Strategic Thinking: The Influence of the Game*

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In order to assess the extent to which features of a game affect the strategic sophistication of the people involved, this study investigates the relevance of differing objectives (matching/mismatching) and of virtually moving first or second in the "hide and seek" game. In three different treatments, mismatchers and matchers are not found to exhibit significantly different levels of reasoning although level averages and winning probabilities always are in favor of the matchers. Varying the virtual timing of the game has a significant impact on the shape of the level distribution. The analysis relies on intrateam communication, whose coding is shown to be stable and replicable.

Keywords: Level of reasoning, task dependence, virtual observability

JEL Classification: C91, D83

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1. Introduction

Hide and seek games are zero-sum two-player games in which some players win by matching and others by mismatching their opponents' action. Such games cleanly reflect the essential strategic features of many economic settings in which one side gains by differentiating itself from others' products, ideas, opinions etc. and the other side gains by imitating them. These situations have been among the first ones for which game theory provided clear-cut predictions (Von Neumann, 1928).

When the possible actions are framed non-neutrally as in most applications, the equilibrium predictions have found little support in experimental investigations by Rubinstein and Tversky (1993) and Rubinstein, Tversky, and Heller (1996, henceforth RT and RTH). These studies implement a hide and seek game in which hiders hide a treasure in one of four locations, labelled "ABAA".[1] Seekers can look for it in one location, whoever holds the treasure at the end wins a prize. RTH observe that the seekers can expect to find the treasure in 32% of the attempts, more often than in equilibrium.

These hide and seek games reflect situations that are rarely of a repetitive structure and are thus usually played as one-shot games. For such situations, the level-k model has been established as a model of strategic thinking by Nagel (1995) and Stahl and Wilson (1995) and has subsequently found considerable empirical support (Costa-Gomes, Crawford, and Broseta, 2001; Camerer, Ho, and Chong, 2004; Costa-Gomes and Crawford, 2006). Bacharach and Stahl (1997; 2000) and Crawford and Iriberri (2007, henceforth CI) were the first to apply the level-k model to games with non-neutral framing.

These models as well as the one proposed here assume heterogeneous types that differ in the number of applied iterated best responses, the level of reasoning k. Level-k players base these best responses on a belief about the actions of a level-0 player that is assumed to play non-strategically. Hence, level-1 players play one best response to what they believe a level-0 player does. Level-2 players best respond to level-1 play, and so on for higher levels. Bacharach and Stahl and CI incorporate the non-neutral framing of the hide and seek games by assuming the level-0 action distribution to reflect the salience of the action labels, e.g. assuming the B to be more frequently played than any A.

The experimental literature has identified various factors that influence strategic reasoning. Education and IQ explain differences in average level of reasoning

[1]In the following they will for clarity be referred to as A_1, B, A_3, and A_4 or by the indices 1234 in some histograms.

across subject populations (Camerer, Ho, and Chong, 2004; Burnham, Cesarini, Johannesson, Lichtenstein, and Wallace, 2009). Likewise, the expected strategic sophistication of opponents is known to influence the strategic reasoning (Agranov, Potamites, Schotter, and Tergiman, 2012). The fact that the difficulty or transparency of a game has an influence on the level-k distribution is folk wisdom but this influence has never been systematically identified. For example, Arad and Rubinstein (2012) observe significantly different distributions in two versions of the money request game. Shapiro, Shi, and Zillante (2014) observe significant differences across versions of "generalized beauty contest" games that add a state-matching motive. Van Elten and Penczynski (2015) find significantly different behavior and level distributions between payoff-symmetric and -asymmetric coordination games. In the survey article by Crawford, Costa-Gomes, and Iriberri (2013, p. 25), the authors identify "the learning about [...] the variation of behavioral parameters across settings and populations" as one of the main outstanding goals in the strategic thinking literature.

Like RTH, Eliaz and Rubinstein (2011) observe an advantage of matchers ("guessers") in terms of the winning probability in a repeated matching pennies game. My study investigates whether the strategic sophistication indeed depends on differences in players' objective or on the virtual timing of the decisions. On the former, I study whether a small and well-defined difference between strategic situations can introduce a significant difference in the average level-k distribution. The hide and seek game is very useful to do this. The randomly allocated hiders and seekers come from the same subject population, get the same instructions, attend the experiment at the same time and face a similar setting, they solely differ in the objective of matching or *mis*matching the opponent's choice. Another advantage of the game is that players' objectives can be reversed by simply exchanging the good for a bad, that is, the "treasure" for a "mine". In contrast to the treasure treatment, RTH indeed observe the hiders to be more successful in the mine treatment, winning in 28% of the cases. Beyond the level of reasoning, the data in this study will illuminate the effects of differing tasks and framing on the level-0 beliefs of players.

Apart from objectives, players furthermore differ in their position in the sequence of events. While these games are usually represented as simultaneous normal-form games, the physical realization of a typical hide and seek situation involves sequential choices, leading to an extensive-form game in which hiders first hide an item and seekers then seek without observing the hiders' choice. Weber, Camerer, and Knez (2004) discuss and find evidence of "virtual observability", the effect found in various studies that timing matters and subgame perfect equilibria are coordinated on even when previous actions are not observable (Cooper, DeJong, Forsythe, and Ross, 1993; Rapoport, 1997). In the third novel treatment named "secret", I investigate a switch in the virtual timing by having the hider hide a secret from the seeker's wiretap. The seeker has the possibility to wiretap one of four rooms labelled "ABAA". The hider discusses a secret in one of those rooms. Now the seeker moves first and is "virtually observable".

One reason for the limited knowledge about the determinants of strategic thinking is the difficulty to observe strategic thinking and the fact that only specific strategic situations like the beauty contest game (Nagel, 1995; Costa-Gomes and Crawford, 2006) or the money request game (Arad and Rubinstein, 2012) are informative about the level of reasoning under reasonably few assumptions. In order to obtain information about subjects' reasoning in addition to choice data, this study applies an experimental design which has been introduced by Burchardi and Penczynski (2014). It features a communication protocol that yields written accounts of individual reasoning from incentivized intrateam communication. In particular, teams of 2 players are playing as one entity. Each team member can initially send a "suggested decision" and a justifying "message" to her team partner in order to communicate her arguments. She has an incentive to do so because both players give – again individually – a "final decision" after the *simultaneous* exchange of their messages. One of those is chosen randomly by the computer to be the "team's action."

The communication transcripts are classified by two research assistants along the lines of a general level-k model. This classification provides information on individuals' level of reasoning and on the impact of the framing on the level-0 beliefs that is subsequently used in the estimation of the model's parameters.

Across treatments, I find that matchers (seekers in treasure and secret, hiders in mine) and mismatchers (hiders in treasure and secret, seekers in mine) do not statistically differ in terms of their average level of reasoning. Although the observed differences are consistently in favor of the matchers, their magnitude is small compared to differences between games observed in the literature.

Significant differences in the shape of the level-k distribution, however, are observed. They are mostly attributable to the sequence of events because the change in the timing in the secret treatment reverses them. In particular, it turns out that second movers (seekers in treasure and hiders in secret) exhibit more level-2 than level-1 reasoning, while first movers in these treatments exhibit more level-1 than level-2 reasoning. This pattern points to a certain ease of starting thinking about the second mover, resulting in cognition that shares similarities with backward induction and that can explain the "virtual observability" results.

The communication data further reveals that the level-0 beliefs are mostly shaped by the salience of the B. They can differ by the role of the subject that is thought about. In the treasure treatment, hiders are believed to shy away from the B while seekers are believed to be attracted by it.

Overall, I view these results as interesting first insights in how the situation may influence the strategic reasoning, made possible by the method of intrateam communication. In future research, it should be feasible to relate the cognition of decision makers to other features of the game, like asymmetry, uncertainty, or rule complexity.

The paper is organized as follows. Section 2 introduces the level-k model in the context of non-neutral framing. Section 3 presents the experimental design and the classification procedure, before section 4 gives the results that follow immediately from the classification. Finally, section 5 describes the estimation procedure and gives the resulting findings before the discussion and conclusion in sections 6 and 7 complete the paper.

2. A level-k model

I will now outline a level-k model that builds on and generalizes the model by CI. The characteristic feature of level-k models is that players differ in their level of reasoning, that is, in the number $k \in \mathbb{N}$ of iterated best responses they apply to their belief of what level-0 players do. Whether a player is hider or seeker is denoted by its role $t \in \{h, s\}$. The probability of a player being level-k is denoted π_k^t.

The framing of the strategic situation is reflected in the level-0 belief, the belief that level-k, $k > 0$, have about the actions of level-0. In particular, the perception of the action space is reflected in frames f as introduced in Bacharach (1993). As in CI, I will focus on the salience of i) the 'B' vs. the 'A's as well as ii) the endpoints vs. the central points. The B-frame, distinguishing A's and B's, yields a partition of the action space $P_B = \{\{B\}, \{A_1 A_3 A_4\}\}$. A level-0 player *favoring* the salient B is reflected by the probability of choosing the cell $\{B\}$, $q > 1/4$, and vice versa. The E-frame, distinguishing end vs. central points

Player's k	Level-0 role	Action a			
		A_1	B	A_3	A_4
0	s	$q < 1/4$	$\mathbf{q > 1/4}$	$q < 1/4$	$q < 1/4$
1	h	$q < 1/4$	$\mathbf{q > 1/4}$	$q < 1/4$	$q < 1/4$
2	s	$\mathbf{q > 1/4}$	$q < 1/4$	$\mathbf{q > 1/4}$	$\mathbf{q > 1/4}$
3	h	$\mathbf{q > 1/4}$	$q < 1/4$	$\mathbf{q > 1/4}$	$\mathbf{q > 1/4}$
4	s	$q < 1/4$	$\mathbf{q > 1/4}$	$q < 1/4$	$q < 1/4$

(a) Seeker with a B-frame.

Player's k	Level-0 role	Action a			
		A_1	B	A_3	A_4
0	h	$\mathbf{p > 1/2}$	$p < 1/2$	$p < 1/2$	$\mathbf{p > 1/2}$
1	s	$p < 1/2$	$\mathbf{p > 1/2}$	$\mathbf{p > 1/2}$	$p < 1/2$
2	h	$p < 1/2$	$\mathbf{p > 1/2}$	$\mathbf{p > 1/2}$	$p < 1/2$
3	s	$\mathbf{p > 1/2}$	$p < 1/2$	$p < 1/2$	$\mathbf{p > 1/2}$
4	h	$\mathbf{p > 1/2}$	$p < 1/2$	$p < 1/2$	$\mathbf{p > 1/2}$

(b) Hider with an E-frame.

