Meaning, Its Evolution, and Credibility in Experimental Cheap-Talk Games

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Overview

- This paper experimentally investigates the first refinement concept for cheap-talk games.
- The refinement concept is called neologism-proofness, proposed by Farrell (1993).
- We investigate how neologism-proofness performs under different language environments (with and without common languages).

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- We investigate how neologism-proofness performs under different language environments (with and without common languages).
  - In the common language environment, we find that equilibria that survive the refinement are played more often in the lab, providing evidence for the predictive power of neologism-proofness.
  - In the absence of common languages, we obtain a few observations where the meaning of a neologism emerged endogenously.

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- In a signalling game, there are two players, a sender (S) and a receiver (R).
- The sender has some private information, which is represented by his type $\theta \in \Theta$.
- The receiver does not observe θ but has prior beliefs about it.

Signalling Games (Cont.d)

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- After receiving the message, the receiver takes an action $a \in A$.
- Payoff to the sender: $U_S(\theta, m, a)$.
- Payoff to the receiver: $U_R(\theta, m, a)$.

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- In a cheap-talk game, $U_i(\theta, m, a)$ is independent of m.
- $U_i(\theta, a)$, i.e. payoffs depend only on type and action.

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- Eliminate some of the beliefs by restricting how out-of-equilibrium (unused) messages should be interpreted.
- Standard refinements Do Not Apply to Cheap-Talk Games.
- Since messages are costless, for every equilibrium with unused message, there exists another outcome-equivalent equilibrium in which all messages are used.

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Meaning and **Credibility**

Neologism-Proofness

Meaning: Natural Language Requirement

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s	30, 20	20, 30	0, 8
t	30, 20	8, 0	20, 30

Table: Game 1

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- Farrell (1993) assumes that for every equilibrium, unused neologism, whose *literal meaning* is that "my type is in K," exists for every subset K of the sender's type space.
- A message, unused in the equilibrium, exists with literal **meaning** "My type is either s or t." (or "I won't tell you my type.")

Neologism-Proofness

Credibility

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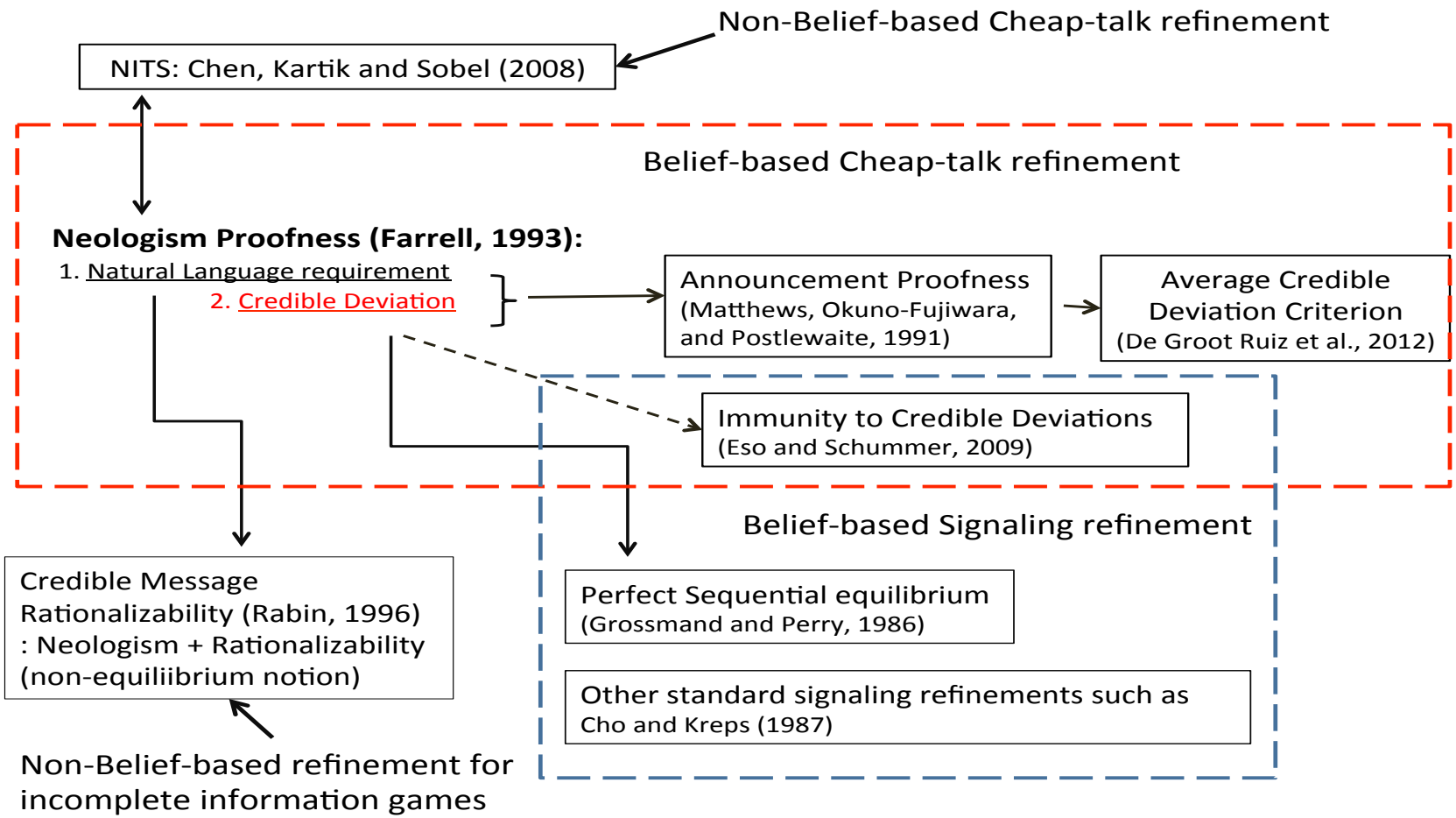
- A **neologism-proof** equilibrium is one in which credible neologism does not exist.

Why Neologism-proofness in the Lab?



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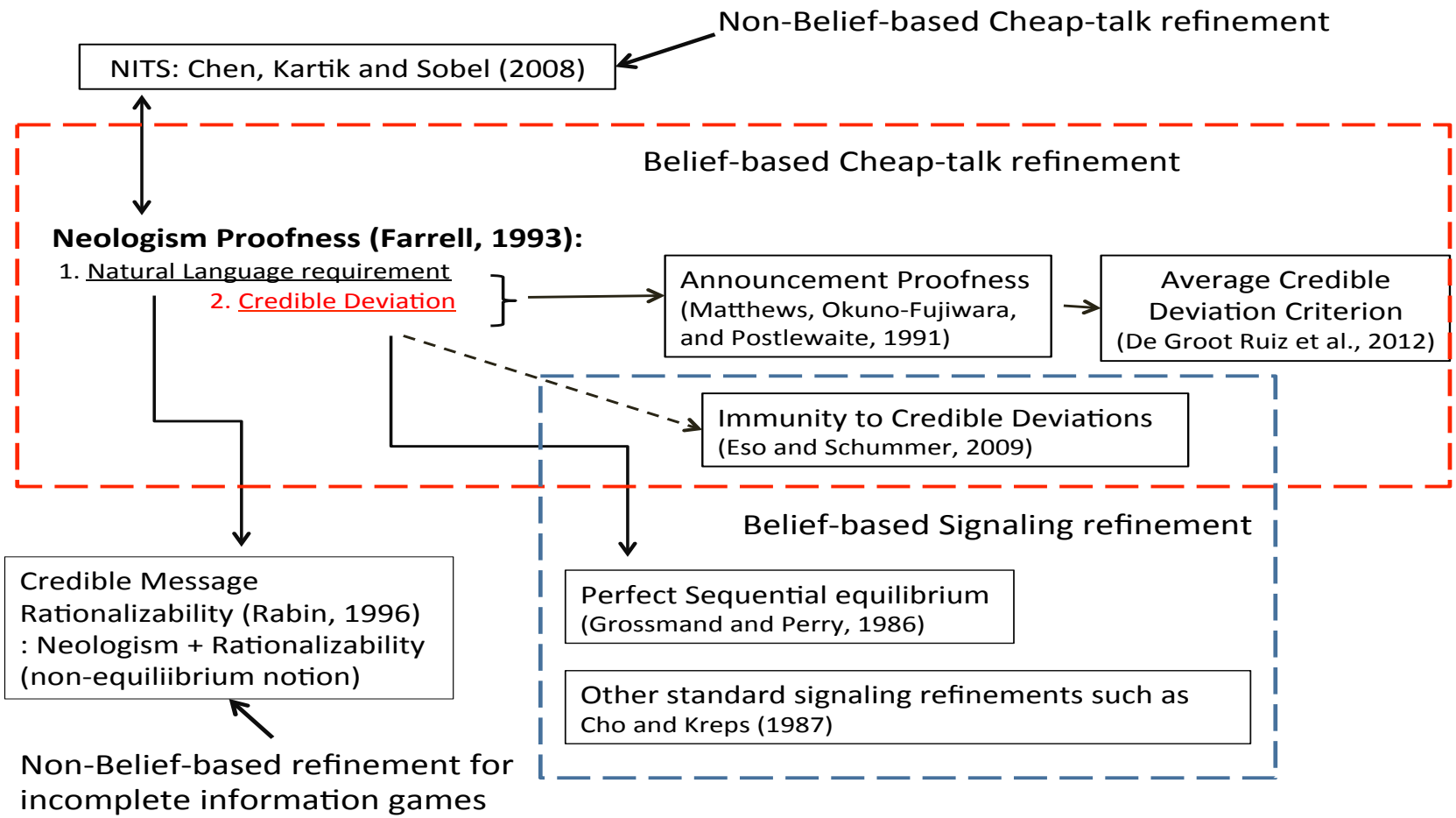

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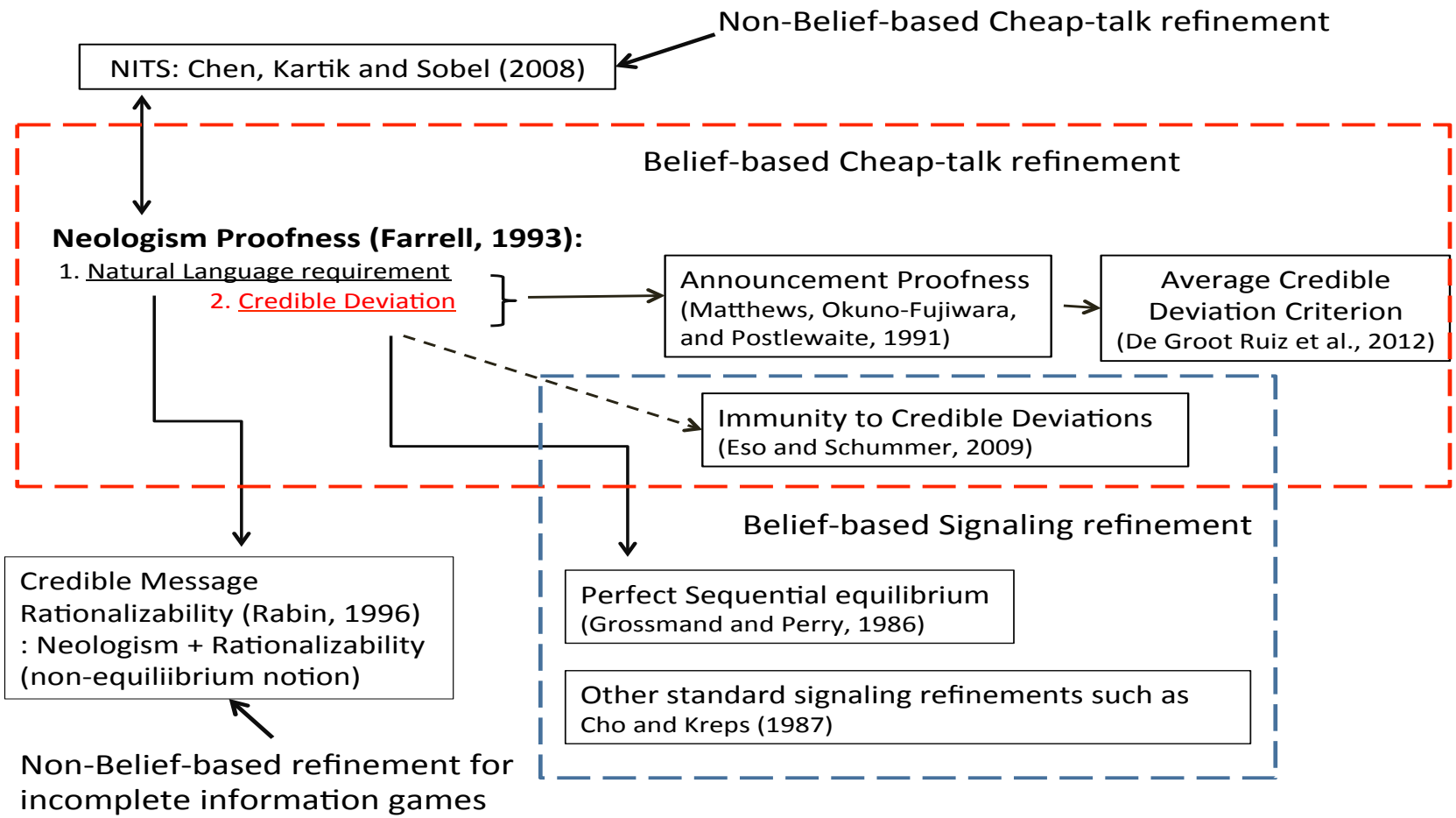

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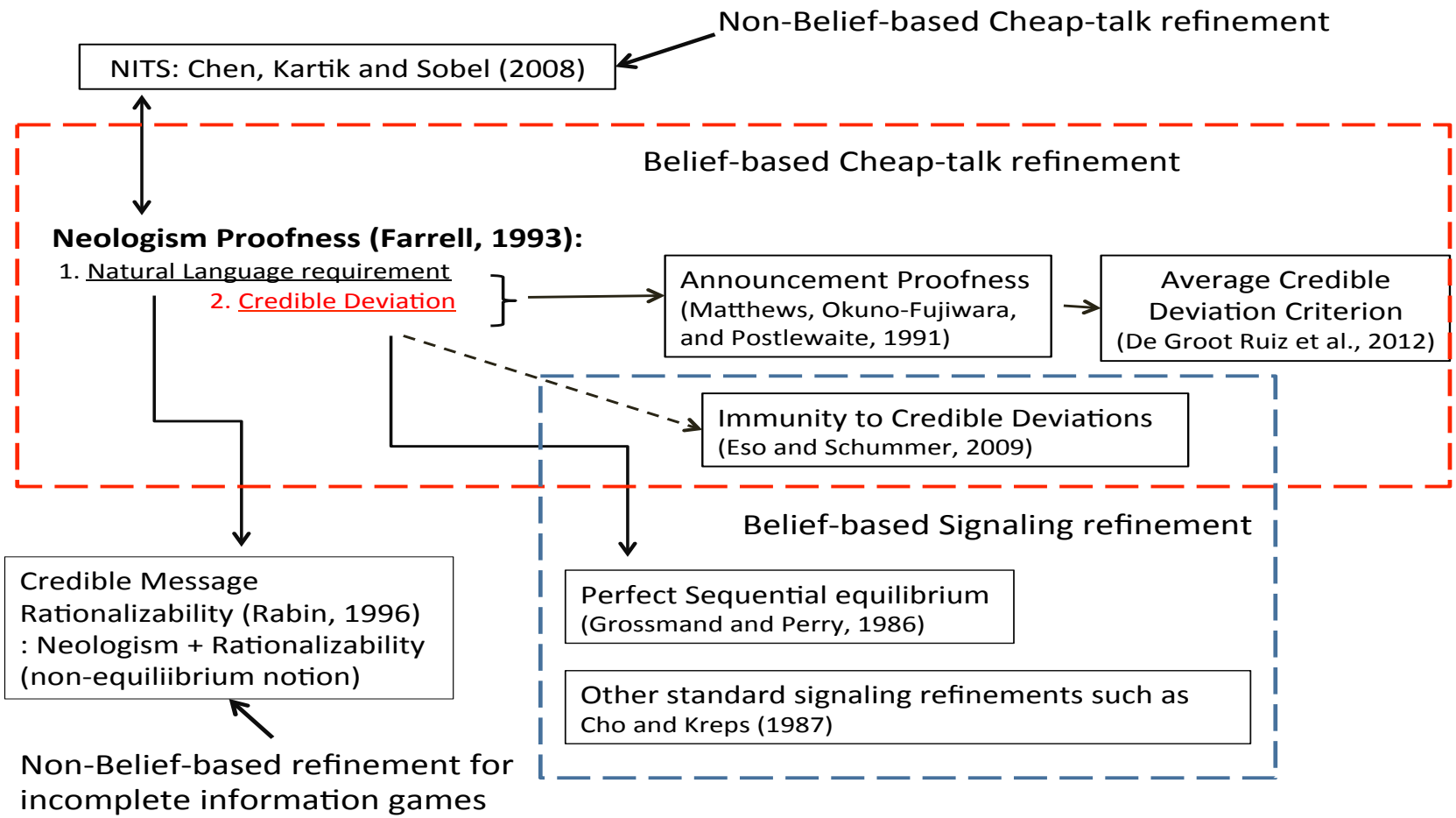

- First, Prevalent, Influential, but NO evidence and still debatable.

