probability $p > 0.5$. Higher levels anchor their beliefs on the behaviour of $L0$ and best-respond to players just one level below theirs. $L1$ best-respond to $L0$, $L2$ to $L1$ and so on. The distribution of levels in the population is exogenously given and $L0$ only exist in the mind of other players. $L1$ in a PC will therefore always choose the label salient strategy $s = \underline{A}$, as the probability of coordination is greater than one half. All levels greater than $L1$ will best-respond by choosing the same strategy. In BS games, how often the label salient strategy is chosen depends on the distribution of levels. For our purposes, without making any further assumption, it suffices to say that $s = \underline{A}$ will be chosen less frequently than in a PC game.

Following Isoni et al. (2019), let us define the probability that a player uses team-reasoning as τ. The probability that a player uses level-k reasoning is $\kappa = 1 - \tau$. If we consider the whole population of players, this probability can be interpreted as a proportion.

We assume that the class of game, be it a simple or a component game, influences these probabilities. For a PC game, where $a = b$, experimental evidence suggests that team reasoning is more prevalent than level-k reasoning, therefore $\tau_{PC} > \kappa_{PC}$. By contrast, level-k thinking is more prevalent in BS games, therefore $\kappa_{BS} > \tau_{BS}$ (van Elten and Penczynski, 2020). We take this to further imply that $\tau_{PC} > \tau_{BS}$.

Hypothesis 1 (Simple games). *The frequency of choice of the salient strategies is greater in the simple PC than in the simple BS games.*

We will derive predictions for the reasoning in the compound games with the help of three assumptions, two specifying the determinants of the mode of reasoning and one specifying exactly which game is reasoned about.

The first assumption spells out how the class of the component games (pc or bs) influence the probability τ. By the virtue of being displayed on top of the screen in $COMP$ and first in $PART$, we assume that component 1 has a stronger influence on the mode of reasoning than component 2.

Assumption 1 (Class of component game). *The probability of the type of reasoning employed, τ, is a function of the class of the pivotal component game. The pivotal component game is component 1 with probabilities $0.5 < p_{COMP} < p_{PART} = 1$.*

Parravano and Poulsen (2015) show that an increase in the *PC* payoffs leads to an increase in coordination while a proportional increase in the payoffs of a *BS* does not lead to a significant change in behaviour. By the nature of our decomposition of a given *BS* game, a higher payoff in a *pc* component leaves unchanged the absolute difference between players' payoffs in the *bs* component. This difference therefore increases in *relative* terms – not in proportional terms – as the *pc* payoff rises. Therefore, while we can reasonably expect that an increase in the *pc* payoffs increases coordination, the behavioural effect of a change in the relative size of the *bs* payoffs is not clear. For simplicity, we assume no effect of differently sliced decompositions. Thus, for example, any compound game that combines component games of classes *bs* and *pc* in the same order and that reduces to a $BS(11, 10)$ game – be it $(7, 6 + 4, 4)$ or $(1, 0 + 10, 10)$ – leads to the same expectations on the modes of reasoning. Our experiment is however designed to be able to falsify this assumption.

Assumption 2 (Component game payoffs). *For any two compound games with the same reduced form game and with the same ordered classes of component games, different payoffs in the component games do not have any effect on the mode of reasoning.*

Assumption 3 asserts that subjects integrate the payoffs of the component games and reason about the reduced game.[7]

Assumption 3 (Integration). *The mode of reasoning is applied to the reduced compound game.*

On the basis of these assumptions, the next two hypotheses spell out the most basic implications of decomposing simple games into a compound game.

Hypothesis 2 (*PC* decomposition). *Decomposing a PC game into pc + pc or bs + bs does not change the frequency of choice of the salient strategy.*

This prediction is driven by assumption 3 on integration, which is critical in *bs + bs*. The modes of reasoning are determined by the pivotal component. Once players realise that pivotal and non-pivotal components reduce to a simple *PC*, players will choose the salient strategy. This is because, applied to the reduced *PC*, both modes of reasoning predict the same level of salient strategy choices.

Hypothesis 3 (*BS* decomposition). *In COMP, decomposing a BS game into bs + pc or pc + bs increases the frequency of choice of the salient strategy. In PART, the frequency of salient choices increases only in pc + bs but not otherwise.*

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[7]Alternatively, one could assume that the reduced game determines the mode of reasoning. However, this would lead to hypotheses that do not distinguish between any compound games derived from the same simple game. Assuming that subjects do not integrate payoffs could be a valid alternative, but would require further assumptions about the determination of the one action to be played in all component games.