Table 1: Examples for ranges of the level-0 belief parameters depending on k and a (salience in bold).

yields a partition $P_E = \{\{A_1A_4\}, \{BA_3\}\}$. A level-0 player *favoring* the salient endpoints is reflected by the probability of choosing the endpoint cell $\{A_1, A_4\}$, $p > 1/2$, and vice versa.

CI favor a role-symmetric level-0 belief while Bacharach and Stahl (1997) model an asymmetric level-0 belief. In my model, this is left open as the data shall indicate the influence of the role on the level-0 actions and beliefs. The frame will be mostly observable in the experiment from the messages. For each level of reasoning k, the level-0 belief magnitudes $q \gtrless 1/4$ or $p \gtrless 1/2$ follow from the action played a and the role t of the player. Tables 1a and 1b illustrate this dependency.

The level k, the frame f and the action a determine whether the level-0 belief is favoring (>) or avoiding (<) salience. For example, a level-2 seeker with a B-frame that plays A_1 has a level-0 belief about a seeker that favors salience. Specifically, she matches (best responds to) a hider who chooses a location other than the B because this hider mismatches (best responds to) a seeker that favors the B.

Note that, the level k and the player's role t determine whether the level-0 player in mind is hider or seeker (column 2). A best response is always applied by a player of one role with respect to the action of the player of the other role.

Therefore, an even-leveled player, $k = 2, 4, 6, \ldots$, has a level-0 belief about a player of her role, and vice versa for odd-leveled players, $k = 1, 3, 5, \ldots$.

3. Experiment procedures

Three treatments were conducted with mainly undergraduate students in the laboratories of the Departments of Economics in Royal Holloway (University of London) and the University of Mannheim. 114 subjects participated in the treasure treatment in Royal Holloway and 110/112 subjects participated in the mine/secret treatments at the University of Mannheim. The participants were mainly undergraduate students. In Royal Holloway, the participants of the experiment were paid a show-up fee of £5. After the first round, three further rounds of hide and seek were played that are not analyzed here.[2] For one randomly chosen round, the winning team won a prize of £10 (£5 per team player). In Mannheim, one round was played and the winning team won a prize of €12 (€6 per team player).

The treasure and mine treatments are identical to the original games played in RT. The hider has to hide a treasure/mine in one of four locations, winning a prize in case the seeker does not find the treasure or does find the mine. The seeker wins otherwise. The secret treatment is structurally the same as the treasure treatment with a different "virtual" timing: The seeker seeks a secret by wiretapping one of four rooms. In order to hide a secret, the hider tries to choose a meeting room that is not wiretapped. While the two choices are made simultaneously, the important difference to the treasure treatment is that the seeker has to move before the hider in any realization of the story. Throughout all treatments, the four locations are labeled "ABAA".

3.1. Communication protocol

Participants were randomly assigned into teams of 2 players. The two members were connected through the chat module of the experiment software.[3] After the explanation of the rules of the game and the indication of being either a hider-

[2]In some sessions, the hide and seek treatments were preceded by beauty contest games that are analyzed in Burchardi and Penczynski (2014). The level estimates of these two games can therefore not be compared. However, the main focus of this paper is on the differences between hiders and seekers.

[3]The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

or seeker-team, each team member could state a so-called suggested decision and justify it in a written message. Once both team members finished entering their message, the suggested decisions and the messages were simultaneously exchanged. Since it was only possible to send one single message that was not limited in length, the communication was undertaken without any prior influence from the team partner, thereby reflecting individual reasoning.

In a next step, both team members individually state their final decision, knowing both the suggested decision and the message of the team partner. It was known that one of the two final decisions would be chosen randomly by the computer to count as the team's action. This design provides incentives to state the full reasoning underlying the suggested decision in a clear and convincing way. Since this paper considers individual reasoning and no team interaction, the analysis will make use of the suggested decision and the message only.[4]

At the start of the experiment, participants were made familiar with the structure of the experiment and the messaging system. Two practice rounds used the exact same software as the later game, but asked the teams to find the years of two historic events.

3.2. Classification of communication transcripts

In order to make use of the communication transcripts in a rigorous way, two PhD students classified the messages with respect to the following parameters of a general level-k model.

Due to the ambiguity of common language, one cannot expect a precise identification of the level of reasoning from the communication. In order to cautiously extract as much information as possible from the messages, I asked the RAs to state a lower bound and an upper bound for the level of reasoning. The lower bound was defined to be the lowest level of reasoning that the statement clearly exhibits, in the sense that any lower level could be excluded on the basis of the verbalized best responses. The upper bound gives the maximum level of reasoning that could possibly be interpreted into the statement. These definitions were chosen in order to exclude only levels that were either clearly surpassed or that were surely not stated in the message.

The level-0 belief characterizes the starting point of the argument of the player.

[4] Using the final decision data, the team interaction and persuasion is analyzed in Penczynski (2012). Players with a relative higher level of reasoning than their partner are more likely to stick to their suggested decision while the partners are more likely to adapt their partner's suggested decision.

The classification can uncover the frame by observing the location that the player thinks is favored by the level-0 player she has in mind. The classifiers were asked to give a ranking over the four locations using a "more attractive than" relation $>$, which represents ordinally how likely a location is described to be chosen by the level-0 player. A B-frame as in examples 2 and 4 below would be coded as $\{B\} > \{A_1, A_3, A_4\}$ or $\{A_1, A_3, A_4\} > \{B\}$, depending on whether $q \gtrless 1/4$. While the frame is a level-independent perception of the action space, in the level-k model $q \gtrless 1/4$ changes with the level (see table 1). Hence, I will only be able to investigate attitudes to salience once the levels are estimated in section 5.[5]

The final parameter of interest is an indicator for equilibrium play which distinguishes randomness due to on the one side level-0 play and on the other side equilibrium play. Assuming that one major difference between these two types is that the latter has good reasons for random play, the classifiers are asked to indicate equilibrium play when the player gives good arguments for random play, for example, by mentioning that any location is a best response to random play. I instructed the RAs to indicate further reasoning characteristics in the form of optional comments.

The RAs' instructions were self-contained and not complemented by verbal comments.[6] The two RAs individually classified the messages. The reconciliation procedures were slightly different in the London and Mannheim sessions. In London, the reconciliation involved the two RAs meeting personally, producing a classification that both agreed upon. In Mannheim, the individual classifications were interchanged via mail so that each classifier could rethink her entries for the cases of disagreement. In case of remaining disagreement on the level bounds, the lower of the two reconciled lower bounds and the higher of the two reconciled upper bounds entered the estimation.[7] The reconciled frames entered the classification when the RAs agreed in terms of B- or E-frame. Appendix A gives

[5]The RAs rankings are not constrained to any frames, the frames rather result from their ranking. Other than B and E, frames A_1, A_3, A_4 have been detected in small numbers (a total of 12/8/7 in treasure/mine/secret). They are therefore pooled with B and E as follows. The locations A_1 and A_4 in the frames of the same name are considered as endpoints in frame E, location A_3 in the frame of the same name is now grouped with the A's in the B-frame. In the 8/4/3 cases in which B and E appeared simultaneously, they were attributed to B.

[6]Questions of the research assistants were addressed via an e-mail list that included both RAs.

[7]Both methods yield similarly precise level intervals. The communication in Mannheim is classifiable in relatively fewer cases than in London, which is not due to the reconciliation method as it is true for the individual classifications pre-reconciliation already.

data on the robustness and replicability of the classifications by quantifying the agreement of 8 different classifiers.

The following examples show how the level bounds and the frames are identified from the messages.

1. Seeker (Proposal: A_3): *"for now it's an absolute guess, I would choose the third box"*
   Lower bound = upper bound: 0.

2. Hider (Proposal: A_4): *"i think hide item behind the b is dangerous. it is distinguish so the seeker team must open the b. so i choose the last a box."*
   Lower bound = upper bound: 1. Level-0: seeker favoring B, $B > A_1A_3A_4$.

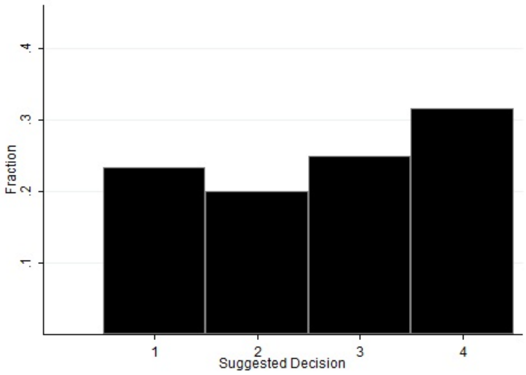
3. Seeker (Proposal: A_1): *"people usually choose the ones in the middle..so i think the hider has put somewhere else other than in the middle?"*
   Lower bound = upper bound: 2. Level-0: seeker avoiding endpoints, $BA_3 > A_1A_4$.

4. Hider (Proposal: B): *"i think that the other team will think that we have hidden it behind an 'a' block as there is more of them, so we wouldnt put it behind the obvious b block by itself"*
   Lower bound: 2, Upper bound: 3. Level-0 ($k = 2$): hider avoiding B, $A_1A_3A_4 > B$. Level-0 ($k = 3$): Seeker favoring B, $B > A_1A_3A_4$.

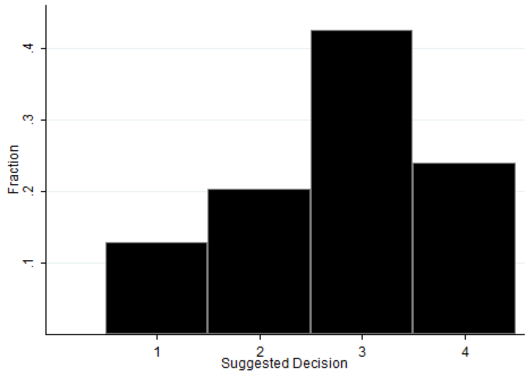
4. Results

This section presents the data on the suggested decisions and the results of the classification. The suggested decisions are summarized in figure 1. Across treatments, matchers' actions are similar to the actions exhibited in CI where a majority plays the central A_3 (1b, 1c and 1f). While CI's data looks similar for hiders and seekers, in my study the mismatchers' most frequently chosen position is A_4, they generally avoid the B. Except for the treasure treatment, the hiders' and seekers' distributions are significantly different (Fisher test, *p*-value=0.182/0.027/0.034).