Limitations of Neologism-proofness

1. Neologism-proofness lacks a general existence property, and therefore we do not know what it predicts when existence fails.

2. It lacks a complete formalization regarding the presence of unsent messages with natural meaning.

3. It falls short of addressing our concern over the usefulness of natural language, as neologism arises off the equilibrium path but language on the path is still arbitrary.

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We thank Joel Sobel for raising these points to us.

Related Literature

- Experimental communication games
  - Dickhaut, McCabe, and Mukherji (1995), Blume et al. (1998, 2001), Gneezy (2005), Cai and Wang (2006), Sánchez-Pagés and Vorsatz (2007), Hurkens and Kartik (2009), and Wang, Spezio, and Camerer (2010)

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- Experimental studies on costly signalling game refinements
  - Brandts and Holt (1992) and Banks, Camerer and Porter (1994)
- Experimental studies on cheap-talk game refinements
  - Blume, Dejong, Kim and Sprinkle (2001): No selection between Neologism-proofness and Pareto Efficiency.
  - Kawagoe and Takizawa (2008): Neologism-proofness vs. Level-k
  - De Groot Ruiz, Offerman, and Onderstal (2014, 2015): Average Credible Deviation Criterion (ACDC) – New criterion, existence guaranteed

Our Games

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t	30, 20	8, 0	20, 30

Table: Game 1

	L	C	R
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Table: Game 2

- Sender's types $\theta \in \{s, t\}$.
- Receiver's action $a \in \{L, C, R\}$.
- (Sender's payoff, Receiver's payoff)

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- As long as $|M| \geq 2$, the two games each has two equilibria.

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- Message space with two elements:

  $$M' = \{\text{“my type is } s\text{”}, \text{“my type is } t\text{”}\}.$$

  This results in Game $1M2$ and Game $2M2$.

▸ Comments on Natural Language Assumptions

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Game 1$M3$

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- If this neologism is believed, the receiver will take L. Payoffs to s and t will be 30.
- Both s and t strictly prefer the neologism to be believed over what they would receive in the equilibrium—**"I won't tell you my type" is self-signalling**.

Our Games

Game $2M3$

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- "I won't tell you my type" is a neologism.
- If this neologism is believed, the receiver will take L. Payoff to s is 50 but payoff to t is 10.
- Only s but not t strictly prefers the neologism to be believed—**"I won't tell you my type" is not self-signalling**.

Our Games

Game 1$M2$ and Game 2$M2$

- For Game 1$M2$ and Game 2$M2$, since message spaces are binary, there is no neologism associated with the respective fully revealing equilibria.
- The respective fully revealing equilibria trivially survive the neologism-proofness.

Our Games

Proposition 1

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The fully revealing equilibrium outcome in Game $1M3$ *cannot be supported as a neologism-proof equilibrium whereas that in Game* $2M3$ *can.*

Proposition 2

The fully revealing equilibrium outcome in Game $1M2$ *and in Game* $2M2$ *can be supported as a neologism-proof equilibrium.*

Experimental Treatments

Two sets of treatments:

- First set: Four treatments
  - Static approach
  - Messages with commonly shared literal meanings
  - Size of message spaces is a control variable.
  - Strategy method, belief elicited
- Second set: Three treatments
  - Dynamic, evolutionary approach: Farrell (1993) discusses the possibility of there being no pre-existing common language that is rich enough to communicate neologism and therefore the meaning of a neologism must evolve.
  - Messages with no a priori meanings
  - Message spaces: $\{\$, \%\}$ (first 20 rounds) $\longrightarrow \{\$, \%, \&\}$ (second 20 rounds)
  - Choice method, no belief elicited.

First Set of Treatments

	Game 1	Game 2
$\|M\|=3$	Game *1M3*	Game *2M3*
$\|M'\|=2$	Game *1M2*	Game *2M2*

- A 2×2 design.

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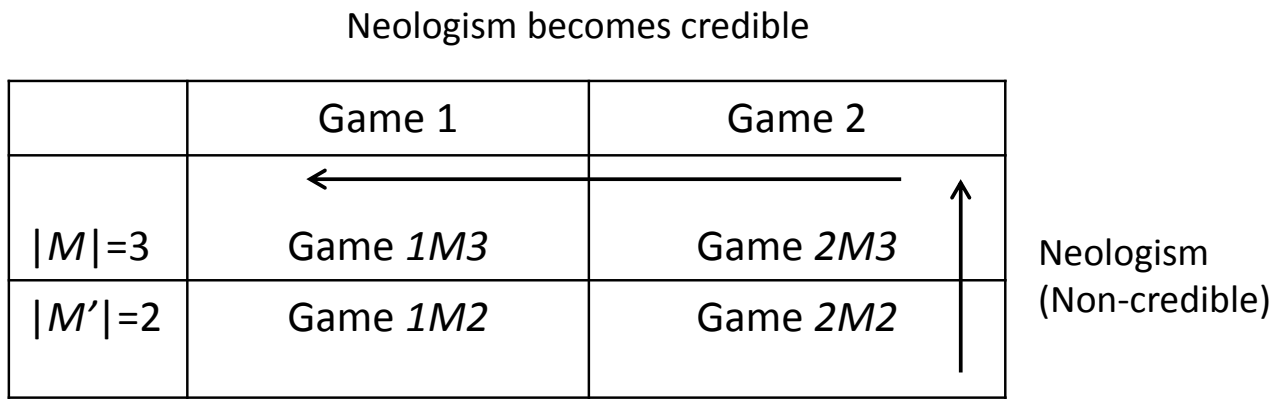
Neologism
(Non-credible)

Hypothesis 1

Effect of the Existence of (Non-Credible) Neologism: *The frequency of fully revealing equilibrium in Game 2M2 is the same as that in Game 2M3.*

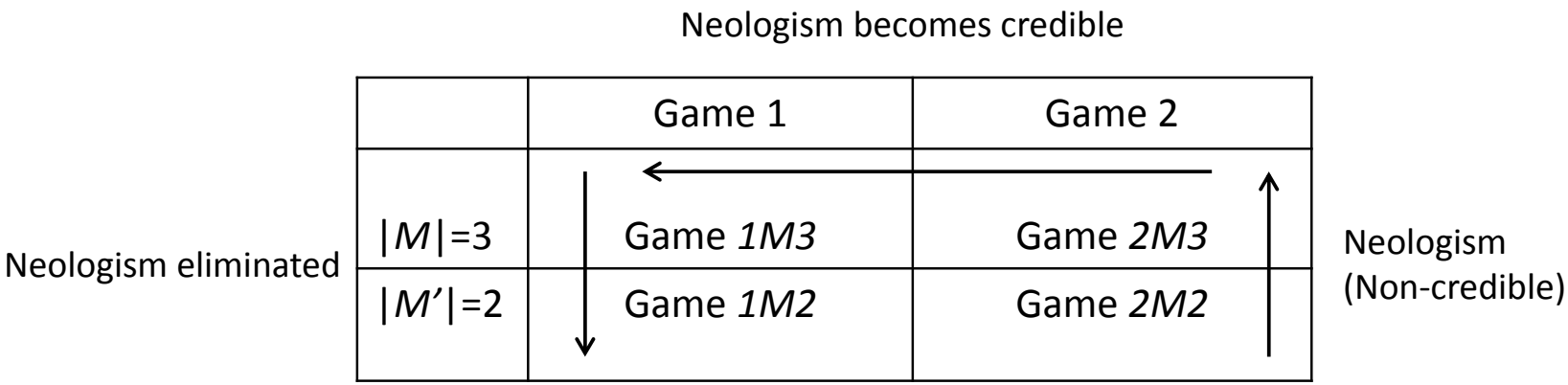
First Set of Treatments



Hypothesis 2

Effect of the Credibility of Neologism: *The frequency of fully revealing equilibrium is higher in Game* 2*M*3 *than in Game* 1*M*3.

First Set of Treatments



Hypothesis 3

Effect of the Existence and Credibility of Neologism: *The frequency of fully revealing equilibrium is lower in Game* 1*M*3 *than in Game* 1*M*2.

Second Set of Treatments

Meaningless M''	Game $1E$	Game $2E$	Game $1E'$
$\lvert M''\rvert = 2 \to 3$	both $\to$ babbling	FRE $\to$ FRE	both $\to$ both

- Message space in Game $1E'$: $\{\$, \%\} \to \{\$, \%$ "My type is s"$\}$

Hypothesis 4

Effect of the Evolution of Meanings of Credible and Non-Credible Neologism:

1. *The meaning that either type is equally likely is endogenously emerged for "&" in Game $1E$, but not in Game $2E$.*
2. *The frequency of "&" being sent is higher in Game $1E$ than in Game $2E$.*
3. *The frequencies of FRE outcome before and after the introduction of "&" are different in Game $1E$. There is no such difference in Game $2E$.*

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- "I Won't Tell You" game in Farrell (1993), Game Γ_2 in Matthews, Okuno-Fujiwara, and Postlewaite (1992), Game 2 in Kawagoe and Takizawa (2008), and Game 1 in Sobel (2013).
- No Pareto Ranking between the two equilibria. Informativeness of the equilibrium cannot be a selection criterion.

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- Other alternative considerations such as other-regarding preferences (fairness and altruism), lying-cost argument, and level-k model of bounded rationality can be ruled out.
- Sender's expected payoffs from the babbling equilibrium (30) and the fully revealing equilibrium (20) are controlled to be the same across the two games.

Experimental Procedures: First Set of Treatment

- The experiment was conducted at The Hong Kong University of Science and Technology using networked computers and z-Tree.
- A total of 160 subjects participated in the experiment.
- Random matching and between-subject design were used.
- Two sessions per treatment; two matching groups per session.
- A matching group consists of 10 subjects, 5 as senders and 5 as receivers.
- A matching group constitutes an independent observation. We thus had a total of 4 observations per treatment.

Strategy Method and Belief Elicitation

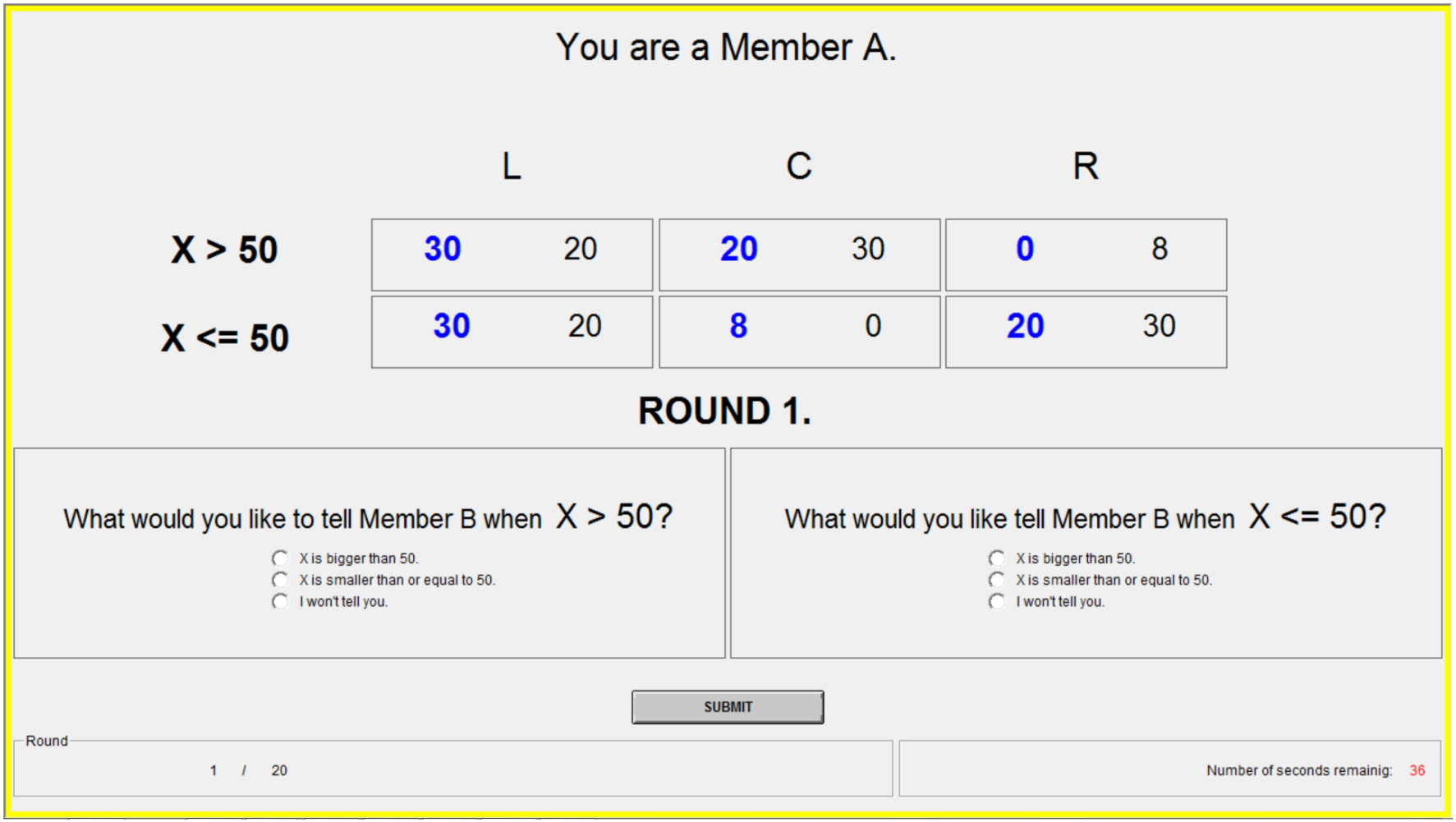


Figure: The Z-tree Screen for Member A (Sender)