In *COMP*, because the first component game is assumed to be more important for the mode of reasoning, a *pc* component 1 leads to more frequent team reasoning and salient choices. A *bs* component 1 leads to more level-*k* reasoning. However, even with a lower probability, the *pc* component 2 can still influence modes of reasoning. For this reason, we expect the frequency of salient strategy choices to be greater than in the simple *BS*. In *PART*, because component 2 does not influence modes of reasoning, a *bs* component 1 implies the same behaviour as in a simple *BS* game.

Hypothesis 4 (BS order). *Decomposing a BS game into bs + pc leads to a lower frequency of choice of the salient strategy than a pc + bs decomposition.*

Compared to *pc + bs*, the *bs* component 1 in *bs + pc* makes team reasoning and thus salient choices less frequent.

Hypothesis 5 (Cartesian games). *In Cartesian games, the salient strategy is chosen in components pc and bs as often as in simple PC and BS games, respectively.*

In Cartesian games, players are not constrained to choose the same strategy in both component games. These games are independent and – under assumption 2 on neutral effects of component game payoffs – predictions in the individual component games *pc* and *bs* are the same as those in the simple *PC* and *BS* games, respectively.

From the perspective of narrow bracketing, the relevance of the components for the mode of reasoning can be viewed as the result of not viewing the compound game as a whole but paying attention to individual components. According to our assumptions, this partial view only influences the choice of mode of reasoning, which is in turn applied to the compound game in its reduced form. Compared to *COMP*, experiment *PART* can be seen as a manipulation that prompts a stronger narrow bracketing effect by displaying the component games one by one.

6 Results

In a battle of the sexes game, whether a simple or a component one, we define player 1 (*P1*) as the player whose payoff is higher in the focal point and player 2 (*P2*) as the other player. For the $bs+bs$ compound game, we let component 1 define *P1*. It follows that *P1* has the lower own-payoff in the focal point equilibrium in the second *bs* component game. The reverse is true for *P2*. We use the same definitions of players in the Cartesian games.

6.1 The simple games

Table 11 shows that the choice frequency of the salient strategy is as expected significantly greater in the *PC* game than in both *BS* games (McNemar test, on pooled *COMP* and *PART* data; $p <$ 0.001 for *PC* vs. *BS* (11, 10), $p <$ 0.001 for *PC* vs. *BS* (12, 9)). In the simple *BS* games, both players choose less often the salient strategy, but the reduction is more pronounced for *P*2.

			BS	
Experiment	Players	*PC*	(11, 10)	(12, 9)
COMP	*All*	0.826	0.630	0.478
	*P*1	–	0.696	0.522
	*P*2	–	0.565	0.435
PART	*All*	0.843	0.608	0.647
	*P*1	–	0.706	0.765
	*P*2	–	0.510	0.529

Table 11: Fractions of salient strategy choices in the simple games *PC* and *BS* by experiment and player type.

Result 1 (Simple Games). *The choice frequency of the salient strategy is greater in PC than in the two BS games.*

6.2 Component game payoff size

In the derivation of the hypotheses, assumption 2 states that behaviour in compound games is not influenced by the specific payoff size of each individual component. This assumption is directly testable in our experiment, which features up to four different payoff decompositions per *BS* game. As the assumption on payoff size is only critical in deriving the hypotheses in compound games with both *pc* and *bs* components, we restrict our analysis to *BS* decompositions.

Table 12 reports the results of a logit regression with clusters at the subject level. The dependent variable is a binary variable that takes value one if the salient strategy is chosen and zero otherwise. The independent variables are the size of the *pc* payoffs ("*pc* payoff"), "Period", "*bs* + *pc*" which takes value one if *bs* is either placed at the top of the screen in *COMP* or displayed first in *PART* and zero otherwise, "*BS* (12, 9)" which takes value one if the compound game reduces to the simple *BS* with payoffs (12,9) in the focal equilibrium and zero otherwise.