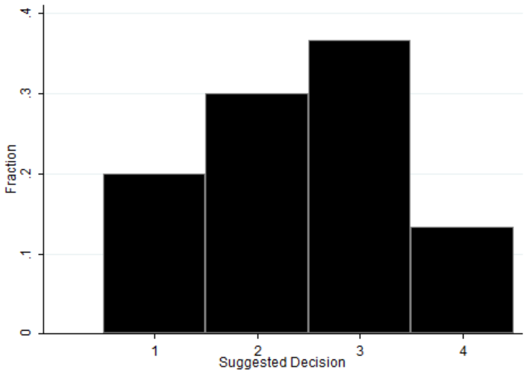
As found by RTH, the switch in objectives in the mine treatment leads to a switch in the behavior between hiders and seekers. Indeed, mismatchers' exhibit the ordinally same distribution (1a and 1d). An exception is the secret treatment in which hiders' actions are not following this pattern (1e).



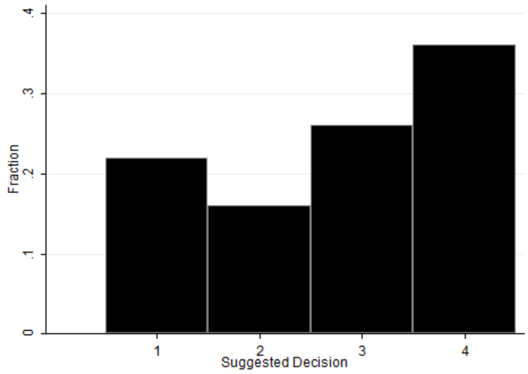
(a) Treasure: 60 hiders.



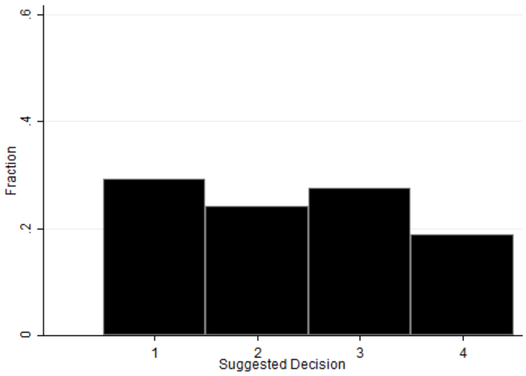
(b) Treasure: 54 seekers.



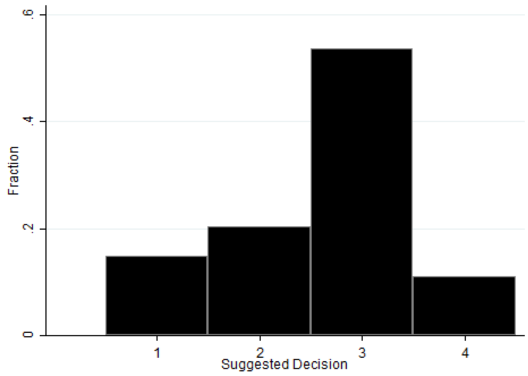
(c) Mine: 60 hiders.



(d) Mine: 50 seekers.



(e) Secret: 58 hiders.



(f) Secret: 54 seekers.

Figure 1: Histograms of suggested decisions.

Table 2 on page 13 indicates the lower and upper bounds of the levels of reasoning of hiders and seekers in the three treatments. Furthermore it indicates the number of subjects that were classified as equilibrium reasoners.

This data gives a first impression of the quality of the communication data and the detected levels of reasoning. It shows that the messages in the treasure treatment lead to fewer non-classifications (NA, 15) than in the mine (25) and in the secret treatment (27). The number of empty messages were 14/19/20. Across treatments, 50%/53%/37% of the subjects have a fully determined level of reasoning because their lower and upper bounds coincide.

Level-k distributions are commonly found to be hump-shaped. Here, the related marginal distributions of the lower and upper bounds are mostly found to be hump-shaped and feature more level-1 than level-2 players. Two exceptions are the seekers in the treasure treatment (2b) and the hiders in the secret treatment (2e) which both exhibit a higher fraction of level-2 than level-1 reasoners in both distributions. This way they stand in contrast to their counterrole players in the same treatments that have a higher fraction of level-1 than level-2 reasoners (2a and 2f). These effects are even more pronounced on the diagonal that shows frequencies of subjects classified with the same lower and upper bounds. The estimation in the next section will clarify whether there is indeed a difference in the level-k distribution due to the differing timing in treasure and secret.

The averages of all indicated lower and upper bounds give a first, very rough measure of possible differences between roles. In the treasure treatment, lower and upper bound averages are higher for seekers than hiders (0.91, 1.38; vs. 0.86, 1.27). In the mine treatment, hiders have a smaller lower bound average (0.97 vs. 1.06), but a higher upper bound average (1.23 vs. 1.21). In the secret treatment, seekers have a slightly smaller lower bound (1.04 vs. 1.07), but a higher upper bound (1.33 vs. 1.22). Again, the estimation will have to clarify whether the (mis)matching or the hiding and seeking induces any significant level differences.

The tables indicate the number of players that are classified to play equilibrium. With 2/4/6 in total (treasure/mine/secret) they are a small fraction of all players.

	Upper Bounds (∅1.27)						
	0	1	2	3	4	NA/ Eq.	Σ
0	9	6	0	0	0	1	16
Lower 1		19	8	0	0	0	27
Bounds 2			2	2	2	0	6
(∅0.86) 3				1	0	0	1
4					0	0	0
NA						8	8
Eq.						2	2
Σ	9	25	10	3	2	11	60

(a) Treasure: Hiders.

	Upper Bounds (∅1.38)						
	0	1	2	3	4	NA/ Eq.	Σ
0	13	8	0	0	0	0	21
Lower 1		2	9	0	0	0	11
Bounds 2			10	3	1	0	14
3	(∅0.91)			0	0	0	0
4					1	0	1
NA						7	7
Eq.						0	0
Σ	13	10	19	3	2	7	54

(b) Treasure: Seekers.

	Upper Bounds (∅1.23)						
	0	1	2	3	4	NA/ Eq.	Σ
0	7	3	0	0	0	2	12
Lower 1		15	7	0	0	4	26
Bounds 2			6	0	0	0	6
(∅0.97) 3				0	0	0	0
4					1	0	1
NA						14	14
Eq.						1	1
Σ	7	18	13	0	1	21	60

(c) Mine: Hiders.

	Upper Bounds (∅1.21)						
	0	1	2	3	4	NA/ Eq.	Σ
0	9	1	0	0	0	0	10
Lower 1		13	1	1	0	0	15
Bounds 2			3	1	0	2	6
3	(∅1.06)			4	0	0	4
4					0	1	1
NA						11	11
Eq.						3	3
Σ	9	14	4	6	0	17	50

(d) Mine: Seekers.

	Upper Bounds (∅1.22)							
	0	1	2	3	4	5	NA/ Eq.	Σ
0	7	3	0	0	0	0	1	11
Lower 1		6	1	0	0	0	5	12
Bounds 2			9	0	0	0	4	13
(∅1.07) 3				0	0	0	1	1
4					1	0	0	1
5						0	0	0
NA							15	15
Eq.							5	5
Σ	7	9	10	0	1	0	31	58

(e) Secret: Hiders.

	Upper Bounds (∅1.33)							
	0	1	2	3	4	5	NA/ Eq.	Σ
0	8	2	0	0	0	0	3	13
Lower 1		9	0	1	0	0	10	20
Bounds 2			3	1	1	0	0	5
3	(∅1.04)			0	1	0	1	2
4					0	0	0	0
5						1	0	1
NA							12	12
Eq.							1	1
Σ	8	11	3	2	2	1	27	54

(f) Secret: Seekers.

Table 2: Level classification. Averages (∅) include only observations with given bound, not NA or Eq.

Table 3 shows that the frame of the level-0 belief can be elicited for 73/56/51 out of the 96/73/60 participants with a classified lower and upper bound. The remainder of classified subjects consists mainly of level-0 reasoners who do not verbalize any reaction to the framing. Two subjects' frames cannot readily be classified as B- or E- frame.

It can be seen that the majority of players feature a B-frame throughout the treatments. A minority divides the locations into middle- and endpoints (E-frame). The relative frequency of the frames are mostly similar across hiders and seekers (Fisher exact test, p-value=0.797/0.257/0.038), a plausible finding under random task allocation.

	Treasure			Mine			Secret		
Frame	B	E	Σ	B	E	Σ	B	E	Σ
Hiders	27	12	39	24	9	33	17	8	25
Seekers	25	9	34	13	10	23	24	2	26
Total	52	21	73	37	19	56	41	10	51

Table 3: Belief classification.

5. Maximum Likelihood Estimation

In this section I estimate the role-specific level distributions and level-0 beliefs. Section 5.1 introduces an econometric model and section 5.2 presents the estimation results.

5.1. The Econometric Model

In the maximum likelihood estimation, I use the individual data about the level bounds $K_i = [\underline{k}_i, \overline{k}_i]$, the frames $f_i \in \{B, E\}$ and the action a_i to estimate the role-specific level probabilities π_k^t and the level-0-role-specific probabilities of favoring salience r_f^t.[8] The probabilities $r_B = Pr(q > 1/4)$ and $r_E = Pr(p > 1/2)$ are introduced to accomodate heterogeneity in the individual level-0 beliefs. As illustrated in table 1, the type, frame, level and action determine the range of the level-0 belief parameters. $I_{f_i}^{t_i}(a_i, k)$ reflects this by indicating for a given type and frame whether the action a_i at level k results from favoring salience or not.

[8]With a little abuse of notation, the superscript in π_k^t refers to the role of the level-k player while in r_f^t it refers to the role of the level-0 player in mind. This notation is chosen because empirically r_f^t does not depend on the role of the player that holds the beliefs.