Strategy Method and Belief Elicitation

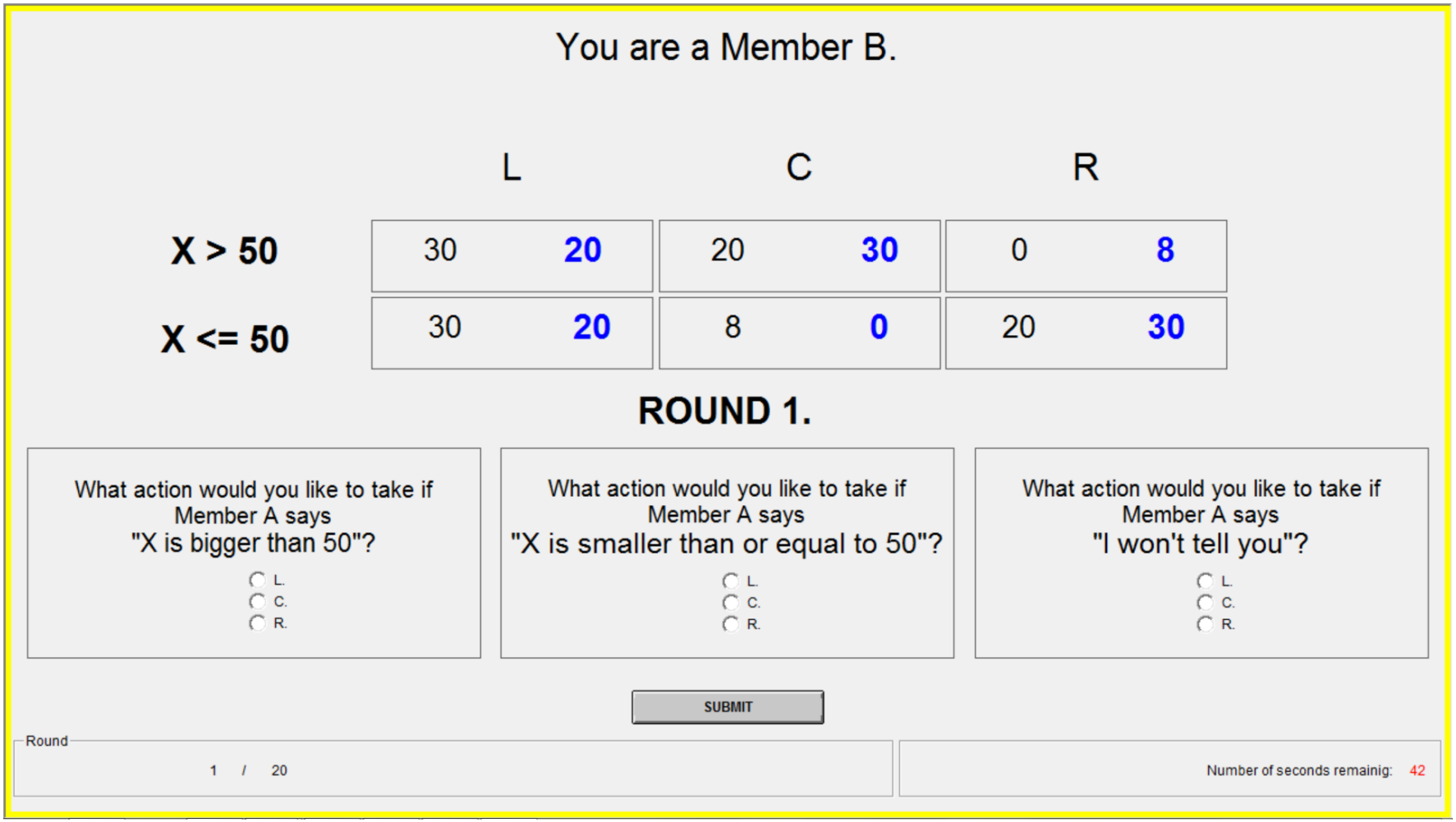


Figure: The Z-tree Screen for Member B (Receiver)

Strategy Method and Belief Elicitation

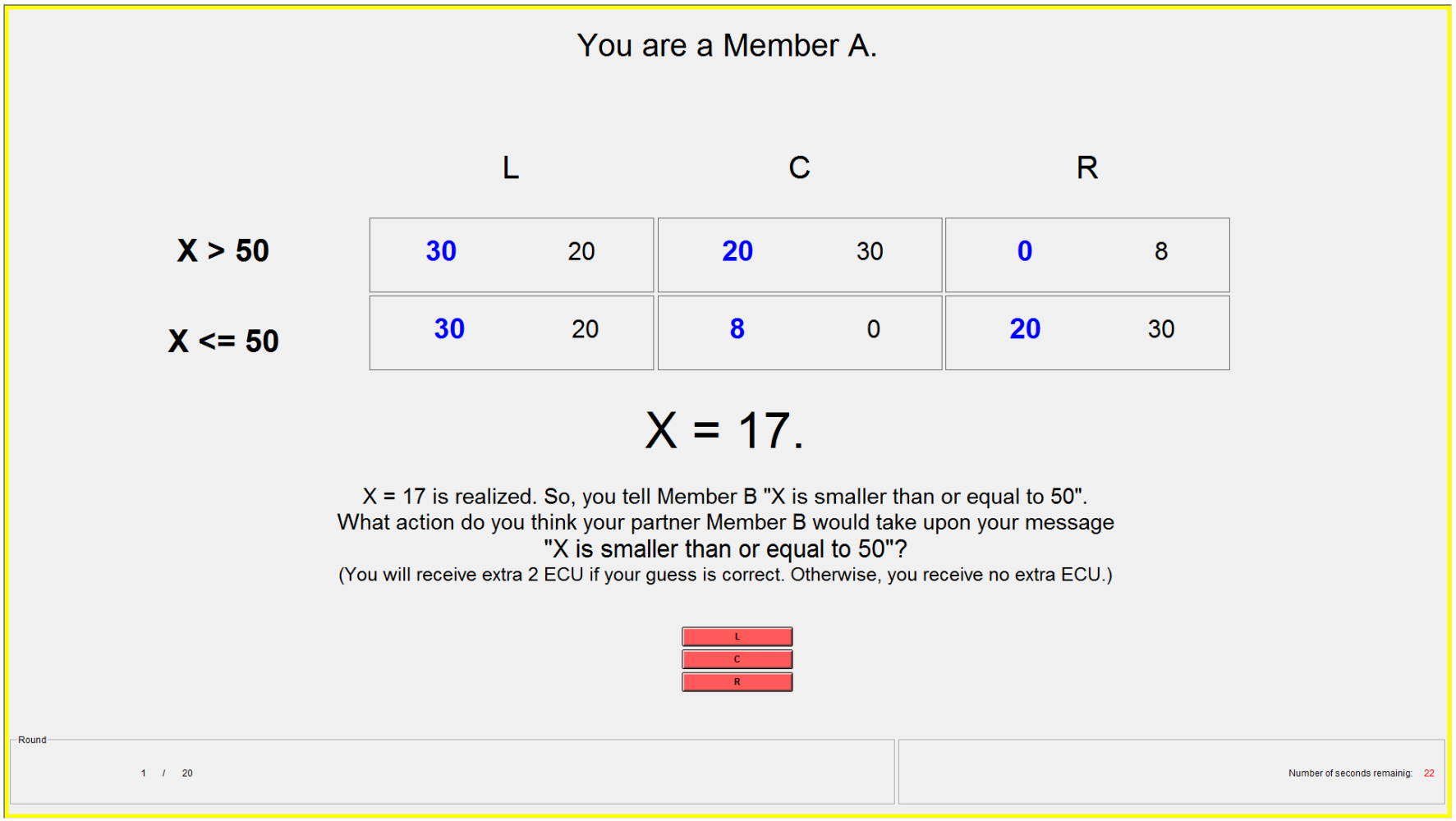


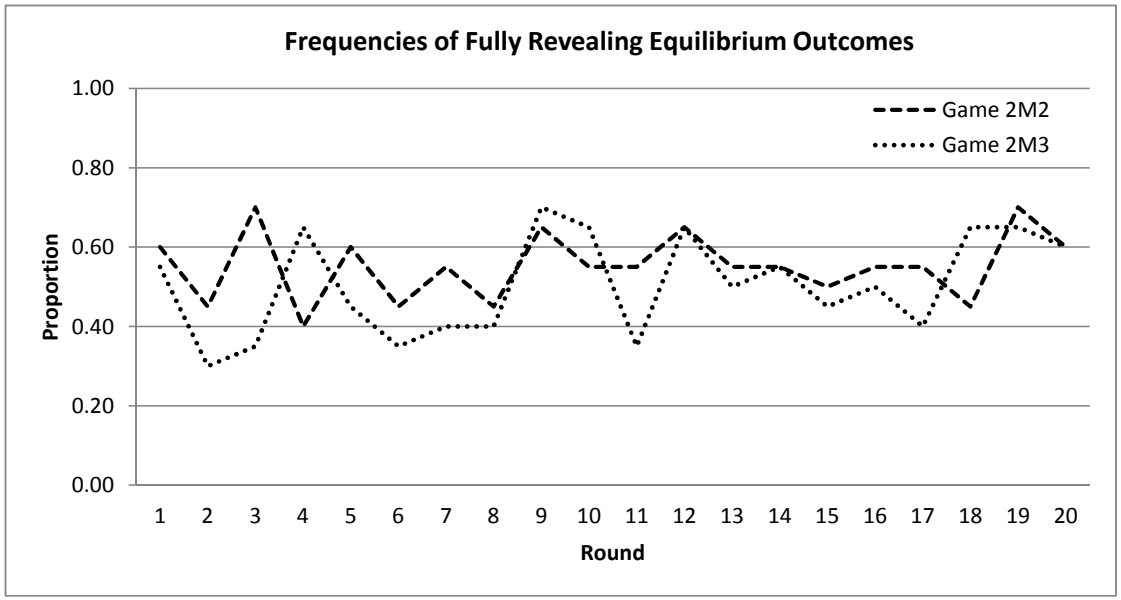
Figure: The Z-tree Screen for Sender's Belief

Experimental Findings

- We first report our findings from the first set of treatments and evaluate the hypotheses using on-path aggregate behavior.
- Results from individuals' strategies and beliefs in the first set of treatments and further, supporting evidence are reported in the paper.
- We then report findings from the second set of treatments.

Findings

Overall Outcomes: Game 2*M*2 and Game 2*M*3

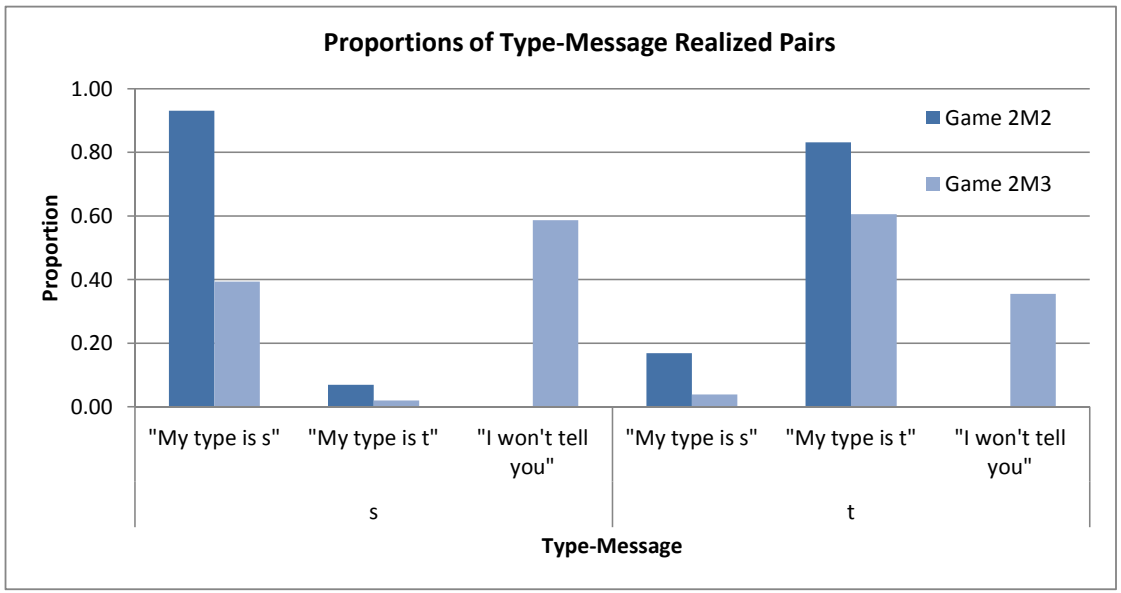


Finding 1

Effect of the Existence of (Non-Credible) Neologism: *Consistent with Hypothesis 1, there was no significant difference in the frequency of fully revealing equilibrium outcomes in Game 2M2 and Game 2M3.*

Findings

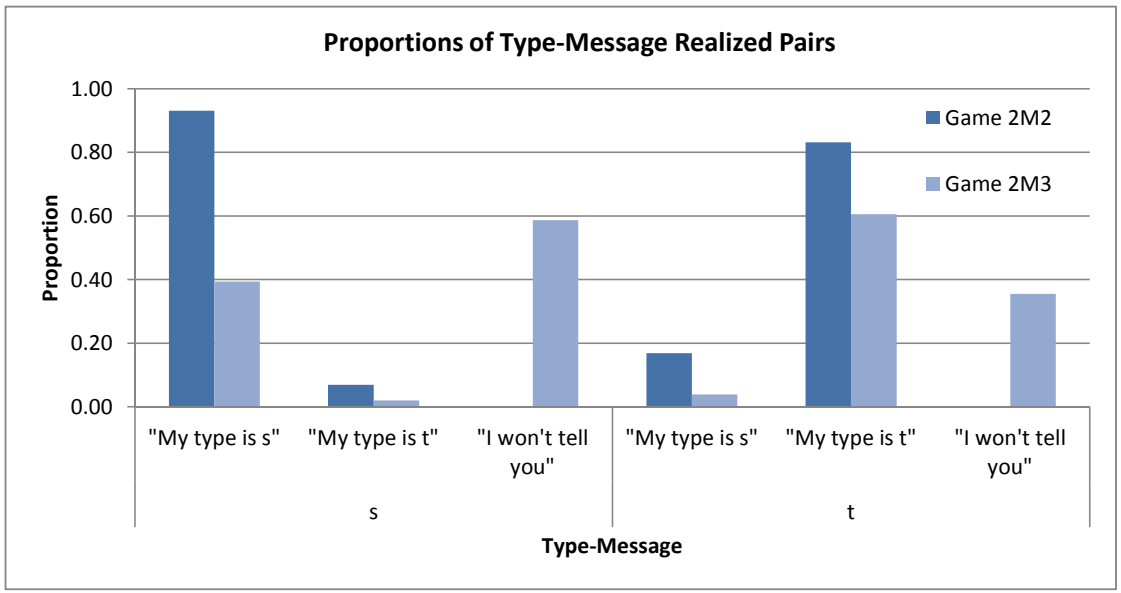
Senders' Behavior: Type-Message: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, senders exhibited truth-telling behavior.

Findings

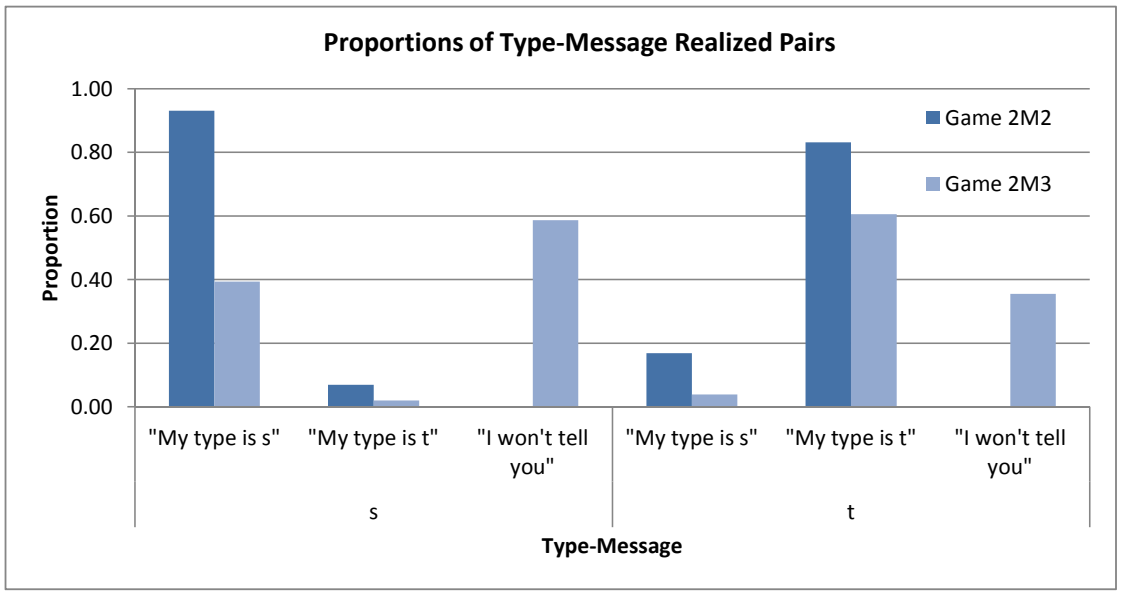
Senders' Behavior: Type-Message: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, senders exhibited truth-telling behavior.
- In Game 2*M*3, there was less truthful behavior.