We estimate six models: three per experiment. "*All*" considers all the experiment's data, "*P*1" and "*P*2" only player 1 and player 2's data, respectively. The estimated coefficient of "*pc* payoff"

	COMP			PART		
	All	*P1*	*P2*	*All*	*P1*	*P2*
pc payoff	0.031	0.041*	0.021	−0.027*	−0.024	−0.031
	(0.022)	(0.023)	(0.027)	(0.015)	(0.019)	(0.019)
Period	0.003	0.006*	0.001	0.000	0.000	−0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
bs + *pc*	−0.021	−0.015	−0.028	−0.118***	−0.020	−0.215***
	(0.022)	(0.028)	(0.026)	(0.032)	(0.045)	(0.043)
BS (12, 9)	−0.004	0.041	−0.049	0.039	0.069	0.010
	(0.024)	(0.041)	(0.030)	(0.053)	(0.054)	(0.070)
N	736	368	368	816	408	408

Notes: Logit regression with standard errors clustered at the subject level. The variable *pc* payoff is categorised as follows: $1 = (0, 0)$; $2 = (4, 4)$, $3 = (7, 7)$, $4 = (10, 10)$ or $(9, 9)$. Significance levels: $* \, p < 0.10$, $** \, p < 0.05$, and $*** \, p < 0.01$. *N*: Number of observations.

Table 12: The effect of the size of the *pc* payoffs on fractions of salient strategy choices.

is positive and marginally significant in *COMP* for *P*1 and negative and marginally significant in *PART* for *All*. The order of the components is relevant in *PART*, and affects significantly only the behaviour of *P*2; the next section will come back to this result. "Period" of play is weakly significant in *COMP* for *P*1. Overall, these results do not show a systematic influence of the *pc* payoff size and are thus supportive of our modelling assumption 2.

6.3 The compound games

Table 13 reports the proportion of salient strategy choices for all compound game types by experiment and player type. Because our main concern is whether behaviour differs across these four compound game types, we focus on averages without distinguishing whether they reduce to the simple *BS* (12, 9) or to the simple *BS* (11, 10).

PC Decomposition. We expect behaviour in *pc* + *pc* and *bs* + *bs* not to differ from behaviour in the simple *PC* game since we assume integration of the component game payoffs and that team reasoning and level-*k* reasoning both predict a salient choice in *PC*. We find evidence in support of this hypothesis only for the compound game *pc* + *pc* in both experiments (Wilcoxon signed-rank test, $p = 0.783$ in *COMP* and $p = 0.601$ in *PART*).[8] Instead, for the *bs* + *bs* decomposition, we observe in both experiments a statistically significant reduction in salient strategy choices compared to the simple *PC* ($p = 0.064$ in *COMP* and $p < 0.001$ in *PART*).

Result 2 (*PC* decomposition). *In both COMP and PART, the choice frequency of the salient*

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[8]Here and after, unless otherwise stated, all within-subject tests are Wilcoxon signed-rank tests.

| Experiment | Players | PC | | BS | | Simple BS |
		pc + pc	bs + bs	bs + pc	pc + bs	Average
COMP	*All*	0.865	0.743	0.598	0.614	0.554
	P1	–	0.783	0.723	0.728	0.609
	P2	–	0.703	0.473	0.500	0.500
PART	*All*	0.843	0.634	0.581	0.699	0.627
	P1	–	0.778	0.730	0.750	0.735
	P2	–	0.490	0.431	0.647	0.520

Notes: The column "Simple *BS* Average" shows the average fraction of salient strategy choices in $BS(11, 10)$ and $BS(12, 9)$. In a *BS* game, $P1$ is the player whose payoff is higher in the focal point. In $bs + bs$, $P1$ is identified in component 1.

Table 13: Fractions of label salient choices in the compound games by experiment and player type.

strategy is significantly lower in bs + bs than in PC.

This result suggests that players do not fully integrate outcomes, in contrast to assumption 3. In *COMP* however, the fact that the frequency of salient strategy choices in $bs + bs$ is significantly greater than in *BS* ($p = 0.015$ in *COMP* and $p = 0.081$ in *PART*), suggests that something akin to partial integration is occurring. In *PART*, on the other hand, the sequential display seems to prevent any kind of integration.

Note that the lower frequency of salient strategy choices in $bs + bs$ compared to that in the simple *PC* is mainly influenced by the behaviour of $P2$ and to a lesser extent by that of $P1$. This is consistent with the assumption that component 1 has a stronger effect on behaviour than component 2 in both experiments but especially in *PART*. Because $P2s$ have a lower own-payoff in the focal point of component 1, they choose the salient strategy less often than the non-salient one. Specifically, in *PART*, the salient strategy is chosen 49% of the times and this selection is changed in the second bs only about 12% of the times, even when it becomes apparent that the compound game reduces to a simple *PC*. This type of behaviour is compatible with some kind of decision inertia, or behavioural spillovers, but it is also possible that once players are distracted by the conflict of interest in the first bs, attention to label salience is lost when the second bs is unveiled. This result is consistent with narrow bracketing.