With independent actions the log-likelihood function is

$$\log L(\pi_k^t, r_f^t; a_i, K_i, f_i) \;=\; \sum_{i=1}^{N} \log \left(\sum_{k \in K_i} \pi_k^{t_i} \cdot \left[r_{f_i}^{t_i} I_{f_i}^{t_i}(a_i, k) + (1 - r_{f_i}^{t_i})(1 - I_{f_i}^{t_i}(a_i, k)) \right] \right).$$

The estimation is based on the set of subjects on which level-0 information exists or whose level bounds coincide (see tables 2 and 3). Equilibrium subjects are excluded. The communication data on level bounds and frames complements the action data and is the crucial ingredient for the estimation. It allows me to estimate the level-k distribution and the level-0 action distribution. Without such data, they are not separately identifiable and further assumptions are required, such as $\pi_0 = 0$ in CI. Levels higher than 4 cannot be distinguished on the basis of action data as the model predicts level-5 to act like level-1, level-6 like level-2 and so on (see CI). Via the communication, higher level reasoners can be detected. However, for computational reasons and due to the low frequency of players with $k > 4$, I will calculate estimates for $k = 0, 1, \ldots, 4$ only.[9] In line with the data here, Arad and Rubinstein (2012) show that levels beyond level-3 are extremely rare.

5.2. Estimation Results

Table 4 gives a first overview of the estimated level distribution π_k for the full samples by treatment when role-symmetry is imposed. All estimated distributions are hump-shaped as expected. For all treatments, the average level is higher than the estimation of Burchardi and Penczynski (2014, BP) in a beauty contest game and lower than the one in CI. Consistently, the share of level-0 players is estimated to be smaller than in BP and higher than in CI.[10] As CI speculate, the differences suggest – with the necessary qualifications regarding subject pools and experimental procedures – that the transparency and cognitive ease differ between the hide and seek and the beauty contest games.

Table 5 splits up the estimation results by hiders and seekers. In all treatments, the matching type features a higher average level of reasoning, but the differences are small in magnitude and non-significant compared to the differences just discussed or other differences between games found in the literature (Shapiro, Shi, and Zillante, 2014; Van Elten and Penczynski, 2015). Given the timing, the switching of roles between treasure and mine is accompanied by shifts

[9]The one level-5 player in the secret treatment is dropped from the estimation.

[10]All the following results are qualitatively robust when the fraction of level-0 players is set to 0. However, the estimated level averages then reach up to 2.27 in the secret treatment.

Level-k	Treasure	Mine	Secret	CI	BP
0	0.26	0.18	0.15	0^a	0.37
	(0.036)	(0.035)	(0.037)		
1	0.38	0.40	0.26	0.19	0.47
	(0.030)	(0.040)	(0.031)		
2	0.27	0.23	0.25	0.32	0.15
	(0.030)	(0.030)	(0.026)		
3	0.07	0.11	0.17	0.25	0.01
	(0.021)	(0.026)	(0.018)		
4	0.03	0.08	0.16	0.25	—
	(0.015)	(0.021)	(0.022)		
Mean	1.24	1.51	1.93	2.55	0.80

[a] Imposed value.

Notes: The table presents the results from a maximum likelihood estimation of the structural model as outlined in section 5.1. Bootstrapped standard errors are given in brackets. These are obtained from 200 iterations of the estimation when sampling 114/110/112 observations from the data.

Table 4: Estimated level distribution $\hat{\pi}_k$.

in the level-1 and level-2 fractions that now favor the matching hider. The small advantage in average levels tracks the deviations from equilibrium in terms of the winning probability. Like in RTH, we observe that matchers outperform mismatchers across all three treatments. Therefore, the nature of the task might be influential via the realized average level of reasoning, the magnitude of the effect is, however, too small to draw a definite conclusion from the present data.

Significant differences between roles can be observed in the fractions of individual levels, particularly in the level-1 of the treasure treatment. While this difference diminishes in the mine treatment, it is reversed between treasure and secret treatment upon the change in the virtual timing. This suggests that the shape of the distribution is strongly influenced by the virtual timing of events. Confirming the conjectures in section 4, the results in the treasure treatment indicate the mode behavior to be level-1 for hiders and level-2 for seekers. The secret treatment with the switched temporal sequence exhibits the exact opposite results: the mode behavior is level-1 for seekers and the hiders' distribution features slightly more level-2 than level-1 reasoners.

Note that in both cases exactly those levels are more prevalent that think about a level-0 player that is the second mover. In the treasure treatment, the seeker is second mover and both level-1 hiders and level-2 seekers start thinking about a level-0 seeker. In the secret treatment, the level-1 seekers, level-2 hiders, and

Level	Treasure		Mine		Secret	
k	Hider	Seeker	Hider	Seeker	Hider	Seeker
0	0.22	0.30	0.15	0.23	0.16	0.15
	(0.051)	(0.054)	(0.046)	(0.071)	(0.058)	(0.048)
1	0.48	0.27	0.42	0.38	0.23	0.29
	(0.048) **	(0.042)	(0.023)	(0.049)	(0.048)	(0.041)
2	0.20	0.34	0.26	0.18	0.30	0.21
	(0.044)	(0.056)	(0.044)	(0.052)	(0.050) +	(0.026)
3	0.07	0.06	0.08	0.18	0.14	0.19
	(0.031)	(0.029)	(0.023) +	(0.057)	(0.033)	(0.021)
4	0.03	0.03	0.09	0.05	0.16	0.16
	(0.021)	(0.021)	(0.026)	(0.035)	(0.036)	(0.025)
Mean	1.22	1.25	1.54	1.45	1.91	1.93
Mode	1	2	1	1	2	1
'Match'		✓	✓			✓
'First'	✓		✓			✓
Pr(win)	0.746	0.254	0.275	0.725	0.738	0.262
Pr_{eq}(win)	0.75	0.25	0.25	0.75	0.75	0.25
N	49	46	41	34	33	37

Notes: The table presents the results from a maximum likelihood estimation of the structural model as outlined in section 5.1. Bootstrapped standard errors are given in brackets. These are obtained from 200 iterations of the estimation when sampling 114/110/112 observations from the data. $^{+}$ (*, **, ***) indicate that the bootstrapped 80% (90%, 95%, 99%) confidence intervals of estimates for hiders and seekers do not overlap. Pr(win) is based on the suggested decisions.

Table 5: Estimated level distribution $\hat{\pi}_k^t$.

level-3 seekers form a level-0 belief with respect to the second-moving hiders. One possible explanation is that it is easier to start thinking about the second mover. This is possibly because her decision is not influencing any subsequent decision maker. The mine treatment only features this pattern in lower levels, not in the higher levels. It might be that the switch of the roles somewhat counteracts the temporal effect. Furthermore, the estimates on levels 3 and 4 are based on few observations and thus possibly more erratic.

Turning to the level-0 beliefs, table 6 shows the estimated probabilities $\hat{r}_B^t = Pr(q > 1/4)$ and $\hat{r}_E^t = Pr(p > 1/2)$. The first two columns report the estimates irrespective of whether the subject of the level-0 belief is a hider or a seeker, while the remaining columns report the estimates by the roles of the level-0 belief subject. It is not reported which role holds the belief as the estimates do not differ in that respect.

In the treasure treatment, players are estimated to be divided between believing the level-0 player to favor and to avoid the B (0.55). The right columns show that it indeed matters whether hiders or seekers are thought about. While level-0 hiders are believed to avoid the B (0.30), level-0 seekers predominantly favor it (0.72). A similar, but smaller effect can be observed in the secret treatment (0.39, 0.52). In the mine treatment, however, both hiders and seekers are estimated to mostly shy away from the B (0.38, 0.33).

The observed level-0 role-dependence features a level-0 belief that could be derived as a best response to a role-symmetric B-frame with $q > 1/4$. Thus, subjects might incorporate intuitively in their belief a role-specific attitude to the locations. Under the assumption of a role-symmetric level-0 belief and in an estimation with less concrete information on the level of reasoning, the level-k estimate would tend to be higher, albeit not fully closing the gap to the CI estimates.

The second column indicates that the level-0 players are mostly believed to favor the midpoints under the E-frame. This tendency is robust across different level-0 roles and in line with the psychological literature (Christenfeld, 1995).

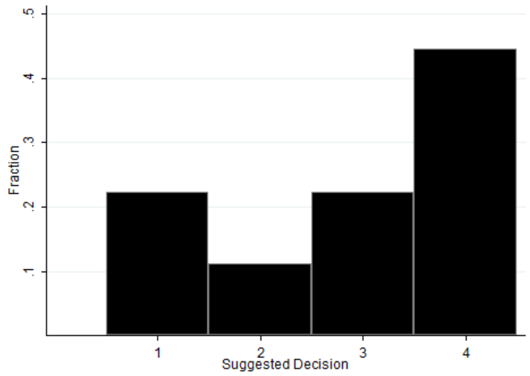
While these results show that beliefs can be symmetric across hiders and seekers in some situations and asymmetric in others, an interesting question is whether these beliefs are consistent with the behavior of level-0 players. To this end, figure 2 shows the actions of those players that were classified level-0 with both lower and upper bounds.

Despite the relatively small sample size, the first four histograms (2a to 2d) show a clear and consistent tendency that level-0 mismatchers avoid the B while level-0 matchers are attracted to it. In that sense, the asymmetric beliefs as estimated in the treasure treatment are consistent with the observed level-0 actions. The histograms 2e and 2f from the secret treatment appear comparatively more erratic but feature similar tendencies. Overall, 10 out of 28 matchers (35.7%) play B while only 1 of 25 mismatchers (4%) plays B. The estimated beliefs in the mine treatment do not conform with the hiders tendency to play B.