Findings

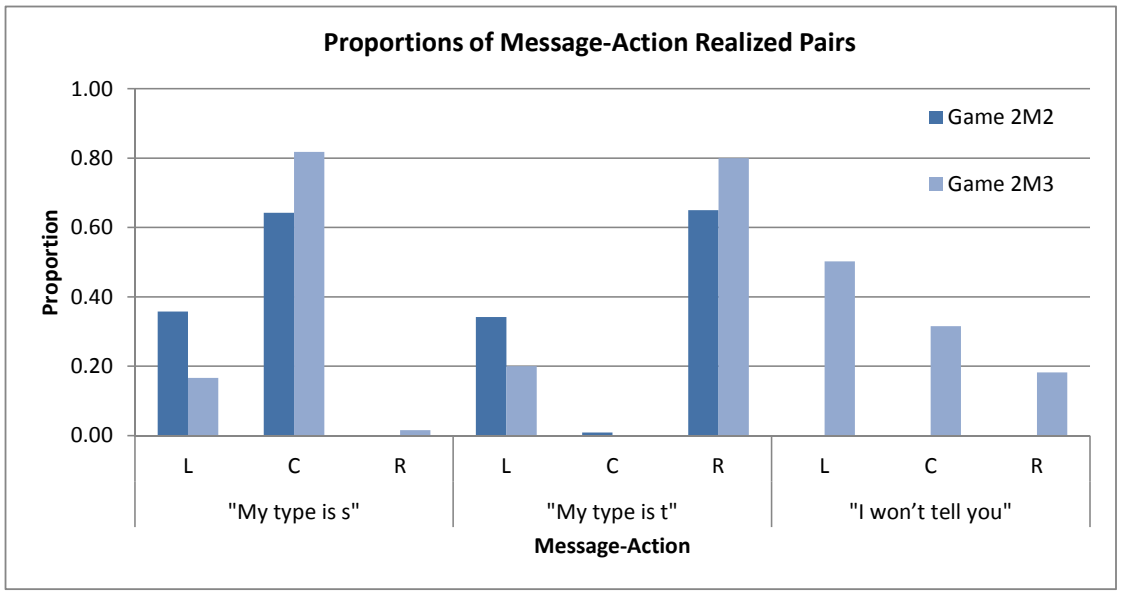
Senders' Behavior: Type-Message: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, senders exhibited truth-telling behavior.
- In Game 2*M*3, there was less truthful behavior.
- Even though the neologism was **non-credible**, it attracted deviating behavior from senders.

Findings

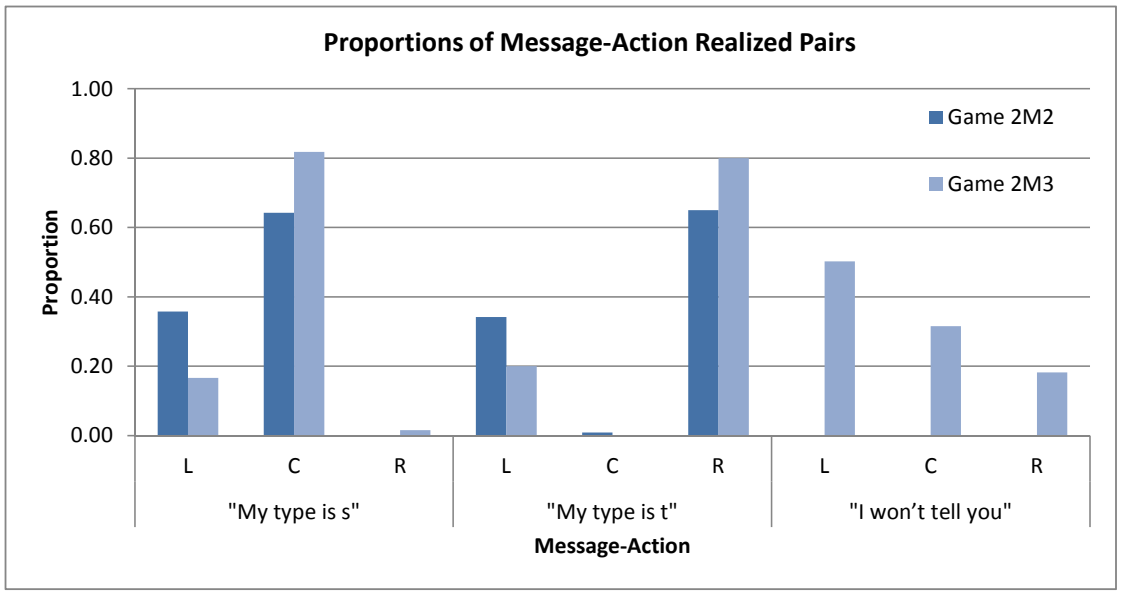
Receivers' Behavior: Message-Action: Game 2*M*2 and Game 2*M*3



- Unlike the case of senders, the presence of non-credible neologism did **not** lead to more deviating behavior from receivers.

Findings

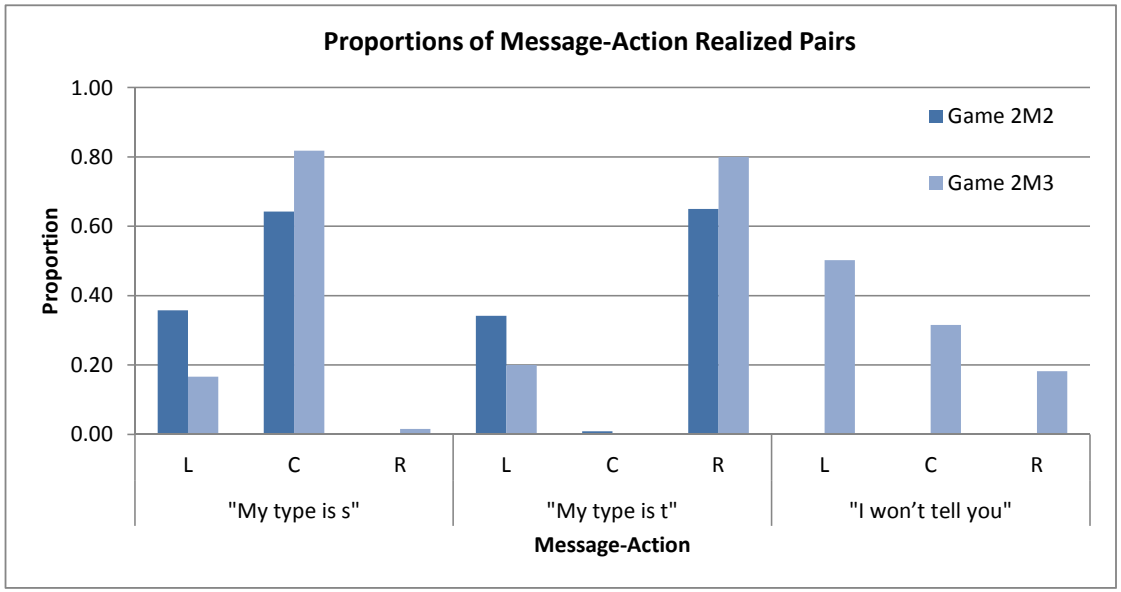
Receivers' Behavior: Message-Action: Game 2*M*2 and Game 2*M*3



- Unlike the case of senders, the presence of non-credible neologism did **not** lead to more deviating behavior from receivers.
- In fact, receivers' behavior in Game 2*M*3 was more in line with the truth-telling equilibrium than receivers' behavior in Game 2*M*2.

Findings

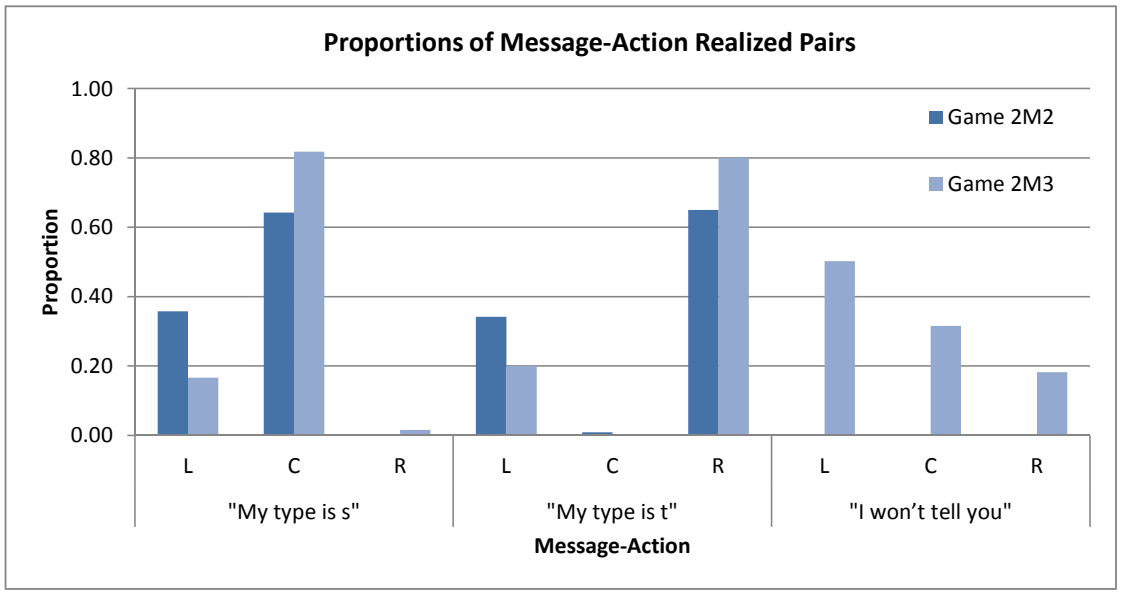
Receivers' Behavior: Message-Action: Game 2*M*2 and Game 2*M*3



- In terms of generating deviating behavior, the presence of non-credible neologism affected **senders but not receivers**.

Findings

Receivers' Behavior: Message-Action: Game 2*M*2 and Game 2*M*3

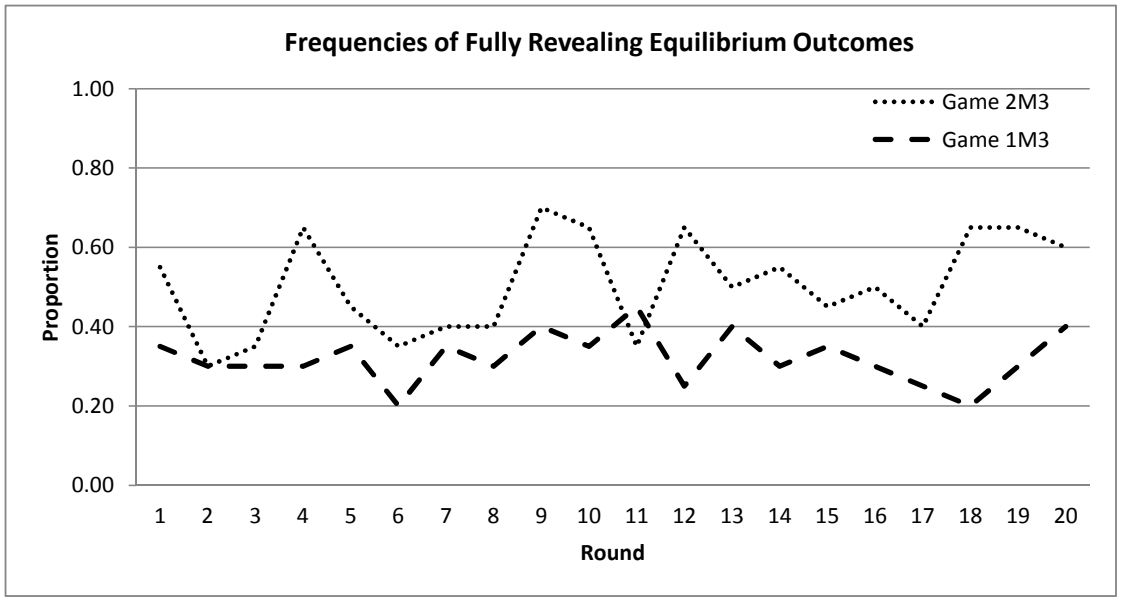


- In terms of generating deviating behavior, the presence of non-credible neologism affected **senders but not receivers**.

- Different senders' behavior roughly **offset** different receivers' behavior to generate the same overall frequencies of fully revealing equilibrium outcomes.

Findings

Overall Outcomes: Game 2*M*3 and Game 1*M*3

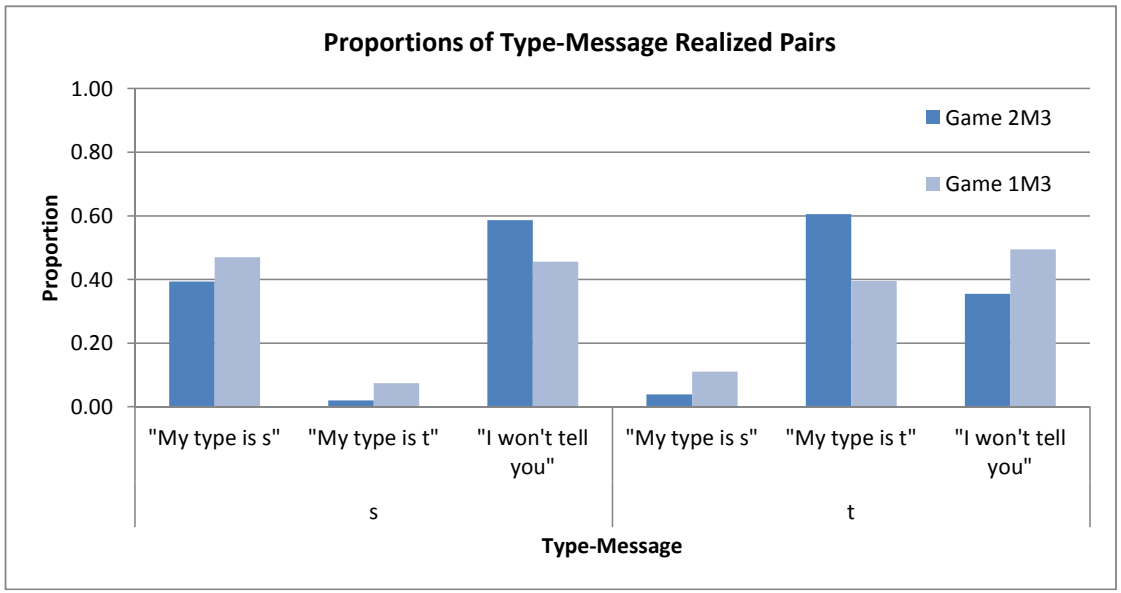


Finding 2

Effect of the Credibility of Neologism: *Consistent with Hypothesis 2, the frequency of fully revealing equilibrium outcomes was significantly higher in Game* 2*M*3 *than in Game* 1*M*3*.*

Findings

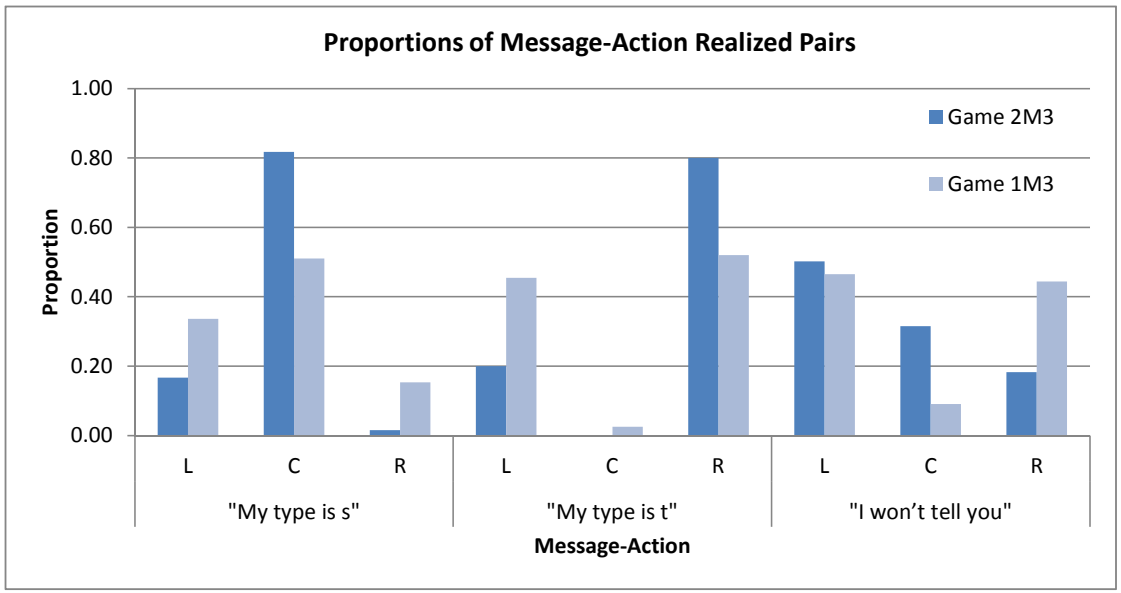
Senders' Behavior: Type-Message: Game 2*M*3 and Game 1*M*3



- The credibility of the neologism has varying and **insignificant** impacts on senders' behavior.