BS Decomposition. Table 13 shows that in *COMP* the mere decomposition of a *BS* into a compound game featuring a pc component does lead to an increase, albeit not significant, in the choice frequency of the salient strategy compared to the simple *BS* ($p = 0.305$ for $bs + pc$ vs. *BS*, and $p = 0.191$ for $pc + bs$ vs. *BS*). In *PART*, only in $pc + bs$ subjects choose this strategy more frequently than in *BS* ($p = 0.014$). In the $bs + pc$ decomposition this strategy is, in fact, chosen less often ($p = 0.055$).

Result 3 (*BS* Decomposition). *In COMP, the BS decomposition does not have a significant effect on the frequency of salient strategy choices compared to a simple BS. In PART instead, we do find that this frequency increases in the pc + bs decomposition and decreases in the bs + pc one.*

The *BS* decomposition in *COMP* does not have the hypothesised significant effect of highlighting the common interests in coordination via the *pc* component. For this decomposition to be effective, *PART*'s stronger emphasis of the component 1 is needed. An implication of this finding, consistent with the literature on focal points, is that the mere information, as in *COMP*, on the presence of a *bs* component influences behaviour more than the knowledge of the presence of a *pc* component. In *PART*'s *pc + bs*, subjects' stronger exposition to the *pc* component makes their behaviour more in line with simple *PC* games.

BS Order. Hypothesis 4 states that, the order in which component games are presented, influences how often the salient strategy is chosen. We do find that this is indeed the case in both experiments, but the effect is statistically significant only in *PART* (*pc + bs* vs. *bs + pc*, $p = 0.694$ in *COMP* and $p < 0.001$ in *PART*).

Result 4 (*BS* Order). *In PART, decomposing a BS game into bs + pc leads to a lower choice frequency of salient strategy than it does in pc + bs. No difference is observed in COMP.*

The difference in salient strategy choices between *bs + pc* and *pc + bs* is mainly driven by the behaviour of subjects in the role of *P2*. *P2*s choose the salient strategy only 43% of the times when the *bs* component is played before the *pc* one. Instead, they choose it significantly more when *bs* is displayed afterwards (*pc + bs* vs. *bs + pc*, $p = 0.539$ for *P1*, $p < 0.001$ for *P2*).

6.4   First component game analysis

Some further insights into the reasoning process in compound games can be gained from the first component game choices in experiment *PART*. Table 14 reports the proportion of compound game choices that differ from the first task choice. This information illustrates the circumstances under which subjects switch their strategy between the first component game and the overall compound game.

Three regularities are noteworthy. First, there is – as expected – little switching in the *pc + pc* compound games. Second, compound games with a first *bs* component game feature low levels of switching. The analysis by player shows that the predominant direction of switches differs between players. This therefore illustrates why the coordination success is low in these compound games. Given that the player identities derive from the *bs* component game, this is the likely source of miscoordination. Finally, the last column shows high levels of switches in the *pc + bs* game to the non-salient strategy. Out of all players choosing the non-salient strategy in this compound

Strategy switch	Players	PC		BS	
Component 1 → Compound game		*pc + pc*	*bs + bs*	*bs + pc*	*pc + bs*
Non-salient → <u>Salient</u>	*All*	0.023	0.134	0.059	0.081
	P1	–	0.034	0.020	0.085
	P2	–	0.293	0.125	0.076
<u>Salient</u> → Non-salient	*All*	0.021	0.098	0.076	0.593
	P1	–	0.294	0.200	0.392
	P2	–	0.013	0.017	0.736

Notes: In a *BS* game, *P1* is the player whose payoff is higher in the focal point. In *bs + bs*, *P1* is identified in component 1.

Table 14: Proportion of strategy switches out of all choices of the indicated compound game strategy.

game, 59.3% did so by switching away from the salient strategy in the first *pc* component game. Overall, switches are in the direction of the non-salient strategy to such an extent that the choice distributions between component 1 and compound game are significantly different ($p < 0.001$). This evidence testifies to the fragility of salient choices once misaligned interests appear in the *bs* component 2. As expected, this tendency is most pronounced for players 2 (73.6%), who are disfavoured by the salient strategy in *bs*.

Experiment *PART* implements both Cartesian and compound games in order to make decisions in the first component stochastically binding. Subjects should treat the first component of a compound game as the first component of a Cartesian game in which the strategy selected, unlike in compound games, cannot be changed when subjects face the second component. As evidenced by Table 15, the proportions of salient strategy choice in both compound and Cartesian games are very similar and their difference is not statistically significant. This provides evidence that our experimental manipulation was successful and that subjects treated choices in the first component as binding.