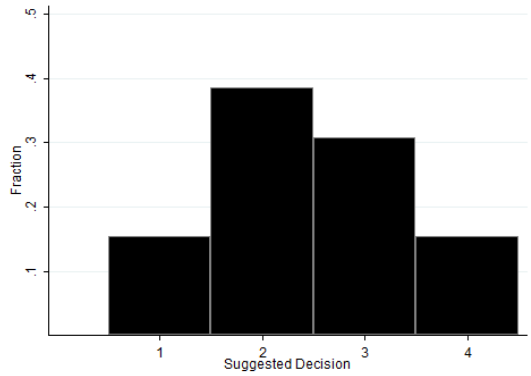
Frame f	B	E	B			E	
Level-0 role	All	All	h		s	h	s
Treasure	0.55	0.25	0.30		0.72	0.37	0.20
	(0.052)	(0.083)	(0.078)	***	(0.060)	(0.197)	(0.085)
Mine	0.36	0.37	0.38		0.33	0.28	0.50
	(0.058)	(0.073)	(0.079)		(0.082)	(0.111)	(0.125)
Secret	0.45	0.23	0.39		0.52	0.22	0.25
	(0.062)	(0.107)	(0.058)		(0.080)	(0.109)	(0.143)

Notes: The table presents the results from a maximum likelihood estimation of the structural model as outlined in section 5.1. Bootstrapped standard errors are given in brackets. These are obtained from 200 iterations of the estimation when sampling 114/110/112 observations from the data. * (**, ***) indicate that the bootstrapped 90% (95%, 99%) confidence intervals of estimates for hiders and seekers do not overlap.

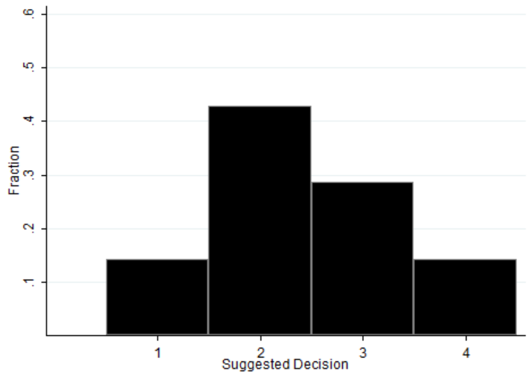
Table 6: Estimated level-0 beliefs $\hat{r}^t_f$.



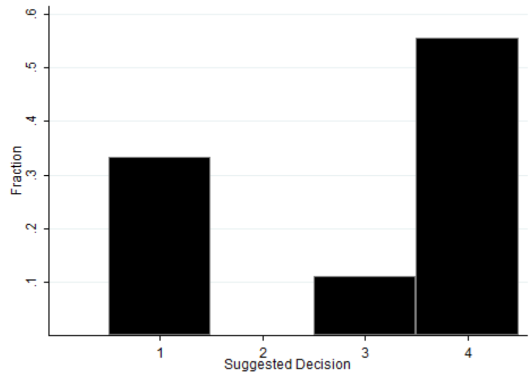
(a) Treasure: 9 hiders.



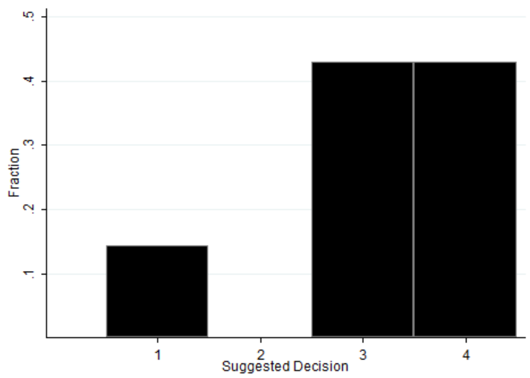
(b) Treasure: 13 seekers.



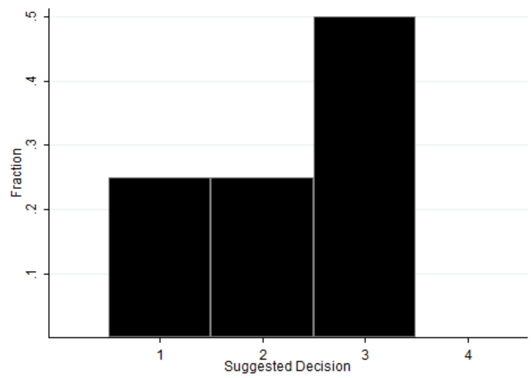
(c) Mine: 7 hiders.



(d) Mine: 9 seekers.



(e) Secret: 7 hiders.



(f) Secret: 8 seekers.

Figure 2: Histograms of suggested decisions of level-0 players.

6. Discussion

This study gives direct insights into the level-k reasoning of subjects. It is strengthening the results by CI that even games with a unique mixed strategy Nash equilibrium are thought about using iterated best responses to initial level-0 beliefs. For example in the treasure treatment, the non-uniform action distributions can be explained by most people starting to think about a level-0 seeker that is attracted to B or the midpoints. The frequently present level-1 hiders avoid the B and play central A_3 or the endpoints. The equally frequent level-2 seekers do the same. Also level-1 seekers that start thinking about a level-0 hider who avoids the B will play alike. Only level-2 hiders tend to play B, "bluffing" against the seeker who believes her to do otherwise.

The sequence of events matters for the shape of the level-k distribution in the treasure and secret treatments. This observation is an interesting extension of the virtual observability literature, where this effect to my knowledge has only been found in games with pure strategy equilibria (Cooper, DeJong, Forsythe, and Ross, 1993; Rapoport, 1997; Weber, Camerer, and Knez, 2004). Weber, Camerer, and Knez (2004, p. 40) relate the findings of simultaneous coordination on subgame perfect Nash equilibria to backward induction: "It is as if the players erase information sets, compute subgame perfect equilibria, then restore the information sets and check that the selected equilibrium is also a Nash equilibrium of the original game." The level distribution results point to a cognitive equivalent of this process that the authors put so nicely in game theory terms. It seems easiest for subjects to start thinking about a non-strategic second mover whose actions are best responded to by the strategic first mover. This leads indeed to a cognitive process reminiscent of backward induction, which can explain the equilibrium selection observed in the literature.

Another result of the paper is that differences in the performance between matchers and mismatchers might be driven by differences in the average level of reasoning, the magnitude of those differences are, however, very small. Eliaz and Rubinstein (2011) observe such a difference in performance between matchers and mismatchers discuss stimulus-response compatibility which suggests that the matching response to a stimulus is easier than a mismatching one. Under that theory, the mismatching objective in the hide and seek game would draw on more cognitive resources that are subsequently not available for further deliberation about the strategic situation. In the context of a level-k model, the limited scope of the effect might be explained with the fact that once level-2 is reached, a player thinks both about one match and one mismatch, only the sequence differs between matchers and mismatchers. Therefore, over the course of the deliberation, the differences between matchers and mismatchers might be small. An alternative mechanism discussed in their paper considers subjects to be primed by the task description into more and less strategic approaches. The level-0 fractions do not provide support for this theory.

The analysis of the level-0 beliefs shows that other channels exist for the objectives to matter. The frame that the label "ABAA" induces in a subject does not differ between hiders and seekers. However, the level-0 belief's attitude towards the B or the endpoints can be shaped by the objective of the level-0 subject. In the treasure treatment, hiders are believed to avoid the B while seekers are believed to be attracted by it. Both beliefs seem congruent with level-0 behavior. Although this does not explain how consistent advantages of matchers arise, it shows that players can have intuitions about the play that turn out to be useful and do not relate to the strategic sophistication in terms of iterated best replies.

7. Conclusion

Using an experimental design with intrateam communication, this study has investigated individual reasoning in the hide and seek game and finds that the average level of reasoning differs only slightly between matchers and mismatchers. The differences are small compared to other differences observed in the literature, but the direction of the observed differences is consistently in favor of the matchers. As in the literature, the matchers outperform mismatchers compared to equilibrium. Therefore, the nature of the task might be influential via the realized average level of reasoning, the magnitude, however, is too small to draw a definite conclusion.

Further, the results show that the "virtual" timing of the strategic situation influences the level-k distribution even under strategic simultaneity. In particular, the reasoning in treasure and secret treatments predominantly starts with the second mover, making odd-leveled first movers and even-leveled second movers more frequent. This finding sheds light on other instances of "virtual observability", explaining the coordination on subgame perfect equilibria in simultaneous games by the structural similarity between general cognitive processes and the procedure of backward induction.

The study finally shows that the level-0 belief can be influenced by the task of the level-0 player, allowing intuitions about likely behavior of different types to enter the reasoning.

I believe that the results contribute to understanding more generally how the level of reasoning depends on the transparency and cognitive difficulty of a game. It shows to which extent small differences in the strategic and temporal setup of a game can systematically make a difference for the strategic reasoning. The influence on reasoning that the scope of uncertainty, the complexity of the rules, the nature of asymmetry, the (non)constant-sum property, etc. have, should be an interesting field of future research.

A. Classification robustness

In order to test the classification for stability and replicability, 6 further RAs individually classified the data of the treasure treatment. Table 7 shows that in 88% of the messages, 5 or more out of 8 RAs put the exact same level lower bound. In 78% of the messages, 5 or more RAs put the exact same level upper bound.

Table 7: Number of subjects for which the 8 RAs' level classifications coincide maximally a given number of times.

	Coinciding RA level classifications							
	8	7	6	5	4	3	2	Total
Lower bounds	42	19	12	14	10	2	–	99
Cumulative fraction	0.42	0.62	0.74	0.88	0.98	1.00	1.00	
Upper bounds	24	22	15	18	14	7	1	101
Cumulative fraction	0.24	0.46	0.60	0.78	0.92	0.99	1.00	

B. Monte Carlo study

In order to check that the estimator does not introduce by itself any bias between matchers and mismatchers, I run two Monte Carlo studies in which the level of reasoning distribution differs by task. The left side of table 8 illustrates the generated data and the estimates for the case in which the hiders have a higher average level-k than the seekers, the right hand side the inverse situation.

The results are based on 200 estimations of 48 datapoints in the treasure treatment generated by a Poisson-distributed level-k distribution and level lower and upper bounds that generate level intervals comparable to the ones in the treasure treatment.[11]

The estimates show that it does not matter whether a distribution is estimated for matchers (seekers) or mismatchers (hiders). Columns (3) and (8) as well as columns (4) and (7) are essentially the same.

[11] The smallest sample in the estimations is 51, determined by the number of subjects with an identified frame and ignoring players classified as level-0. The generated level bounds are off by one level with probability 0.24, generating possible level sets of cardinality 1 in 57.76%, cardinality 2 in 36.48% and cardinality 3 in 5.76% of cases.

Table 8: Results from 2 Monte Carlo studies with 200 estimations of the generated data.