Findings

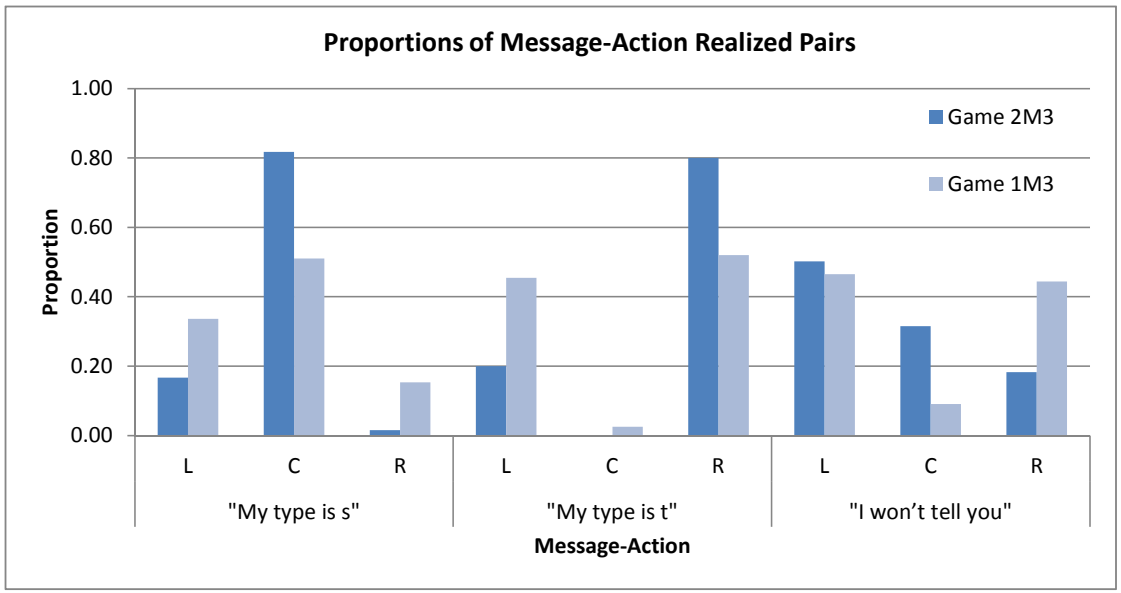
Receivers' Behavior: Message-Action: Game 2*M*3 and Game 1*M*3



- For the receivers, the credibility of the neologism decreased the frequencies of truth-telling equilibrium behavior.

Findings

Receivers' Behavior: Message-Action: Game 2*M*3 and Game 1*M*3

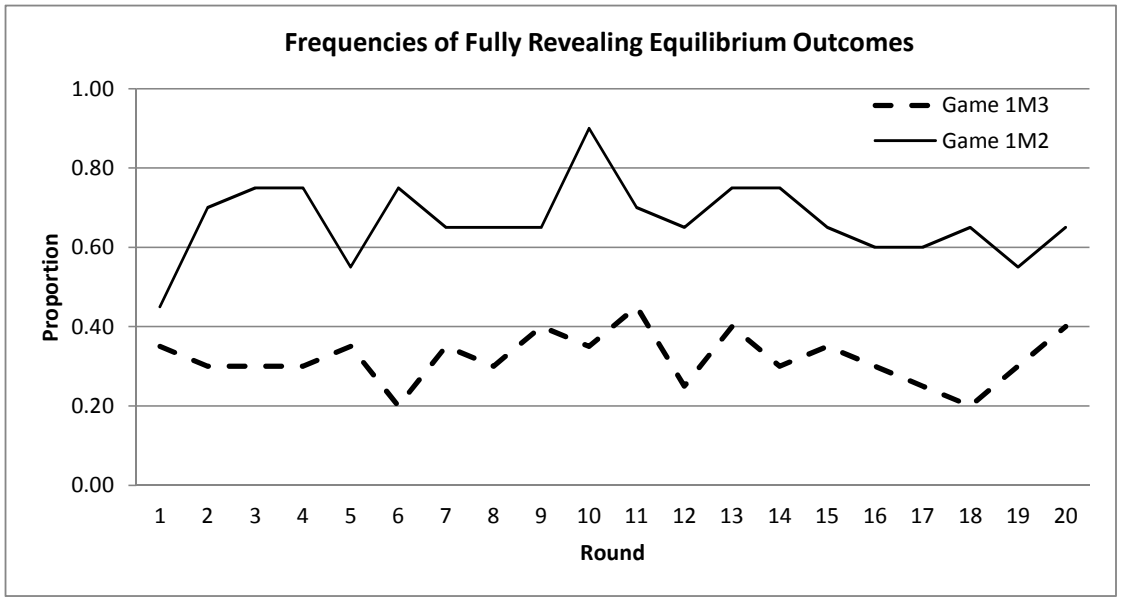


- For the receivers, the credibility of the neologism decreased the frequencies of truth-telling equilibrium behavior.

- In terms of generating deviating behavior, the credibility of the neologism affected **receivers but not senders**.

Findings

Overall Outcomes: Game 1*M*3 and Game 1*M*2

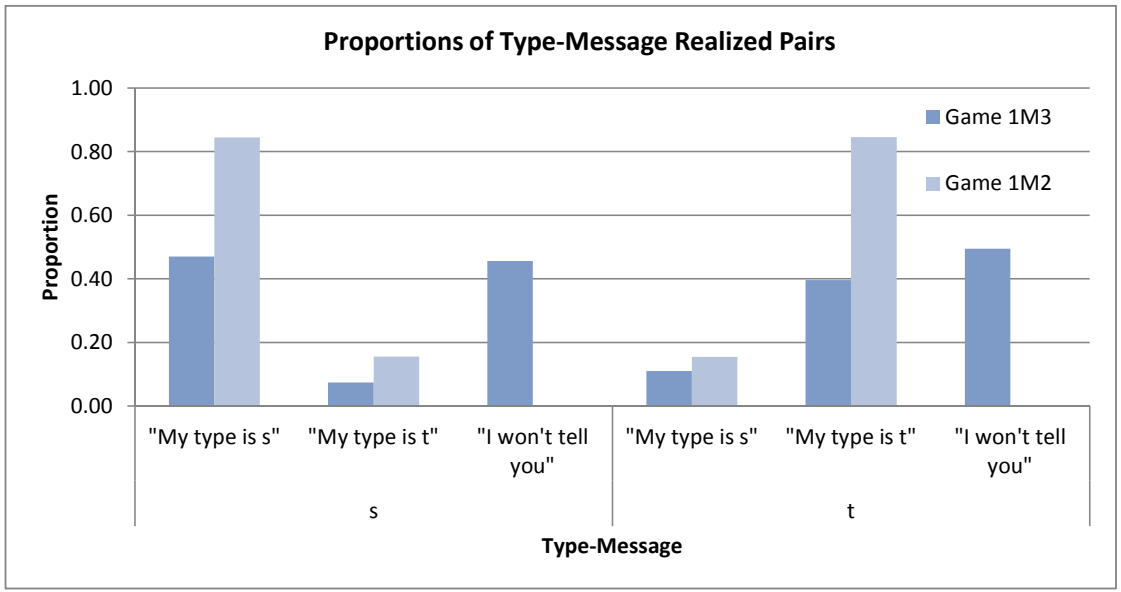


Finding 3

Effect of the Existence and Credibility of Neologism: *Consistent with Hypothesis 3, the frequency of fully revealing equilibrium outcomes was significantly lower in Game* 1*M*3 *than in Game* 1*M*2*.*

Findings

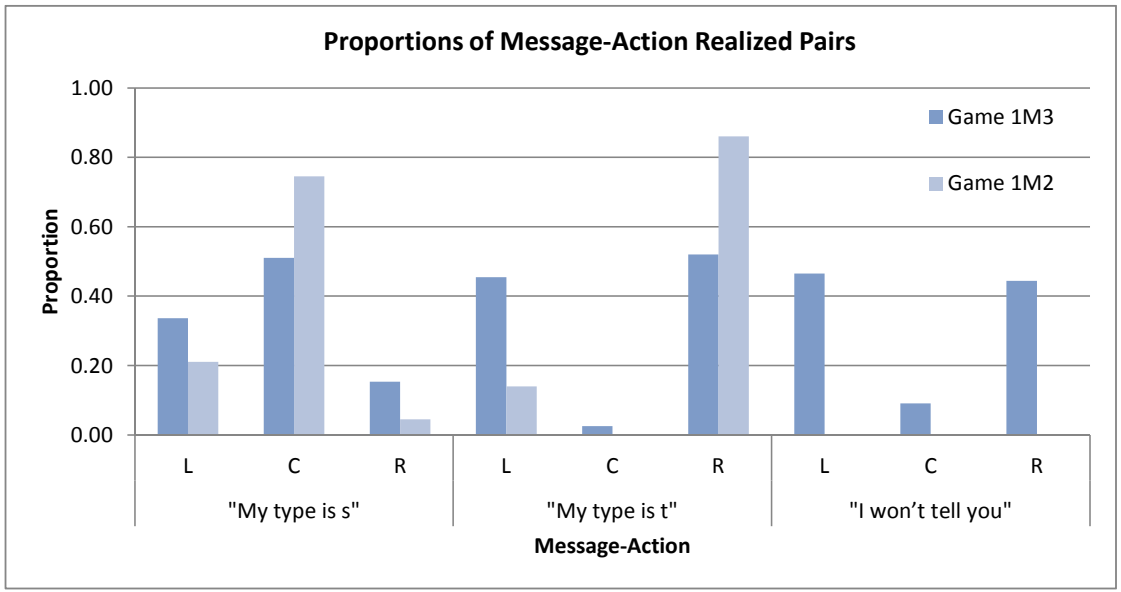
Senders' Behavior: Type-Message: Game 1*M*3 and Game 1*M*2



- The elimination of credible neologism increased the frequencies of senders' truth-telling behavior.

Findings

Receivers' Behavior: Message-Action: Game 1$M3$ and Game 1$M2$



- The elimination of credible neologism increased the frequencies of receivers' truth-telling equilibrium behavior.

Experimental Procedures: Second Set of Treatment

- A total of 132 subjects participated in the experiment.
- Random matching and between-subject design were used.
- Two sessions per treatment; four to six matching groups per session.
- A matching group consists of 4 subjects, 2 as senders and 2 as receivers.
- A matching group constitutes an independent observation. We thus had a total of 9-12 observations per treatment.

Introduction of Third Message

You are a Member A.

	L		C		R	
X > 50	**30**	20	**20**	30	**0**	8
X <= 50	**30**	20	**8**	0	**20**	30

So far, you have participated in 20 rounds of decision making, where two messages % and $ are available for every Member A.

Now, you will participate in **another 20 rounds** of decision making, where **one additional message, &,** will be made available to every Member A.

Thus, Member A now has **three available messages** to choose from. All other things will remain the same as before.

If you have any questions, please raise your hand. Otherwise, please click the OK button.

OK

Round

21 / 40

Number of seconds remainig: 56

A Few Observations to Highlight

Observation 1

The frequency of the third message "&" being sent is significantly higher in Game 1E (47%) than in Game 2E (25%).

A Few Observations to Highlight

- We identify the groups in which distinct meanings have emerged for the two initial messages in the first 20 rounds.
  1. For each message, there is one type who sent the message at least 60% of the time, and
  2. For at least one message, there is one type who sent the message for more than 70%.
- There are 5 and 10 groups out of 12 that belong to this category respectively in Games $1E$ and $2E$.
- For our analysis, we exclusively look at the behavior of these groups.

A Few Observations to Highlight

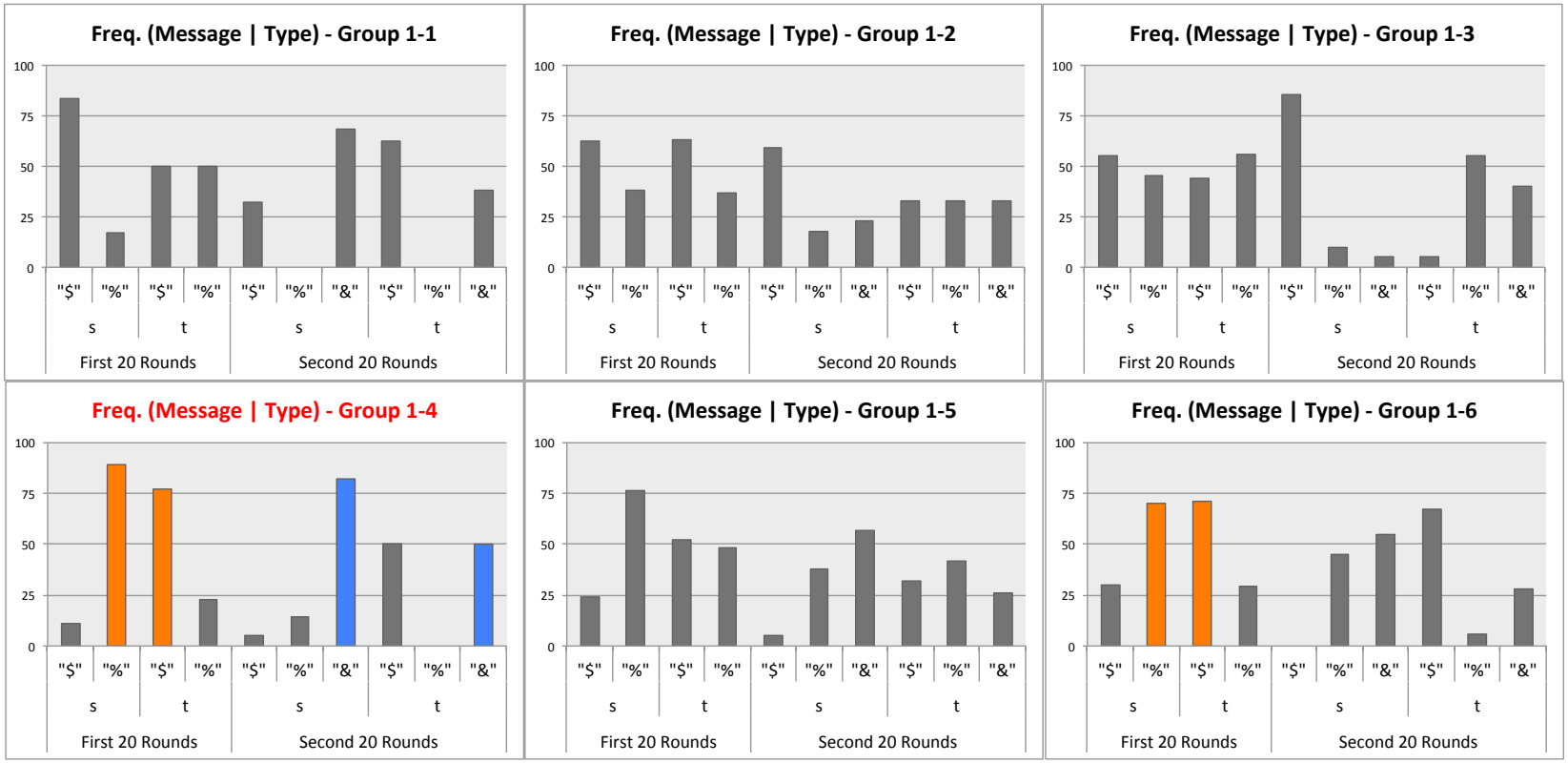


Figure: Freq. (Message | Type) - Game 1*E*

Observation 2

In 3 out of 5 groups in Game 1*E*, *a meaning not present before the introduction of the third message "&", that the sender is equally likely to be of either type, endogenously emerges for "&".*