First Component	Compound Games		Cartesian games	
	P1	*P2*	*P1*	*P2*
bs	0.79	0.37	0.77	0.40
pc	0.80	0.84	0.84	0.83

Table 15: Proportion of salient strategy in the first component in *PART*.

6.5 The Cartesian games

Table 16 reports proportions of salient strategy choices in Cartesian games by game type and component. These games feature only in *PART* and differ from compound games in that players' actions are not constrained.

Both components of the Cartesian game $pc \times pc$ show choice frequencies of salient strategies above 80%. In line with our predictions, these frequencies are not significantly different from those observed in the simple *PC* game ($p = 0.104$ and $p = 0.724$ for *PC* vs. $pc1$ and $pc2$ respectively). Similarly, the choice frequency in each individual component of $bs \times bs$ is not statistically different from the average frequency observed in the simple *BS* games ($p = 0.694$ and $p = 0.963$ for average *BS* vs. $bs1$ and $bs2$ respectively). These results are also supportive of assumption 2 on the component game payoffs.

Players	$pc \times pc$		$bs \times bs$		$pc \times bs$		$bs \times pc$	
	$pc1$	$pc2$	$bs1$	$bs2$	$pc1$	$bs2$	$bs1$	$pc2$
All	0.807	0.846	0.578	0.598	0.853	0.603	0.591	0.716
P1	–	–	0.791	0.464	0.868	0.779	0.750	0.804
P2	–	–	0.366	0.732	0.838	0.426	0.431	0.627

Notes: $pc1$ and $bs1$ are the component games displayed first; $pc2$ and $bs2$ are the component games displayed after.

Table 16: Proportion of salient strategy choices in Cartesian games by component game and player.

In both Cartesian games $pc \times bs$ and $bs \times pc$, subjects choose significantly more often the salient strategy in the pc component than in the bs one ($p < 0.001$). In addition, the choice frequency in pc is significantly greater in $pc \times bs$ than in $bs \times pc$ ($p < 0.001$). This difference is mainly driven by *P2*'s behaviour. When the pc component is displayed before the bs one, *P2*s choose the salient strategy 83.8% of the times. When the pc component is displayed after the bs one, the choice frequency drops to 62.7% ($p < 0.001$). As a consequence, the choice frequency in the pc component is significantly different from that in the simple *PC* if the pc component is displayed after the bs one but not vice versa ($p < 0.001$ for $pc2$ vs. *PC* in $pc \times bs$ and $p = 0.233$ for $pc1$ vs. *PC* in games and $bs \times pc$).

For both Cartesian games $pc \times bs$ and $bs \times pc$, salient strategy choices in the bs component are not significantly influenced by the displaying sequence ($p = 0.491$). Moreover, in line with our predictions, the salient strategy in these components is chosen as frequently as in both *BS* games ($p = 0.285$ for $bs1$ vs. *BS* and $p = 0.963$ for $bs2$ vs. *BS*).

Result 5 (Cartesian games)**.** *The salient strategy is chosen as often in bs games as it is in the simple BS games. In pc games the salient strategy is chosen as often as in the simple PC games*

only when it is not displayed after a bs component.

6.6   Relevance of compound and Cartesian games

The results of our first application of compound games provide evidence of their relevance in understanding behaviour. In particular, our experiment shows that game decompositions lead to differences in behaviour that are influenced not only by whether the component games are independent, as in Cartesian games, or linked, as in compound games, but also by the order in which they are displayed.

Cartesian games provide evidence of stronger behavioural spillovers from a *bs* component to a *pc* than from a *pc* to a *bs* one. This suggests that behaviour consistent with level-*k* reasoning is more persistent than behaviour compatible with team reasoning. In other words, in this instance, the collective mode of reasoning is more fragile than the individualistic one and hinders possible learning transfers from the *pc* component to the *bs* one.

Compound games provide evidence of narrow bracketing in that a decomposition of a *PC* into a *bs* + *bs* game leads to a decrease in salient strategy choices compared to a *pc* + *pc* decomposition. Although the two *bs* components reduce to a simple *PC*, once opposed motives are highlighted by the first *bs* component, they cannot be reconciled by the second *bs* component. Although, theoretically, players' interests in a *bs* + *bs* compound game are aligned, behaviourally that game is closer to a battle of the sexes game, seemingly because outcome integration is only partially carried out. The sequential component display implemented in *PART* is not necessary for this decomposition to alter behaviour, because this alteration is, to a lesser extent, also observed in *COMP*.