	Hiders with higher level-k				Seekers with higher level-k			
	Gen. data		Estimates		Gen. data		Estimates	
Level-k	Hider	Seeker	Hider	Seeker	Hider	Seeker	Hider	Seeker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0	0.23	0.34	0.208	0.271	0.34	0.23	0.272	0.212
1	0.34	0.37	0.278	0.305	0.37	0.34	0.296	0.283
2	0.26	0.20	0.242	0.210	0.20	0.26	0.211	0.240
3	0.13	0.07	0.161	0.126	0.07	0.13	0.130	0.159
4	0.05	0.02	0.111	0.088	0.02	0.05	0.091	0.106
Average	1.44	1.05	1.69	1.46	1.05	1.44	1.47	1.66

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Supplementary Material

'Strategic Thinking: The Influence of the Game'

Stefan P. Penczynski

The instructions for the treasure treatment are shown. The ones for the mine and secret treatment are analogous. Their German instructions can be obtained upon request.

C. Experiment instructions

The experiment instructions were distributed sequentially in 2 handouts and read aloud by the experimenter. Further handouts distributed later are not relevant for the present paper.

Handout 1 - Treasure

Welcome to the experiment!

Introduction

You are about to participate in an experiment in team decision making. The experiment is funded by the Michio Morishima fund, the London School of Economics and the German Society of Experimental Economic Research. Please follow the instructions carefully.
In addition to the participation fee of £5, you may earn an additional amount of money. Your decisions and the decisions of the other participants determine the additional amount. You will be instructed in detail how your earnings depend on your and the others' decisions. All that you earn is yours to keep, and will be paid to you in private, in cash, after today's session.
It is important to us that you remain silent and do not look at other people's screens. 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, exclaim out loud, etc., you will be asked to leave. Thank you.

Since this is a team experiment, you will at various times be matched randomly with another participant in this room, to form a team that plays as one entity. Your team's earnings will be shared equally between you and your team partner.
The experiment consists of four rounds and the way you interact as a team to take decisions will be the same throughout the experiment.

Now, let us explain how your ***Team's Action*** is determined. In fact, both your team partner and you will enter a ***Final Decision*** individually and the computer will choose randomly which one of your two final decisions counts as your team's action. The probability that your team partner's final decision is chosen is equal to the probability that your final decision will be chosen (i.e. your chances are 50:50). However, you have the possibility to influence your partner's final decision in the following way: Before you enter your final decision, you can propose to your partner a ***Suggested Decision*** and send him one and only one text ***Message***. *Note that this message is your only chance to convince your partner of the reasoning behind your suggested decision. Therefore, use the message to explain your suggested decision to your team partner.* After you finish entering your suggested decision and your message, these will be shown to your team partner. She/he will then make her/his final decision. Similarly, you will receive your partner's suggested decision and message. You will then make your final decision. As outlined above, once you both enter your final decision, the computer chooses randomly one of your final decisions as your team's action.

If you have any questions at this point, please raise your hand. In order for you to get familiar with the messaging system, you will now try it out in a **Test Period**. Please turn the page for further instructions.

Test period

A participant in this room is now randomly chosen to be your team partner. The **Test Period** has two rounds, with one question to answer in each round. Since this is only a test, your earnings will not depend on any decision taken now. In both test rounds you will need to answer a question about the year of an historic event. The team that is closest to the correct year wins.

As described, you will be able to send one ***Suggested Decision*** with your proposed year and an explaining ***Message***. After having read your partner's suggested decision and message, you will enter your ***Final Decision***. As described earlier, either your or your partner's final decision will be chosen randomly to be your ***Team's Action***.

The messenger allows ***Messages*** of any size. However, you have to enter the message line by line since the input space is only one line. Within this line you can delete by using the usual "Backspace" button of your keyboard. By pressing "Enter" on the keyboard, you add the written sentence to the message. Please note that only added sentences will be sent and seen by your partner. *The words in the blue input line will* ***not*** *be sent.* You can always delete previously added sentences by clicking the "Clear Input" button. The number of lines you send is not limited. You can therefore send messages of any length. You finally send the message to your partner by clicking the "Send Message" button.

When you are ready, please click the "Ready" button to start the **Test Period**.

Handout 1 - Mine/Secret (Translation from German)

Willkommen

Introduction

Welcome to today's experiment. The experiment is funded by the University of Mannheim. Please follow the instructions carefully.
You may earn a considerable amount of money. Your decisions and the decisions of the other participants determine this amount. You will be instructed in detail how your earnings depend on your and the others' decisions. All that you earn is yours to keep, and will be paid to you in private, in cash, after today's session.
It is important to us that you remain silent and do not look at other people's screens. 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, exclaim out loud, etc., you will be asked to leave. Thank you.

Since this is a team experiment, you will at various times be matched randomly with another participant in this room, to form a team that plays as one entity. The experiment is conducted anonymously and identities of you, your team partner or other participants will not be revealed. Your team's earnings will be shared equally between you and your team partner.
The experiment consists of three parts. The way you interact as a team to take decisions will be the same throughout the experiment.

Now, let us explain how your ***Team's Action*** is determined. In fact, both your team partner and you will enter a ***Final Decision*** individually and the computer will choose randomly which one of your two final decisions counts as your team's action. The probability that your team partner's final decision is chosen is equal to the probability that your final decision will be chosen (i.e. your chances are 50:50). However, you have the possibility to influence your partner's final decision in the following way: Before you enter your final decision, you can propose to your partner a ***Suggested Decision*** and send him one and only one text ***Message***. *Note that this message is your only chance to convince your partner of the reasoning behind your suggested decision. Therefore, use the message to explain your suggested decision to your team partner.* After you finish entering your suggested decision and your message, these will be shown to your team partner. She/he will then make her/his final decision. Similarly, you will receive your partner's suggested decision and message. You will then make your final decision. As outlined above, once you both enter your final decision, the computer chooses randomly one of your final decisions as your team's action.

If you have any questions at this point, please raise your hand. In order for you to get familiar with the messaging system, you will now try it out in a **Test Period**. Please turn the page for further instructions.

Test Period

A participant in this room is now randomly chosen to be your team partner. The **Test Period** has two rounds, with one question to answer in each round. Since this is only a test, your earnings will not depend on any decision taken now. In both test rounds you will need to answer a question about the year of an historic event. The team that is closest to the correct year wins.

As described, you will be able to send one ***Suggested Decision*** with your proposed year and an explaining ***Message***. After having read your partner's suggested decision and message, you will enter your ***Final Decision***. As described earlier, either your or your partner's final decision will be chosen randomly to be your ***Team's Action***.

The messenger allows ***Messages*** of any size. However, you have to enter the message line by line since the input space is only one line. Within this line you can delete by using the usual "Backspace" button of your keyboard. By pressing "Enter" on the keyboard, you add the written sentence to the message. Please note that only added sentences will be sent and seen by your partner. *The words in the blue input line will* ***not*** *be sent.* You can always delete previously added sentences by clicking the "Clear Input" button. The number of lines you send is not limited. You can therefore send messages of any length. You finally send the message to your partner by clicking the "Send Message" button.

When you are ready, please click the "Ready" button to start the **Test Period**.

Handout 1 - Mine/Secret (German original)

At the start, the following introduction was handed out.

Willkommen

Einleitung

Ich begrüße Sie zum heutigen Experiment. Das Experiment ist finanziert durch die Universität Mannheim. Bitte befolgen Sie die Anweisungen sorgfältig.
Sie haben die Möglichkeit, einen beträchtlichen Geldbetrag zu verdienen. Ihre Entscheidungen und die Entscheidungen anderer bestimmen diesen Betrag. Sie werden im Detail unterrichtet, wie dieser Betrag von Ihren Entscheidungen und den Entscheidungen anderer abhängt. Was Sie verdienen wird Ihnen nach der Sitzung privat und in bar ausgezahlt.
Es ist wichtig, dass Sie während der Sitzung nicht reden und nicht auf andere Bildschirme schauen. Wenn Sie Fragen haben oder Hilfe brauchen, heben Sie die Hand und jemand wird zu Ihnen kommen. Wenn Sie sprechen, laut werden, etc. werden Sie aufgefordert, das Experiment zu verlassen.

Die Entscheidungen in diesem Experiment werden im Team getroffen. Sie formen dementsprechend einige Male mit einem zufällig ausgewählten Versuchsteilnehmer in diesem Raum ein Team, das als eine Einheit agiert. Das Experiment wird anonym durchgeführt, Identitäten von Ihnen, Ihren Teampartnern oder anderen Mitspielern werden nicht preisgegeben. Ihre verdienten Geldbeträge werden gleichmäßig zwischen Ihnen und Ihrem Teampartner aufgeteilt.
Das Experiment besteht aus 3 Teilen. Die Interaktion im Team ist im gesamten Experiment die gleiche.

Wie wird die ***Teamentscheidung*** getroffen? Ihr Teampartner und Sie werden beide eine individuelle ***endgültige Entscheidung*** eingeben und der Computer wird zufällig eine der beiden Entscheidungen aussuchen und als ***Teamentscheidung*** werten. Die Wahrscheinlichkeit, dass die endgültige Entscheidung Ihres Teampartners gewählt wird, ist gleich der Wahrscheinlichkeit, dass Ihre endgültige Entscheidung gewählt wird, d.h. die Chancen sind 50:50. Sie haben allerdings die Möglichkeit, die Entscheidung Ihres Partners auf die folgende Weise zu beeinflussen: Bevor Sie Ihre endgültige Entscheidung treffen, können Sie Ihrem Partner einen ***Entscheidungsvorschlag*** machen und ihm genau eine ***Nachricht*** schicken. *Beachten Sie, dass diese Nachricht die einzige Möglichkeit ist, Ihren Partner von den Gründen hinter Ihrer Entscheidung zu überzeugen. Nutzen Sie deshalb die Nachricht um Ihren Entscheidungsvorschlag zu erklären.* Nachdem Sie Ihren Entscheidungsvorschlag und Ihre Nachricht eingegeben haben, werden diese Ihrem Partner gezeigt, der dann die endgültige Entscheidung treffen wird. Gleichzeitig werden Sie die Nachricht und den Entscheidungsvorschlag Ihres Partners empfangen und können dann Ihre endgültige Entscheidung treffen. Wie beschrieben wird der Computer dann eine der beiden endgültigen Entscheidungen zufällig als Teamentscheidung auswählen.