A Few Observations to Highlight

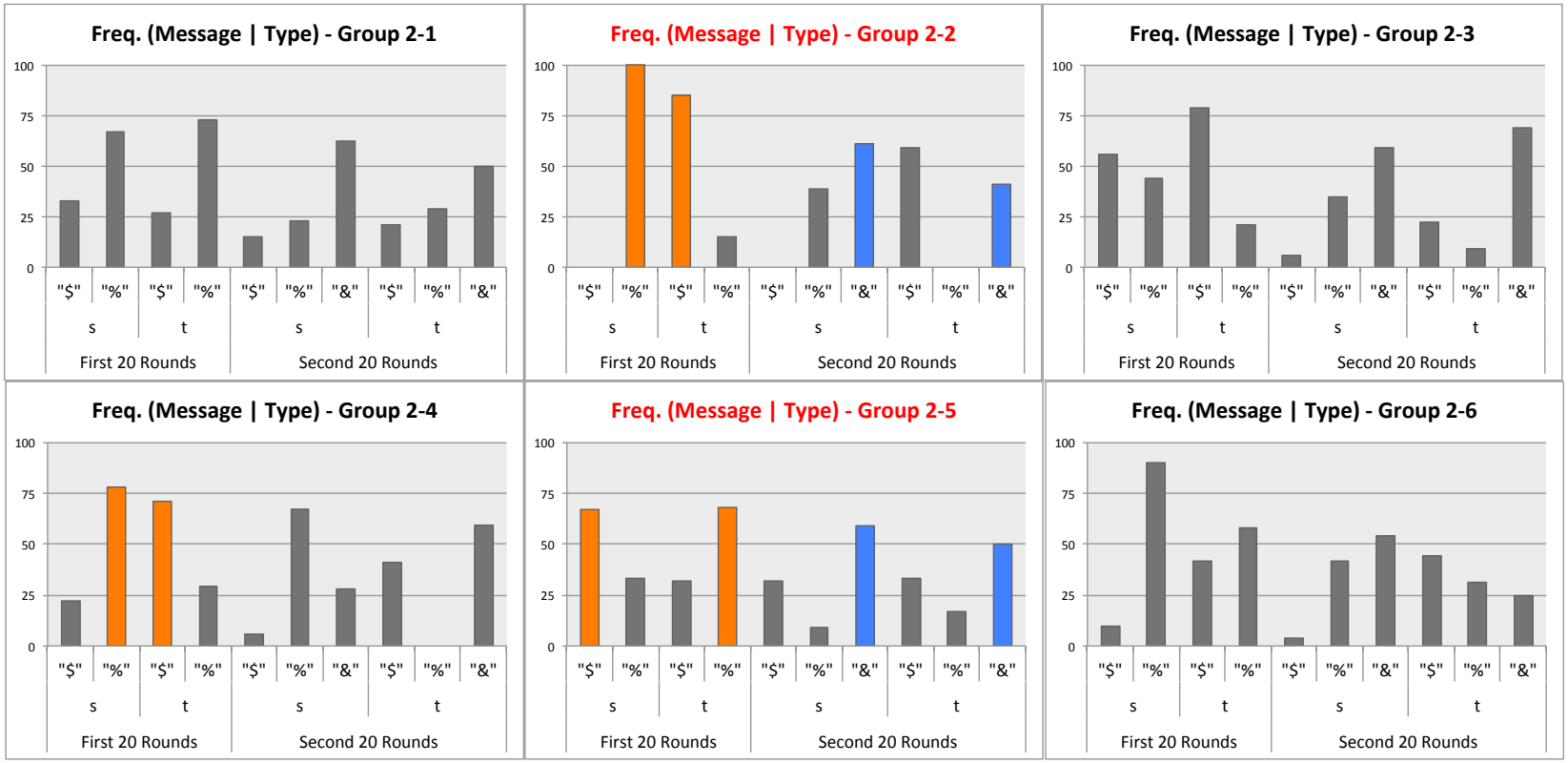


Figure: Freq. (Message | Type) - Game 1E

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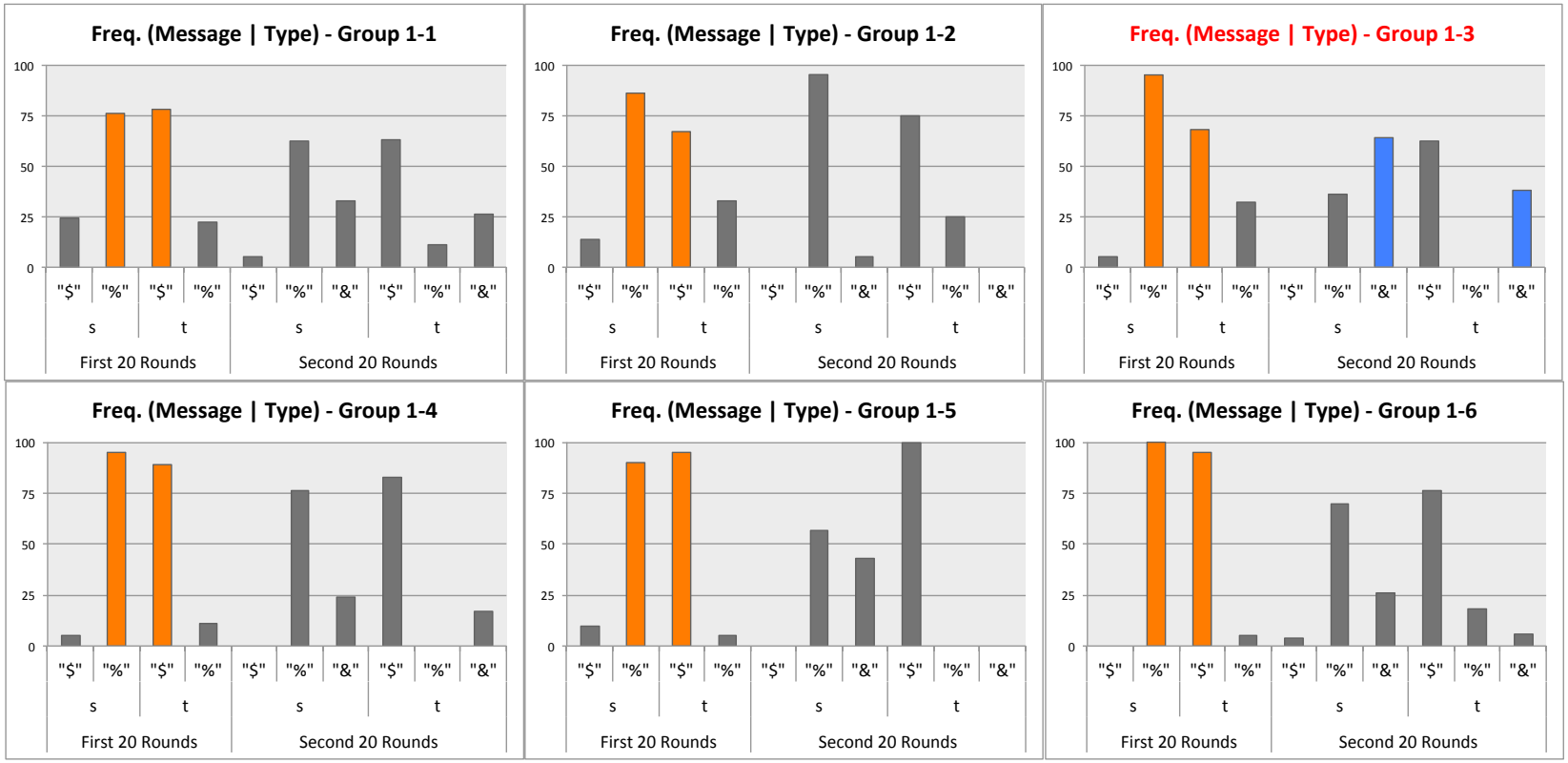
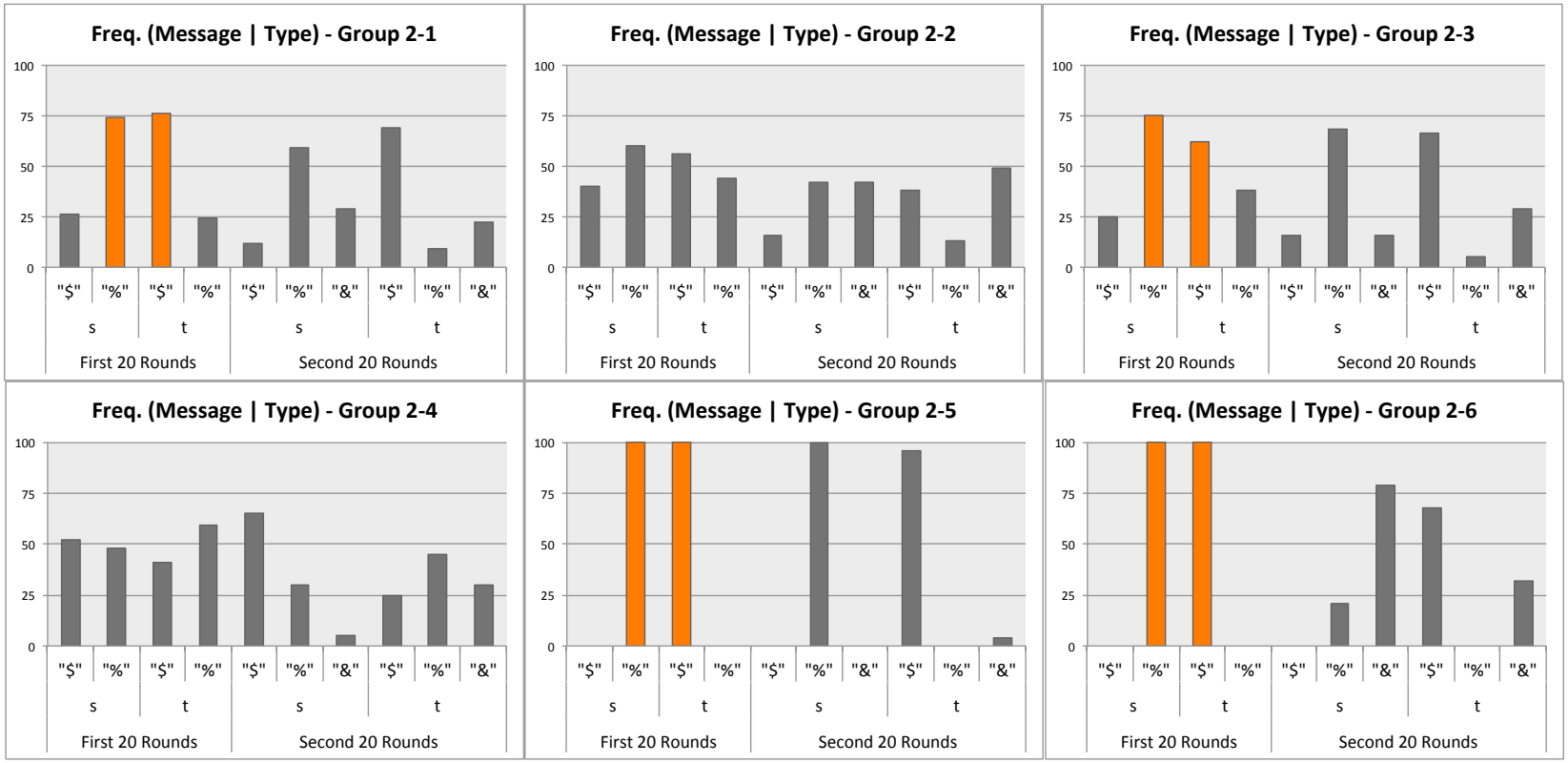


Figure: Freq. (Message | Type) - Game 2E

Observation 3

In (at most) 1 out of 10 groups in Game 2E, a meaning not present before the introduction of the third message "&", that the sender is equally likely to be of either type, endogenously emerges for "&".

A Few Observations to Highlight



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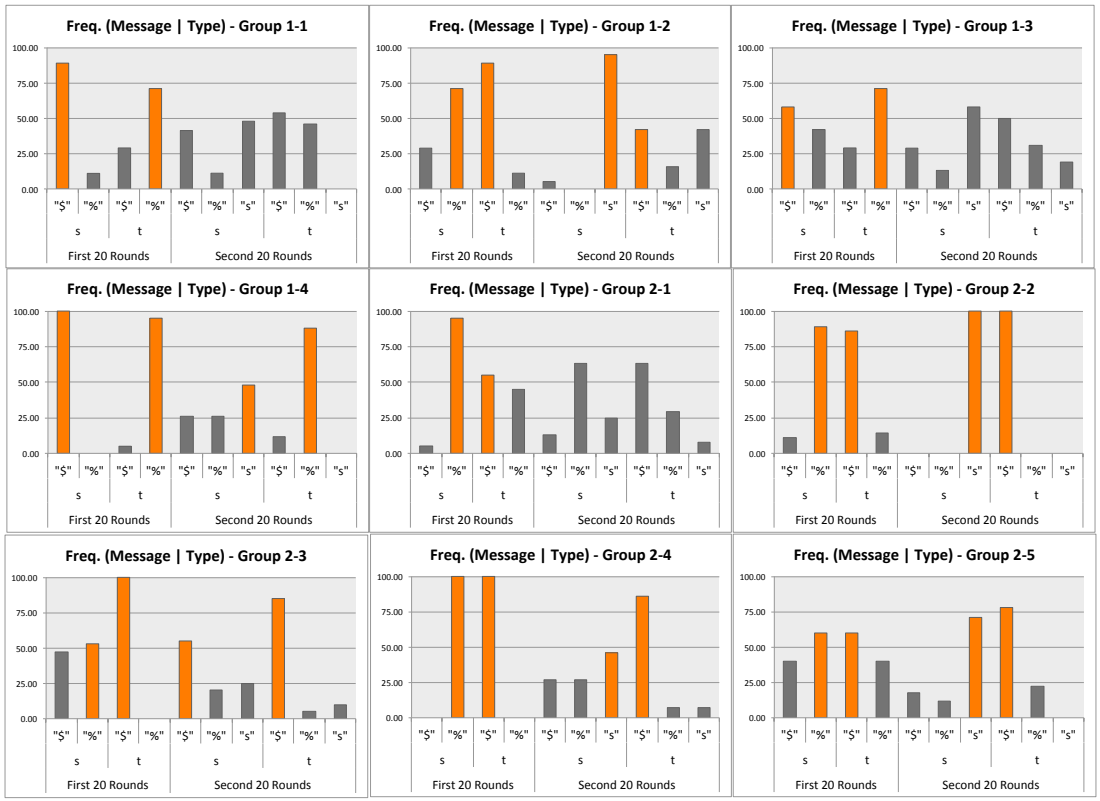

Figure: Freq. (Message | Type) - Game 1E'

Observation 4

The result we obtained in Game 1E *is not due to the experimenter demand effect!*

Summary

- We find that neologism played an evident role in how subjects played the games.

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Summary

- We find that neologism played an evident role in how subjects played the games.
- Overall, fully revealing equilibria that are robust in the sense of being neologism-proof were played more often.
- The mere existence of meaningful neologism, even though non-credible, attracted deviating behavior on senders' part.
- Receivers' behavior, on the other hand, was affected by whether the neologism was credible or not, with credible neologism attracting more deviating behavior from separating strategies.

Appendix

Comments on Natural Languages and Message Spaces

- Farrell's (1993) notion of "*natural* languages" requires two things:
  1. **Common** language: Each message has its literal meaning associated with a type in the type space.
  2. **Rich** language: The message space is large enough.

  $\Rightarrow$ For any subset K of the sender's type space, a message with its literal meaning"my type is in K" exists.