Finally, our experiment shows that the sequential display implemented in *PART* increases the influence of component 1 on behaviour at the expense of component 2, as if, once subjects engage in the type of reasoning triggered by that first component, that reasoning or behaviour cannot be forgotten but spills over to the second component.

7   Discussion

The *BS* compound games in our study are examples of decompositions *by motive*. These compound games can be formal representations of verbalised motives and can thus reflect the framing of a *BS*-type strategic interaction or of complex negotiations better than simple games. As such, they can be language-independent tools that could be employed to study, for example, cross-cultural differences in games and motives.

An advantage of this formal representation is its scrutiny of the relationship between games and

their verbal account. For example, the separation of a *BS* game into two motives clarifies the verbal description's failure to motivate the zero payoffs off the diagonal. For a complete verbalisation of the *BS* normal form game, a third sentence and component should reflect that "all music turns equally unenjoyable when consumed alone" as the preference for a composer is fundamentally independent of the other's action (see table 17).

$$
\begin{array}{c|cc}
 & B & S \\
\hline
B & 11,10 & 0,0 \\
S & 0,0 & 10,11 \\
\end{array}
=
\begin{array}{c|cc}
 & B & S \\
\hline
B & 4,4 & 0,0 \\
S & 0,0 & 4,4 \\
\end{array}
+
\begin{array}{c|cc}
 & B & S \\
\hline
B & 7,6 & 7,7 \\
S & 6,6 & 6,7 \\
\end{array}
+
\begin{array}{c|cc}
 & B & S \\
\hline
B & 0,0 & -7,-7 \\
S & -6,-6 & 0,0 \\
\end{array}
$$

Table 17: Decomposition of *BS* game into three components.

To the extent that they are representations of motives, compound games become useful diagnostic tools to assess the empirical strength of a motive. If, for example, the behaviour in simple and associated compound games is different, the required payoff change in one component to equate behaviour in the simple and the compound game is informative about the relative strength attributed to the motives in the original simple game.

Decompositions by motive could lead to the definition of a finite set of behaviourally elementary component games. These component games would be irreducible to more elementary cognitive motives, lead to shortest possible verbalisations, possibly invoke specific types of reasoning as do *pc* and *bs*, and might simplify the game comprehension despite the presence of multiple components. Beyond a set of motives, it is not difficult to think of decomposing games by player, by strategies, by cell, or even randomly. All these decompositions could lead to further interesting applications.

As one example, consider the compound Prisoner's Dilemma game in table 18. This decomposition is not by motive but *by cell* and isolates two elementary *PD* components: the Hi-Lo (*hl*) component that identifies the benefits from cooperation and the off-diagonal *bs* component that identifies the "temptation" from defection. Would such a decomposition increase cooperation?

$$
\begin{array}{c|cc}
 & \text{Cooperate} & \text{Defect} \\
\hline
\text{Cooperate} & 4,4 & 1,5 \\
\text{Defect} & 5,1 & 2,2 \\
\end{array}
=
\begin{array}{c|cc}
 & C & D \\
\hline
C & 4,4 & 0,0 \\
D & 0,0 & 2,2 \\
\end{array}
+
\begin{array}{c|cc}
 & C & D \\
\hline
C & 0,0 & 1,5 \\
D & 5,1 & 0,0 \\
\end{array}
$$

Table 18: Decomposition of *PD* into *hl* + *bs*.

The comparison of a simple game and an associated compound game is independent of utility specifications because the payoff consequences of the compound game are identical to the ones of the simple game. Only when the payoff integration is incomplete, the precise utility functions – be they classic or reference-dependent – and the kind of utility aggregation become relevant.

Investigating the drivers of the behavioural differences between simple and compound games is beyond the scope of this paper. Other than the mechanism we assume here via the classes of the component games and the ensuing mode of reasoning, complexity and beliefs might play a role. A game's complexity might derive from the number of component games as well as the payoff transparency in a non-trivial way. Game decompositions that transparently expose all strategic incentives of the simple game might make the compound game easier to understand and therefore less complex. Conversely, non-transparent payoffs of, say, a random decomposition into two components, might impede the perception and understanding of the simple game. In this case, the extent of narrow bracketing can even be reduced if the player sees the integration of payoffs as a useful decision-making aid. In terms of beliefs, compound games might affect behaviour both directly through their framing and indirectly through players' beliefs about the effect of the frame on another player's behaviour. To deepen our understanding of behaviour in compound games, the role of complexity and beliefs deserves further investigation.