Wenn Sie jetzt Fragen haben, heben Sie bitte Ihre Hand. Um das Kommunikationssystem kennenzulernen, werden Sie nun eine **Testrunde** absolvieren. Bitte wenden Sie das Blatt für weitere Anleitungen.

Testrunde

Ein Teilnehmer in diesem Raum wird nun zufällig als Ihr Partner ausgesucht. Die Testrunde besteht aus zwei Perioden, in denen jeweils eine Frage zu beantworten ist. Da dies lediglich ein Test ist, können Sie nun kein Geld gewinnen. In beiden Runden werden Sie eine Frage zur Jahreszahl eines historischen Ereignisses beantworten. Das Team gewinnt, das am nächsten an der korrekten Jahreszahl liegt.

Wie beschrieben werden Sie die Möglichkeit haben, einen ***Entscheidungsvorschlag*** mit der vorgeschlagenen Jahreszahl zu machen und eine erklärende ***Nachricht*** zu schicken. Nachdem Sie den Entscheidungsvorschlag und die Nachricht Ihres Partners gelesen haben, werden Sie Ihre endgültige Nachricht eingeben. Entweder Ihre oder Ihres Partners ***endgültige Entscheidung*** wird zufällig als ***Teamentscheidung*** ausgewählt.

Das Kommunikationssystem erlaubt ***Nachrichten*** beliebiger Länge. Sie müssen die Nachricht allerdings Zeile für Zeile eingeben, da das Eingabefeld nur einzeilig ist. Innerhalb dieser Zeile können Sie mit der normalen "Backspace"-Taste Ihres Keyboards Eingaben löschen. Sie fügen den Text in der Eingabezeile zu Ihrer Nachricht hinzu, indem Sie "Enter" drücken. Bitte beachten Sie, dass ausschließlich Eingaben, die Sie der Nachricht hinzugefügt haben, von Ihrem Partner gesehen werden. *Die Eingaben in der blauen Eingabezeile werden* ***nicht*** *übermittelt.* Hinzugefügte Nachrichten können Sie jederzeit löschen, indem Sie den "Löschen"-Button auf dem Bildschirm klicken. Die Anzahl der Zeilen ist nicht limitiert. Sie können dementsprechend Nachrichten jeglicher Länge senden. Sie senden die Nachricht endgültig, wenn Sie den "Senden"-Button klicken.

Wenn Sie bereit sind, klicken Sie bitte "Bereit", um die **Testrunde** zu starten.

After the test period, the instructions for part I were handed out.

Handout 2 - Treasure

Start Part I

You are about to start Part I of the experiment. You are now randomly matched with a new partner. For each of the next four rounds you will be matched with a new team partner, i.e. in each of the following rounds you will play with a different person.
In this part of the experiment your team will play against only one other team. In each of the four rounds you play against a different team. From the four rounds, one round is chosen randomly and will be considered for determining the payoff. If your team wins this selected round, your team will earn £10 (£5 per team player). Please note that you will be informed of your opponent's team action of the chosen round at the end of Part II. There will be *no feedback* after the individual rounds.

Your task is the following:
In the beginning, the computer will tell you whether your role throughout Part II is "***Hider***" or "***Seeker***".
If you are ***Hider***, your task is to hide an object behind one of four items. In rounds 1 and 2, the object is a ***Treasure***. In rounds 3 and 4, the object is a ***Mine***. The hider team wins the round if the treasure was not found by the seeker or if the mine was found by the seeker. The seeker does not observe where you hide the object. The seeker will look behind one item in each round, not more and not less.
If you are ***Seeker***, your task is to find the treasure in rounds 1 and 2 and to avoid the mine in rounds 3 and 4. The seeker team wins the round if it chooses the particular item behind which the treasure ***was*** hidden or if it chooses an item behind which the mine ***was not*** hidden.

Just like before, you can send a ***Suggested Decision*** and an explaining ***Message*** to your team partner. *(And note again that the words in the blue input line will* ***not*** *be sent. Press "Enter" to add them to the message.)* From your two ***Final Decisions*** the computer again chooses the ***Team's Action***.

When you click the "Ready" button, you will start the first round of **Part I** of the experiment.

Handout 2 - Mine (Translation from German)

Start Part I

You are about to start the experiment. You are now randomly matched with a new partner. Your team will now play against one of the other teams. This part lasts for one period. If you win in this period, your team will earn 12 EUR and you accordingly 6 EUR. Please note that you will not be informed of your success now but at the end of the experiment.

Your task is the following:
In the beginning, the computer will tell you whether your task is to "***hide***" or "***seek***" an object.
If your task is to ***hide***, your task is to hide an explosive mine at one of four locations. You win if the mine was found by the seeker team. The seeker does not observe where you hide the mine and has to go to one location.
If your task is to ***seek***, your task is to avoid the mine. You win if you choose the location at which the mine is ***not*** hidden.

Just like before, you can send a ***Suggested Decision*** and an explaining ***Message*** to your team partner. *(And note again that the words in the blue input line will* ***not*** *be sent. Press "Enter" to add them to the message.)* From your two ***Final Decisions*** the computer again chooses the ***Team's Action***.

When you click the "Ready" button, you will start the first part of the experiment.

Handout 2 - Secret (Translation from German)

Start Part I

You are about to start the experiment. You are now randomly matched with a new partner. Your team will now play against one of the other teams. This part lasts for one period. If you win in this period, your team will earn 12 EUR and you accordingly 6 EUR. Please note that you will not be informed of your success now but at the end of the experiment.

Your task is the following:
In the beginning, the computer will tell you whether your task is to "***hide***" or "***uncover***".
If your task is to ***hide***, your task is to discuss a secret at one of four locations and protect yourself from the wiretap of the other team. You win if the secret was not found by the seeker team and you discuss it at a wiretap-free location.
If your task is to ***uncover***, your task is to uncover the secret of the other team. You can place a wiretap at one location and win if you choose the location at which the other team discusses the secret. The other team cannot see where you place the wiretap and has to choose one location.

Just like before, you can send a ***Suggested Decision*** and an explaining ***Message*** to your team partner. *(And note again that the words in the blue input line will **not** be sent. Press "Enter" to add them to the message.)* From your two ***Final Decisions*** the computer again chooses the ***Team's Action***.

When you click the "Ready" button, you will start the first part of the experiment.

Handout 2 - Mine (German original)

Teil I

Sie starten nun das Experiment. Sie werden nun zufällig mit einem neuen Partner gematcht. Ihr Team spielt nun gegen eines der anderen Teams. Dieser Teil dauert eine Periode. Wenn Sie in dieser Periode gewinnen, wird Ihr Team 12 EUR und Sie dementsprechend 6 EUR gewinnen. Sie werden nicht in dieser Periode über Ihren Erfolg informiert, sondern erst am Ende des Experiment.

Ihre Aufgabe ist die folgende:
Der Computer wird Ihnen anfangs anzeigen, ob Ihre Aufgabe das "***Verstecken***" oder das "***Suchen***" eines Objektes ist.
Ist Ihre Aufgabe "Verstecken", so besteht Ihre Aufgabe darin, eine explosive Mine an einem von vier möglichen Orten zu verstecken. Sie gewinnen wenn die Mine vom anderen Team gefunden wird. Das andere Team kann nicht sehen, wo Sie die Mine platzieren und muss sich an einem Ort begeben.
Ist Ihre Auggabe "Suchen", so besteht Ihre Aufgabe darin, eine Mine zu vermeiden. Sie gewinnen wenn Sie einen Ort wählen, an dem die Mine ***nicht*** versteckt ist.

Wie zuvor können Sie einen ***Entscheidungsvorschlag*** und eine erklärende ***Nachricht*** zu Ihrem Teampartner senden. *Und beachten Sie noch einmal, dass die Eingaben in der blauen Eingabezeile nicht gesendet werden. Drücken Sie "Enter" um sie der Nachricht hinzuzufügen.* Von den beiden ***endgültigen Entscheidungen*** wird der Computer zufällig eine als ***Teamentscheidung*** auswählen.

Wenn Sie den "Bereit"-Button klicken starten Sie den ersten Teil des Experiments.

Handout 2 - Secret (German original)

Teil I

Sie starten nun das Experiment. Sie werden nun zufällig mit einem neuen Partner gematcht. Ihr Team spielt nun gegen eines der anderen Teams. Dieser Teil dauert eine Periode. Wenn Sie in dieser Periode gewinnen, wird Ihr Team 12 EUR und Sie dementsprechend 6 EUR gewinnen. Sie werden nicht in dieser Periode über Ihren Erfolg informiert, sondern erst am Ende des Experiments.

Ihre Aufgabe ist die folgende:
Der Computer wird Ihnen anfangs anzeigen, ob Ihre Aufgabe das "***Verstecken***" oder das "***Aufdecken***" ist.
Ist Ihre Aufgabe "Verstecken", so besteht Ihre Aufgabe darin, ein Geheimnis an einem von vier möglichen Orten zu besprechen und sich vor einer Abhörwanze des anderen Teams zu schützen. Sie gewinnen wenn das Geheimnis vom anderen Team nicht gefunden wird und Sie es an einem wanzenfreien Ort besprechen.
Ist Ihre Aufgabe "Aufdecken", so besteht Ihre Aufgabe darin, das Geheimnis des anderen Teams aufzudecken. Sie können eine Abhörwanze an einem Ort platzieren und gewinnen, wenn Sie den Ort wählen, an dem das andere Team das Geheimnis bespricht. Das andere Team kann nicht sehen, wo Sie die Wanze platzieren und muss einen Ort wählen.

Wie zuvor können Sie einen ***Entscheidungsvorschlag*** und eine erklärende ***Nachricht*** zu Ihrem Teampartner senden. *Und beachten Sie noch einmal, dass die Eingaben in der blauen Eingabezeile nicht gesendet werden. Drücken Sie "Enter" um sie der Nachricht hinzuzufügen.* Von den beiden ***endgültigen Entscheidungen*** wird der Computer zufällig eine als ***Teamentscheidung*** auswählen.

Wenn Sie den "Bereit"-Button klicken starten Sie den ersten Teil des Experiments.

After part I, the instructions for further parts were handed out, with different games in the two experimental laboratories. Since these parts are not relevant for this present paper they are omitted.

D. Classification instructions

The self-contained classification instructions were given to the RAs.