- One more assumption is made to make sure that an unsent message exists in any equilibrium:

  > *"S prefers where possible to use messages that are* **short, simple and straightforward**. *For example, if type t wants (and is expected) to reveal himself, and if both the English sentences, "I am t" and "I am either v or u" are interpreted in equilibrium as meaning "I am t" then S will prefer former." (Farrell, 1993: pp. 518)*

Appendix

Comments on Natural Languages and Message Spaces

- Imposing a lying cost / preference for truth-telling is very common in the literature:
  - Kartik (2009, RES), Chen, Kartik, and Sobel (2008, ECMA), Hurkens and Kartik (2008, Experimental Economics)
  - Lexicographical Lying Cost and Evolutionary Stability: Demishelis and Weibull (2008, AER), Heller (2014, AER)
  - Level-k models with truthful $L0$ senders: Crawford (2003, AER), Cai and Wang (2006, GEB)
- Note that it is impossible to discuss a lying cost / preference for truth-telling without introducing some kind of "literal meaning" for a message.
- What Farrell (1993) assumes— **a lexicographical preference for simple, truthful, and straightforward messages**— is not too far from the standard in the literature.

▸ Back

Further Findings

Strategy Categories

- Leveraging on the strategy method, we examine the strategy individual subjects adopt and provide the resulting aggregate frequencies that fit into the strategy categories we devise.

- The objective is to see whether the findings we have seen so far were supported by subjects playing the corresponding strategies.

Further Findings

Strategy Categories

- Leveraging on the strategy method, we examine the strategy individual subjects adopt and provide the resulting aggregate frequencies that fit into the strategy categories we devise.
- The objective is to see whether the findings we have seen so far were supported by subjects playing the corresponding strategies.
- For senders, we have four strategy categories:
  - Literal babbling (sending "I won't tell you" for both s and t)
  - Non-revealing (s and t sending the same message)
  - Truth-telling (s sending "My type is s" and t sending "My type is t")
  - Fully revealing (s and t sending different messages)

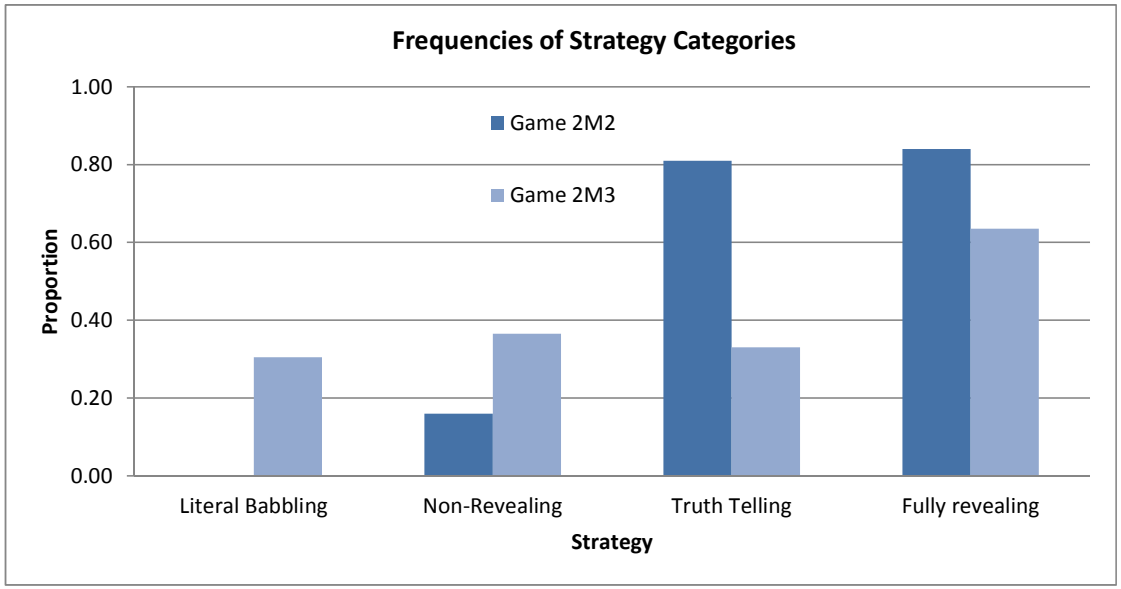
Further Findings

Strategy Categories

- For receivers, we have two strategy categories:
  - Pooling (taking L after all available messages)
  - Separating (taking C after "My type is s" and taking R after "My type is t," and, for three-message games, taking any action after "I won't tell you")

Further Findings

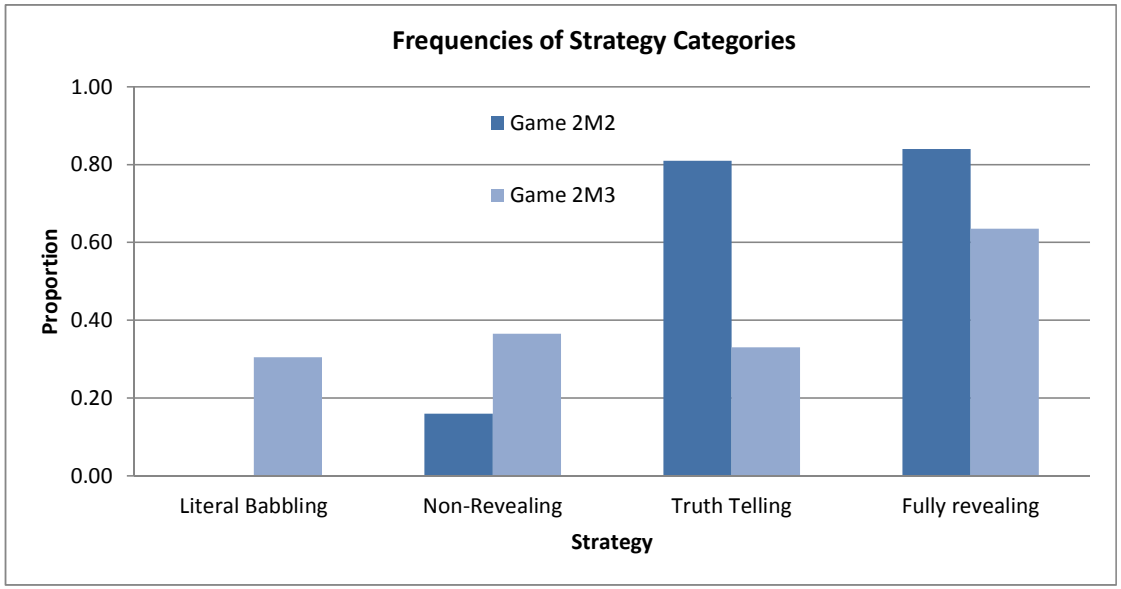
Senders: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, almost all fully revealing strategies were truth-telling.

Further Findings

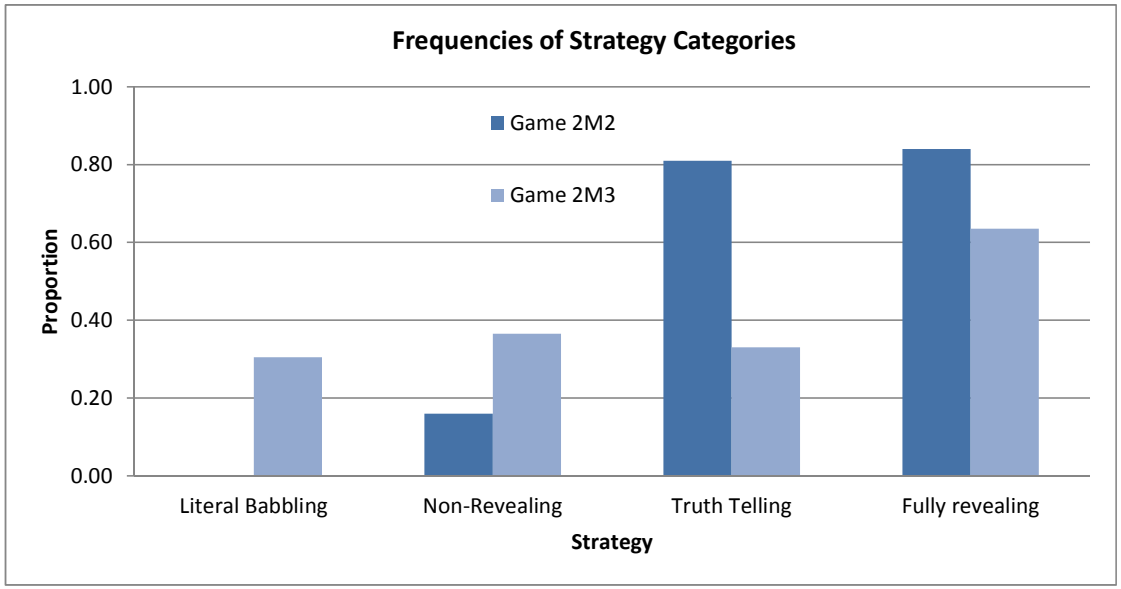
Senders: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, almost all fully revealing strategies were truth-telling.
- In Game 2*M*3, "I won't tell you" was paired with another message which effectively revealed senders' types.

Further Findings

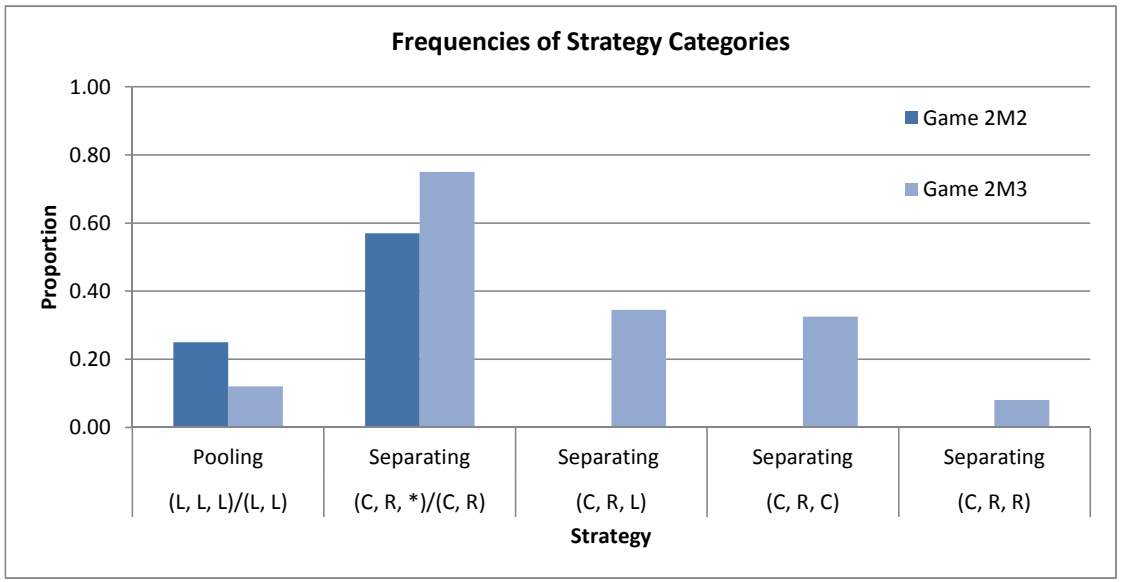
Senders: Game 2*M*2 and Game 2*M*3



- In Game 2*M*2, almost all fully revealing strategies were truth-telling.
- In Game 2*M*3, "I won't tell you" was paired with another message which effectively revealed senders' types.
- The finding that non-credible neologism attracted senders' deviating behavior was supported.

Further Findings

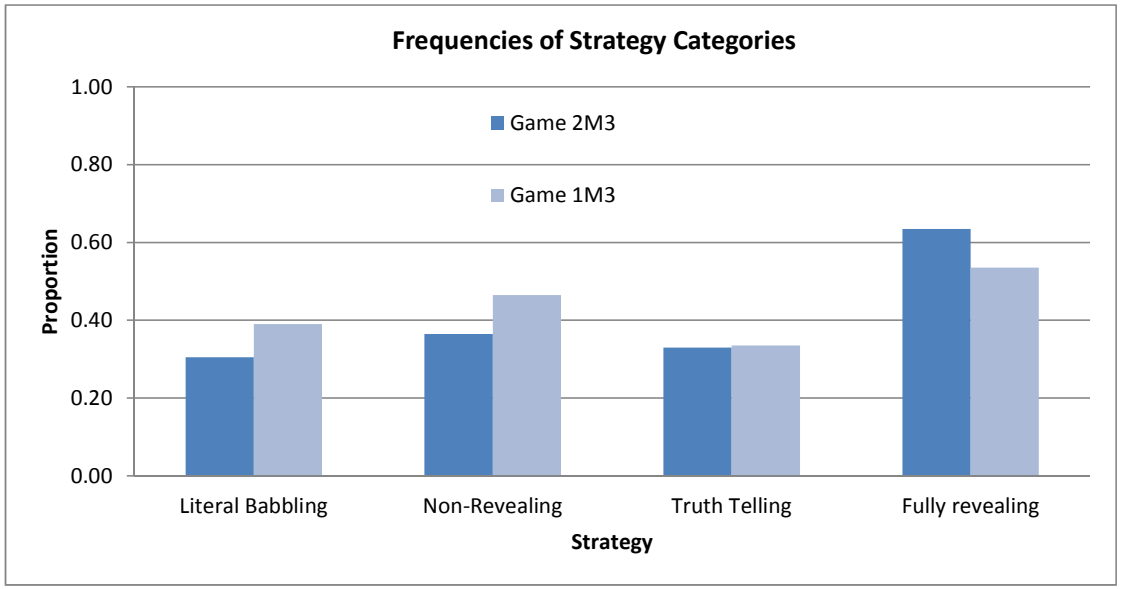
Receivers: Game 2*M*2 and Game 2*M*3



- Consistent with the finding that receivers' behavior in Game 2*M*3 was more in line with truth-telling equilibrium than receivers' behavior in Game 2*M*2.

Further Findings

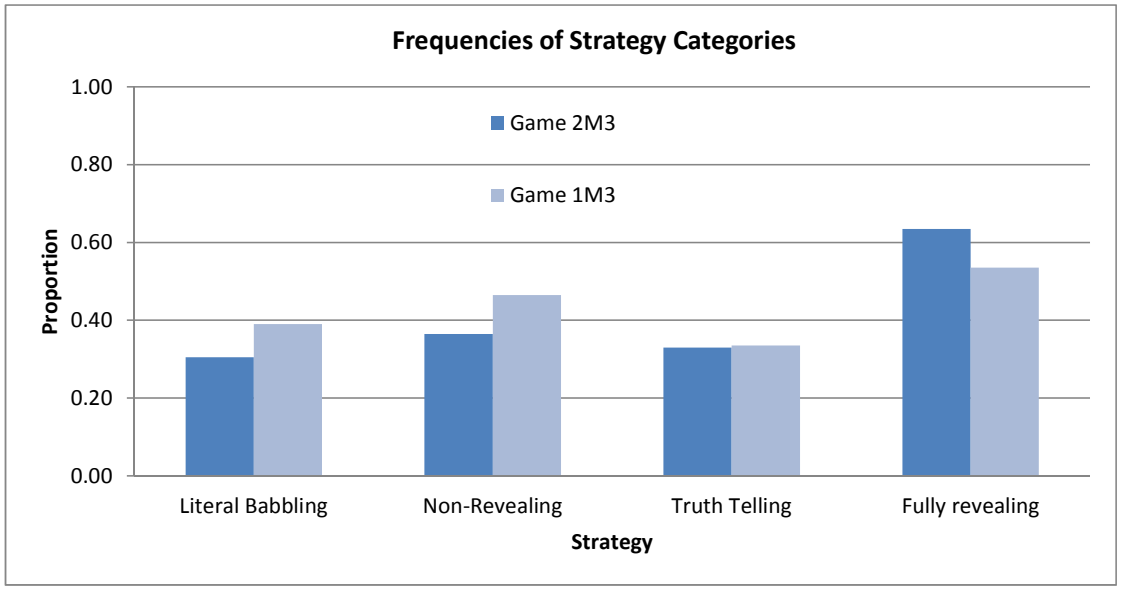
Senders: Game 2*M*3 and Game 1*M*3



- There was more babbling/non-revealing strategies in Game 1*M*3 than in Game 2*M*3.