In contrast to Cartesian games, important properties of component games such as dominance-solvability and Nash equilibria do not necessarily find analogues in the reduced form of a compound game. Take the decomposition of a Hi-Lo coordination game in table 19. Iterated deletion of dominated strategies leads to the same strategy pair (A, A) in both component games, but is not applicable in the reduced game. In compound games, the defining requirement to play the same strategy across components allows players to exchange binding commitments to strategy B, despite it being a dominated strategy for each player in one component game.[9]

	A	B			A	B			A	B
A	4, 4	0, 0	=	A	2, 2	0, 0	+	A	2, 2	0, 0
B	0, 0	5, 5		B	0, 0	-1, 6		B	0, 0	6, -1

Table 19: Decomposition of *HL*.

We do not implement standard Cartesian games in *COMP* as our objective is to investigate the behavioural relevance of compound games. Cartesian games are instrumental to the achievement of this objective in *PART*. However, our results show that, in fact, these games offer some unique insights into behaviour that are complementary to those offered by compound games. As such, they should be object of further investigations either on their own or in conjunction with compound games.

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[9]We are indebted to Bob Sugden for these considerations.

8 Conclusion

The goal of this paper was to introduce the concept of compound game and – with an application informed by the literature on focal points – to investigate whether these games are behaviourally meaningful. We find that salient choices are more frequent in a *PC* game than in its *bs + bs* compound game and that separating a *pc* component in a *BS* game is effective only when the *pc* component is displayed first. Furthermore, our results suggest that, for the decompositions we employ, heuristics such as narrow bracketing and behavioural spillovers can help rationalise observed behaviour.

We believe that the theoretical and experimental framework developed in this paper can be further expanded to study behaviour in different contexts, to provide a formal analysis of verbal descriptions of simple games, and to encompass different kinds of decompositions.

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A   Appendices

A.1   Experimental instructions

Below are the instructions for both experiments *COMP* and *PART*. The paragraphs that are experiment specific are enclosed in square brackets, written in italics and preceded by the experiment in which they appear.

Introduction

This is an experiment in the economics of decision-making. If you follow the instructions and make appropriate decisions, you can earn an appreciable amount of money. You will receive your earnings for today's session in cash before you leave the laboratory.

It is important that you remain silent and do not look at other people's work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your cooperation.

We will now describe the session in more detail. Please follow along with these instructions as they are read aloud.

Everyone in the room is receiving exactly the same instructions.

Only experiment *COMP*:

[You will be presented with thirty (30) different scenarios, one

after the other. Each scenario is an interaction between you and an other person. Everyone in the room will make decisions in the same 30 scenarios.]

Only experiment *PART*:

[You will be presented with thirty-one (31) different scenarios, one after the other. Each scenario is an interaction between you and an other person. Everyone in the room will make decisions in the same 31 scenarios.]

At the end of the experiment, the computer will randomly pair you with an other person in the room and one of the scenarios will be randomly selected. The decisions that you and the other person have made in this scenario determine how much money each of you will be paid. Because you will not know which scenario will be selected until you have made decisions in all of them, you should treat each scenario as if it was the selected one. So, when thinking about each scenario, remember that it could be the selected one and think about it in isolation from the others. Your total earnings for the session will be given by the earnings from the selected scenario, plus a € 4 participation payment.

The scenarios

In each scenario you will face either one or two allocation tasks. Only experiment *PART*: *[You will only discover after you face the first task whether there is going to be a second one.]*

Scenarios with one task In the scenario with one task you and the other person will be asked to choose between two options, such as the ones shown in Figure 1, by clicking on the button "Choose this option" next to it. The options are the same for you and the other person.

Figure 3: The Scenario with One Task

Options describe allocations of money between you and the other person. One option will always be underlined while the other one will not be underlined. Options will be identified in the same way for both you and the other person. Consider Figure 1 as an example, if

in your non-underlined option, you receive € c and the other person receives € d, in the non-underlined option of the other person, you also receive € c and the other person receives € d. The same holds true for the underlined option. So, options that are highlighted in the same way for you and the other person will also report identical allocations between you and the other person.

It might happen that options feature identical allocations.

<u>You receive € a and the other receives € a</u>
You receive € a and the other receives € a

We will say that the two options however are different because one is underlined and the other one is not.