Classification document

Hide and Seek game - Period 1

In the following I will describe the classification process for the analysis of the experiment. It is assumed that you are familiar with the level-k model as it has been introduced by Nagel (1995) or represented by Camerer, Ho, and Chong (2004). The model here is extended to incorporate salience in the level-0 belief according to Bacharach and Stahl (2000). In order to clarify potential questions of terminology and introduce the main features of the model, appendix "Model and terminology" reproduces the main features of the model in the terminology used in this document.

After your individual classification, you will meet with your co-classifier to reconcile your classification. In this process, try to agree on common classifications if possible and note them in the third sheet provided. If an agreement is not possible and both of you keep your initial individual classification, simply note nothing in the third sheet. If you have questions about the procedure at any point, please write an email to me and I will clarify any point in an email to both of you.

Please read this document and the instructions for the experiment entirely in order to get an overview and then start the classification based on the player's sent message and action proposal. Note that the framing of the four possible locations is 'ABAA' in periods 1 and 3 and '1234' in periods 2 and 4. A player can be of two types, hider or seeker. It is useful to go through the process first for all hiders and then for all seekers. This way, you keep the perspective of one type of player and do not get confused.

Please read the messages of each player, taking into account his action, and note for each player every possible level of reasoning. These should lie in an interval between the lower and upper bound of the level reasoning, as specified later in detail. Below you find detailed instructions for classifying each player. It is important that you limit yourself to making inferences only from what can clearly be derived from the message stated, i.e. do not try to think about what the player might have thought.

IMPORTANT: When you think that the information does not clearly lend itself to any inference, simply do not note any classification. Consequently, do not note anything if no statement has been made! Please note only those classifications for which you are certain. Make use of the comments space if you are not certain but still want to indicate a feature of the reasoning. Similarly, please comment if the statement exhibits some argument that does not fit the level-k model as I present it here.

Levels

For the lower bound on the level of reasoning, you should ask yourself: "What is the minimum level of reasoning that this statement clearly exhibits?" Once noted, you should be able to say to yourself: "It seems impossible that the players' level of reasoning is below this number!" Here I ask you to be very cautious with the classification, not giving away high levels easily.
The upper bounds should give the maximum level of reasoning that could be interpreted into the statement. Therefore, you should ask yourself: "What is the highest level of reasoning that can be underlying this statement?" Once noted, you should be able to say: "Although maybe not clearly communicated, this statement could be an expression of this level. If the player reasoned higher than this number, this was not expressed in the statement!"
For both lower and upper bound, please refer to the following characterisation of the different levels.
Note that there are two necessary conditions for a player to exhibit a level greater than 0. First, the player has to be responsive to the salience of the games' framing. Secondly, the player has to be strategic in best-responding to his level-0 belief, which is shaped by salience. If he did not react to salience, he would have no reason to chose one over the other object, resulting in random play. Interestingly, this random play is observationally equivalent to equilibrium behaviour. Therefore, the level-0 players can be those that react to salience and do not play strategically, or they can ignore the framing and hence play randomly. As far as possible, we want to distinguish uniform random level-0 play and equilibrium play. However, regarding the level classification, you can classify every random play as level-0 play. The equilibrium play is taken into account by a specific dummy.

Level 0 The player does not exhibit any strategic reasoning whatsoever. Different versions of this might be randomly chosen or purely guessed actions, misunderstanding of the game structure or other non-strategic 'reasons' for picking a location, e.g. by taste or salience. It is important that no best-responding to the other's play occurs. There could be considerations of what others might play, but without best responding to it. Examples[a]: "Well, it's a pure guess", "There are no arguments. Simply choose any."

Level 1 This player best responds to some belief (in the treasure game, a hider mismatches the belief of the other's action, a seeker matches his belief of the other's action). However, he does not realise that others will be strategic as well. Example: "They are probably picking B, so we do as well", "Its at the end and people would naturally go for the middle, no?"

Level 2 This player not only shows the basic strategic consideration of playing best response (matching/mismatching), but also realises that other players best respond as well according to the belief they entertain. A level-2 player clearly contemplates how the other player might best respond to his frame. The player plays a best response to this hypothesised consideration. Example: "They may think most will look in the middle two, therefore choosing one in the end. I therefore choose the first one."

Level 3 This player realises that others could be level-2 and reacts by best responding to the associated expected play. Put differently, he realises that others realise that others best respond to their initial belief. Therefore, a level-3 player clearly states that his opponent expects that he (the level-3 player at question) best-responds to a certain belief.

Level 4, 5, ... The process goes on in a similar fashion. The reasoning enters a cycle, in the sense that level-5 will come to the same best response as level-1. Please indicate in the comment section if the player reaches this cycling phase and recognises this pattern.

Level-0 belief

If level reasoning is observed in the statement, there has to be a starting point in the argument which states an attraction or aversion to one or more of the locations. This is then not derived by strategic reasons, but is an intuitive reaction to the framing of the locations. Otherwise, level reasoning would not occur.

Please indicate the underlying level-0 belief that is connected with each possible level of reasoning. Note that the level-0 belief of a person reasoning on an odd level, i.e. level 1, 3, 5, etc. is always with respect to how a player of the opposite side intuitively reacts to the framing. The belief of a person reasoning on an even level, i.e. level 2, 4, 6, etc. is always with respect to what the opposite type believes about the own type's intuitive reaction. You will have this in mind and can note it for completeness in the "H/S"-box, but since it follows from your level indication, it is not essential.

[a] All examples have been made up for illustrative purposes.

Usually, the most information one can get out of the communication is the most and least attractive location respectively. For example, as a seeker, I might communicate that the hider is most attracted to the B and then play central A. This indicates that the hider was believed to choose central A with the (weakly) lowest probability and B with highest probability. It follows that it will usually not be possible to rank *all* the locations by their attractiveness.

To reflect the exhibited level-0 beliefs please denote every level-0 belief by ranking the four locations with a 'more attractive than' relation. The locations are coded according to their position as '1', '2', '3', and '4'. In the example of the previous paragraph, the resulting statement is $2 > 14 > 3$, since B in the 2nd position is the most attractive location for the hider and central A, the '3', the least attractive. Not putting anything between numbers indicates that their level of attractiveness cannot be distinguished, as in this case with the two A's at the beginning (position '1') and at the end (position '4'). Of course, depending on whether you get more or less information out of the communication, your statement can be $14 > 23$ or $2 > 4 > 3 > 1$. This notation should be flexible enough to encode every piece of information on the level-0 belief that is present in the communication.

Imagine a seeker that you classify to be level-1 or level-2. If you determined his level-0 belief to be $2 > 134$ (H) in the case he is level-1, then the level-0 belief should follow to be $134 > 2$ (S) in the case he is level-2.[a] For all cases where nothing in the communication speaks against this, feel free only to note the level-0 belief for the first conjectured level. A statement on each possible level's level-0 belief is only necessary if you think it does not follow in this mechanical way.

In order to keep the overview over the best responses that are connected with certain types at certain levels, I will make a small Excel-sheet available, which calculates automatically the best responses as a function of a specified level-0 belief. This will help you to get a feeling for the mapping of communication and action into the parameters.

Dummy

Equilibrium play In the description of the levels, I said that the level-0 player that does not react to the salience is considered to play randomly due to a lack of arguments for a specific option. Similarly, a player that plays according to the Nash equilibrium will have no argument for or against a specific option, therefore exhibiting the exact same behaviour. In order to distinguish the two where possible, please indicate here whether the player gives convincing arguments for his random play by mentioning that any location is a best response to random play. It is important that the fully random play of the others is considered and used in the best response argument. Put '1' if the player does so. Otherwise, the player will fit the description of level-0 players and the dummy should take the value '0'. Do not tick anything if the player is clearly neither one nor the other type or if the statement does not allow for a classification along these lines.

[a]This follows because for this last level-0 belief for a seeker, the previous level-0 belief of the hider constitutes a best response. Given the action of the player at hand, this is the way the levels and level-0 beliefs co-move.

Concluding remarks

You might have noticed that there will be no classification of the population belief. This is because the opponents as a team are a single entity and a non-degenerate population belief makes only sense in a probabilistic interpretation. Also, the action will always[a] maximally reflect the mode of the probabilistic population belief, making it observationally equivalent to a degenerate population belief. This is why the population belief has not been discussed in the context of this game in the literature. At the current point of the study I let these details remain in the background. Still, please indicate in a comment if a player exhibits any non-degenerate population belief.

Compared to the Beauty Contest, it might at times be difficult to distinguish what is a level-0 belief and what is derived through level reasoning. Try to stick to what is written down and look for clearly stated arguments of reasoning.

[a] I abstract from considerations due to the cycling of behaviour from level 5 onwards.

Model and terminology

The level-k model of bounded rationality assumes that players only think through a certain number (k) of best responses.[a] The model has four main ingredients:

Population distribution This distribution reflects the proportion of types with a certain level $k \in \mathbb{N}_0 = \{0, 1, 2, 3, 4, 5, \ldots\}$.

Level-0 distribution By definition, a level-0 player does not best respond. Hence, his actions are random to the game and distributed randomly over the action space. In our case, the action space is $\mathcal{A} = \{\{1\}, \{2\}, \{3\}, \{4\}\}$ and contains the four possible locations to hide or seek the object. The model incorporates salience by assuming higher probabilities in the level-0 distribution for actions that are salient. In our case, the level-0 distribution would not assign a uniform probability of 0.25 to each possible action, but $p > 0.25$ to the salient one and $q_i < p$ for the remaining actions.

Level-0 belief In the model, the best responses of players with $k > 0$ are anchored in what they believe the level-0 players play. Their level-0 belief might not be consistent with the level-0 distribution. For best responding, all that matters is the expected payoff from choosing a particular location. One would therefore seek (hide) the treasure where the probability is highest (lowest), that the opponent chooses the same location.

Population belief Players do not expect other players to be of the same or a higher level of reasoning. For a level-k player, the population belief is therefore defined on the set of levels strictly below k. It follows that level-0 players have no defined belief, level-1 players have a trivial belief with full probability mass on $\{0\}$, level-2 players have a well defined belief on $\{\{0\}, \{1\}\}$. From level 3 higher order beliefs are relevant as level-3 players have to form a belief about level-2's beliefs.

[a] See the paper by Camerer, Ho and Chong (2004) for a more detailed account of one version of the model.