Further Findings

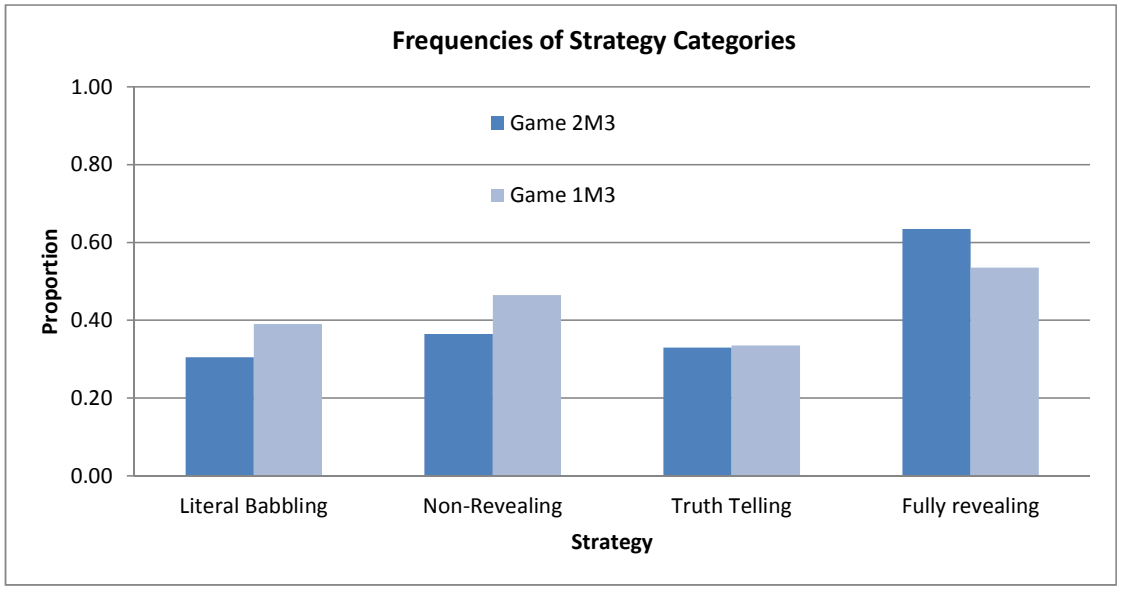
Senders: Game 2*M*3 and Game 1*M*3



- There was more babbling/non-revealing strategies in Game 1*M*3 than in Game 2*M*3.
- The differences are, however, not significant.

Further Findings

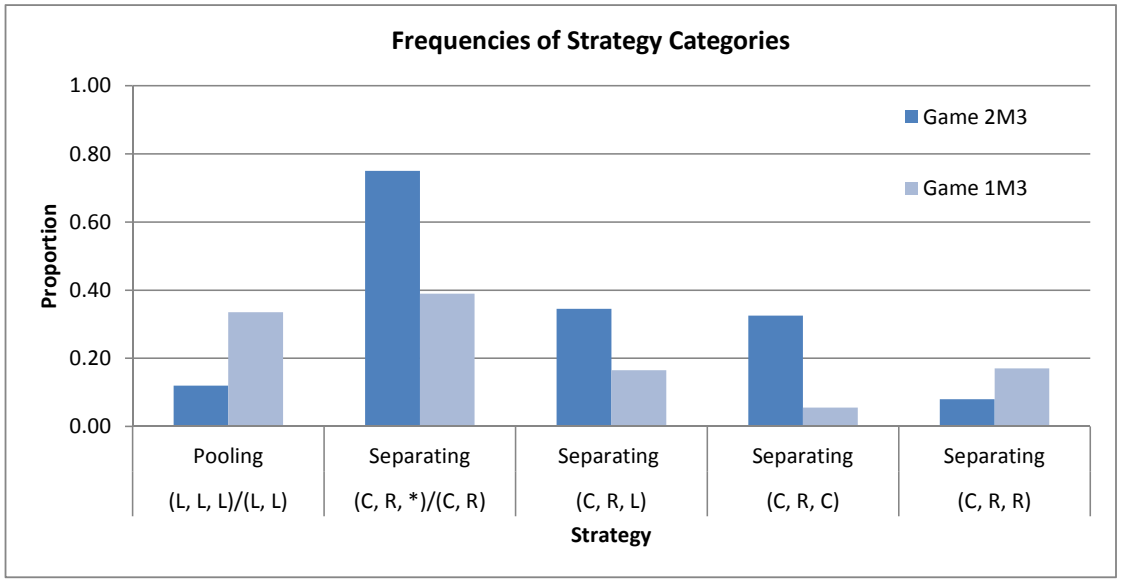
Senders: Game 2*M*3 and Game 1*M*3



- There was more babbling/non-revealing strategies in Game 1*M*3 than in Game 2*M*3.
- The differences are, however, not significant.
- Consistent with the finding that the impact of the credibility of the neologism on senders was limited.

Further Findings

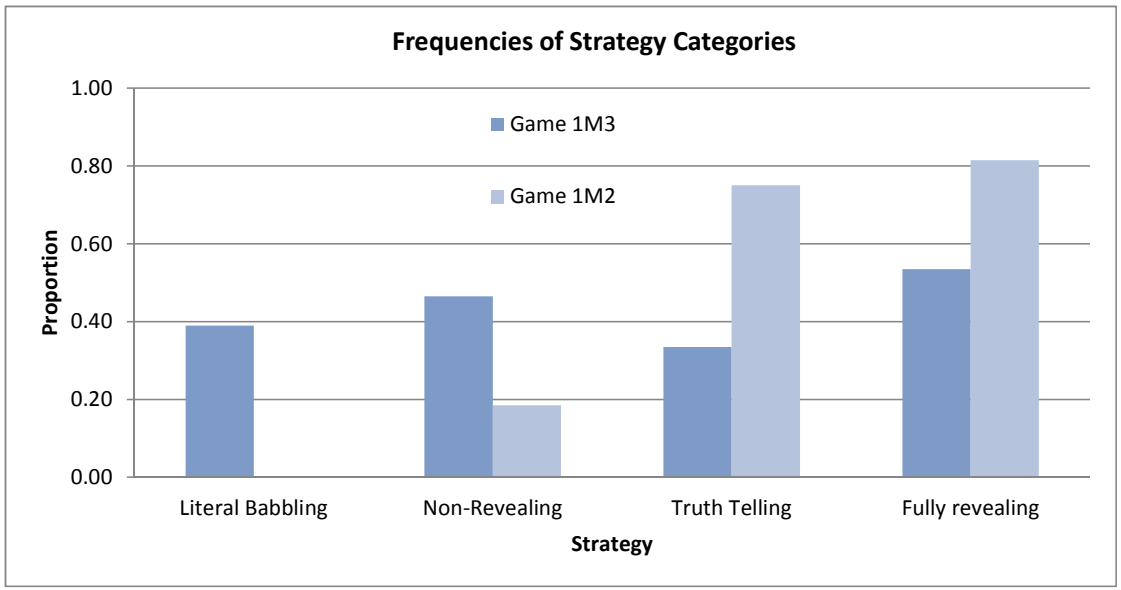
Receivers: Game 2*M*3 and Game 1*M*3



- Consistent with the finding that the credibility of the neologism attracted deviating behavior from receivers. ▸ Some implications on Level-*K*

Further Findings

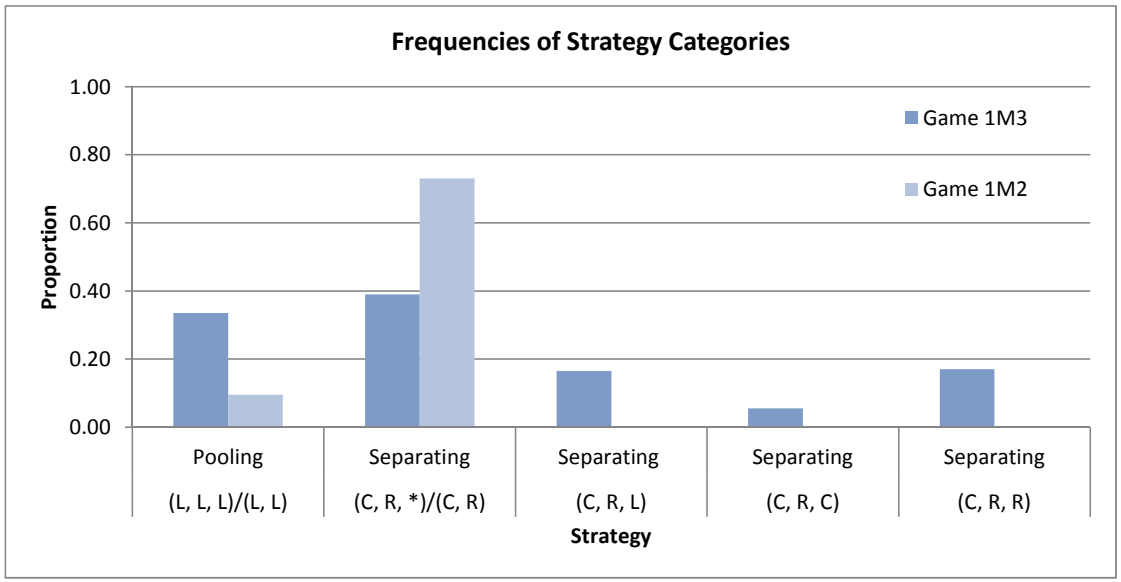
Senders: Game 1$M3$ and Game 1$M2$



- Consistent with the finding that the elimination of neologism that was credible increased the frequencies of senders' truth-telling behavior.

Further Findings

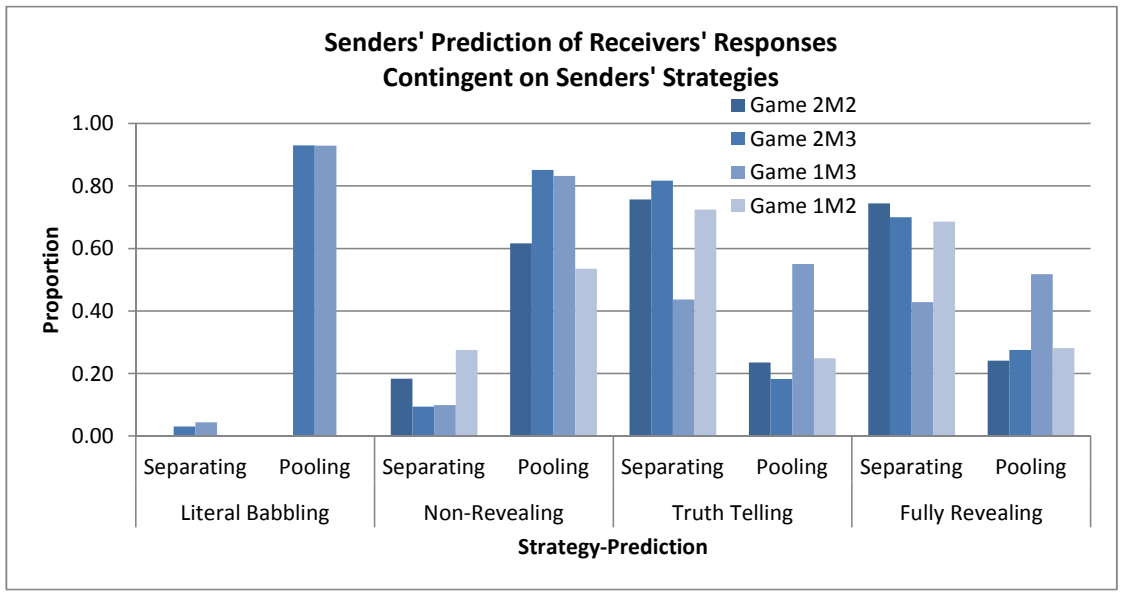
Receivers: Game 1*M*3 and Game 1*M*2



- Consistent with the finding that the elimination of neologism that was credible increased the frequencies of receivers' truth-telling equilibrium behavior.

Further Findings

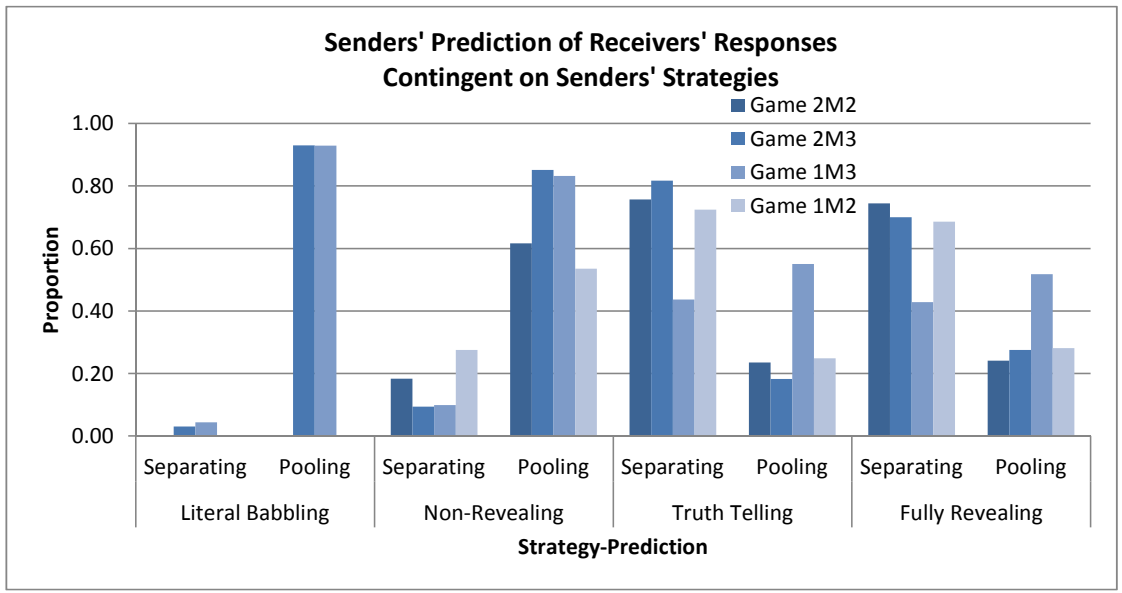
Senders' Beliefs on Receivers' Actions: Equilibrium vs. Level-k



- Overall, senders' strategies were consistent with their reported beliefs, except for truth-telling and fully revealing strategies in Game $1M3$

Further Findings

Senders' Beliefs on Receivers' Actions: Equilibrium vs. Level-k



- Overall, senders' strategies were consistent with their reported beliefs, except for truth-telling and fully revealing strategies in Game 1M3
- In Game 1M3, senders adopted truth-telling and fully revealing strategies even when they anticipated that receivers would ignore their messages. This suggests that senders may be (lexicographically) lying averse.

Level-k Analysis: Honest Sender and Credulous Receiver

Table: Level-k Predictions for Game $1M3$

	Sender's Strategy		Receiver's Strategy		
	s	t	"My type is s."	"My type is t."	"I won't tell you."
L_0	"My type is s."	"My type is t."	C	R	L
L_1	"I won't tell you."	"I won't tell you."	C	R	L
$L_{k\geq 2}$	"I won't tell you."	"I won't tell you."	C	R	L

Table: Level-k Predictions for Game $2M3$

	Sender's Strategy		Receiver's Strategy		
	s	t	"My type is s."	"My type is t."	"I won't tell you."
L_0	"My type is s."	"My type is t."	C	R	L
L_1	"I won't tell you."	"My type is t."	C	R	C
$L_{k\geq 2}$	"My type is s." or "I won't tell you."	"My type is t."	C	R	C

- Like neologism-proofness, the level-k model predicts a babbling outcome for Game $1M3$ and a fully revealing outcome for Game $2M3$.

Level-k Analysis: Honest Sender and Credulous Receiver

Table: Level-k Predictions for Game $1M3$

	Sender's Strategy		Receiver's Strategy		
	s	t	"My type is s."	"My type is t."	"I won't tell you."
L_0	"My type is s."	"My type is t."	C	R	L
L_1	"I won't tell you."	"I won't tell you."	C	R	L
$L_{k\geq 2}$	"I won't tell you."	"I won't tell you."	C	R	L

Table: Level-k Predictions for Game $2M3$

	Sender's Strategy		Receiver's Strategy		
	s	t	"My type is s."	"My type is t."	"I won't tell you."
L_0	"My type is s."	"My type is t."	C	R	L
L_1	"I won't tell you."	"My type is t."	C	R	C
$L_{k\geq 2}$	"My type is s." or "I won't tell you."	"My type is t."	C	R	C

- Like neologism-proofness, the level-k model predicts a babbling outcome for Game $1M3$ and a fully revealing outcome for Game $2M3$.
- Unlike neologism-proofness, the model fails to predict the systematic difference between receiver's strategies in Games $1M3$ and $2M3$. ▸ Data