While options are uniquely identified for both you and the other person, their relative position (i.e. whether they are at the top or at the bottom) is randomly decided by the computer in every scenario. Some participants will have the underlined option at the top and some at the bottom in some scenarios, and the opposite in some others.

If you and the other person both choose the same option we will say that there is a match.

If you and the other person choose different options, we will say that there is a mismatch.

After you have made your choice, click on the button "OK" to proceed to the next scenario.

Scenario with two linked tasks

Task 1 in this scenario looks exactly the same as that of the scenario with only one task (Figure 1). However, after you click on the button "OK" in task 1, you and the other person with will be presented with a second linked task (Figure 2).

Figure 4: The Scenario with Linked Tasks

In these scenarios, you and the other person will be asked to choose one option from each task.

Let us call twins those options that, in both tasks, are either non-underlined or underlined. In scenarios with linked tasks, you both

will have to choose twins. You cannot choose, for example, the underlined option in task 1 and the non-underlined option in task 2. If you do not choose twins you will not be able to proceed to the next scenario. If you were to click on the "OK" button despite this, a pop-up dialog box will appear (see Figure 3).

Notice that the term twins identifies your options in both tasks and is different from the term match. There is a match, in both tasks, only if you and the other person choose the same twins (you both choose the underlined options or you both choose the non-underlined options) and a mismatch, in both tasks, if you and other person choose different twins (you choose the underlined twins and the other chooses the non-underlined twins, or vice-versa).
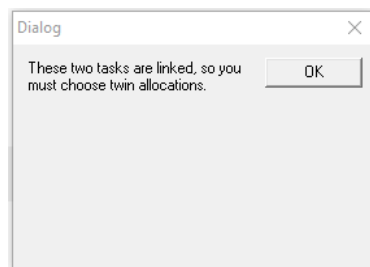
Figure 5: Not Choosing Twin Allocation in the Linked Tasks Scenario

Only experiment *COMP*:

[Given that decisions in both tasks are linked, you will be allowed to change the option you selected in both tasks before you click on the "OK" button. Once you leave a scenario, you will not be able to go back to it to modify your choices. So, click on the "OK" button only when you are sure those are the options you want to choose.]

Only experiment *PART*:

[Given that decisions in both tasks are linked, you will be allowed to change the option you selected in the first task when you are presented with the second one. Once you have chosen your preferred twin options, click on the "OK" button to proceed to the next scenario.]

Only experiment *PART*:

*[**Scenarios with two unlinked tasks***

Task 1 in this scenario looks exactly the same as that in the scenario with only one task (Figure 1) and in the scenario with linked tasks (Figure 2). After you click on the "OK" button in task 1, you and the other person will be presented with a second unlinked task (Figure 4).

In these scenarios, you and the other person will be asked to choose one option from each task.

The two tasks are unlinked in that your decision in the second task is independent of your decision in the first task. That is, you can choose whichever option you prefer in the second task independently of which option you have chosen in the first task.

Given that decisions in both tasks are unlinked, you will NOT be able to change the option you selected in the first task, once you are presented with the second one.

Once you have chosen your preferred options, click on the "OK"

Figure 6: The Scenario with Unlinked Tasks

button to proceed to the next scenario. Once you leave a scenario, you will not be able to go back to it to modify your choices. So, click on the "OK" button only when you are sure that those are the options you want to choose.

What you will know about the scenarios

Each scenario will have at least one task and some will have two tasks. You will only know whether the scenario involves two tasks after you have made your decision in the first task. Then, if the scenario has two tasks, you will also be told whether the tasks are

linked or unlinked. Given the limited amount of information you have on the type of scenario, you should always choose in the first task as if your decision was final, as you might not be able to change it if the scenario involves only one task or unlinked tasks.]

Earnings

When you have finished all 31 scenarios, you will be told which of them was selected to determine your earnings. The decisions you and the other person made in that scenario will determine how much each of you will be paid. You will not be able to change your choices at this stage.

The rules that determine your earnings in each task of that scenario are:

o If there is a match you earn the amount(s) reported in the option(s). o If there is a mismatch you earn nothing.

In the scenarios with unlinked tasks, if there is a match in one task and a mismatch in the other task, each of you will only earn the amount reported in the matched allocations and nothing in the other. In the scenarios with linked tasks instead there will be either a match or a mismatch in both tasks, as in those scenarios you can only choose twins. If there is a match each of you will earn the sum of the amounts reported in the chosen allocations in both tasks. If there is a mismatch each of you will earn nothing.