Verifiability in Communication
An Experimental Analysis

Agata Farina
NYU

Guillaume Frechette
NYU

Alessandro Lizzeri
Princeton

Jacopo Perego
Columbia

October 2022

Plan

A prospective experimental analysis (i.e., no data, hence no real results)

Goals today:

1. Introduce research question
2. Present experimental design
3. Discuss current challenges

Overview

Communication is a fundamental economic problem

advertising to consumers, financial disclosure, political campaigning, organizations (project selection, hiring, etc.)

Communication is a fundamental economic problem

advertising to consumers, financial disclosure, political campaigning, organizations (project selection, hiring, etc.)

Sender	**Receiver**
with private information	with authority to choose action

Communication is a fundamental economic problem

advertising to consumers, financial disclosure, political campaigning, organizations (project selection, hiring, etc.)

Sender	communicates →	Receiver
with private information		with authority to choose action

Overview

Communication is a fundamental economic problem

advertising to consumers, financial disclosure, political campaigning, organizations (project selection, hiring, etc.)

Sender		**Receiver**
with private information	communicates →	with authority to choose action

Two core ingredients:

- Some conflict of interest btw Sender and Receiver
- Norms about what Sender can say given what she knows

Overview

Two communication paradigms:

Overview

Two communication paradigms:

Cheap Talk e.g., Crawford Sobel ’82

Disclosure (or, more generally, **costly signalling**) e.g., Milgrom ’81

They differ in what sender can say given what she knows

Two communication paradigms:

Cheap Talk e.g., Crawford Sobel '82

Disclosure e.g., Milgrom '81

They differ in what sender can say given what she knows

Overview

Two communication paradigms:

Cheap Talk e.g., Crawford Sobel ’82

- “Soft” information – Messages are Unverifiable
- Large frictions in information transmission

Disclosure e.g., Milgrom ’81

They differ in what sender can say given what she knows

Two communication paradigms:

Cheap Talk e.g., Crawford Sobel ’82

“Soft” information – Messages are Unverifiable

Large frictions in information transmission

Disclosure e.g., Milgrom ’81

“Hard” information – Messages are Verifiable

No frictions in information transmission, “Unravelling” principle

They differ in what sender can say given what she knows

Overview

Two communication paradigms:

Cheap Talk

e.g., Crawford Sobel '82

"Soft" information – Messages are Unverifiable

Large frictions in information transmission

Disclosure

e.g., Milgrom '81

"Hard" information – Messages are Verifiable

No frictions in information transmission, "Unravelling" principle

They differ in *how verifiable information is*

This Paper

We study experimentally the **role of verifiability** in communication

- That is, how changes in verifiability affect how effectively people communicate

This Paper

We study experimentally the **role of verifiability** in communication

- That is, how changes in verifiability affect how effectively people communicate

What we (want to) do:

1. A model to introduce rich variations in verifiability
2. Develop comparative statics that isolate role of verifiability
3. A parsimonious experimental design that test qualitative predictions against observed behavior

model

Essentially, Milgrom (1981)

Essentially, Milgrom (1981)

1. **Sender** privately observes the state θ:
   - $\theta \in \Theta$ distributed according to $p \in \Delta(\Theta)$

Essentially, Milgrom (1981)

1. **Sender** privately observes the state θ:
   - $\theta \in \Theta$ distributed according to $p \in \Delta(\Theta)$
2. Given θ, Sender draws N signals:
   - An exogenous information structure $f : \Theta \to \Delta(\Omega)$
   - N iid draws from $f(\cdot|\theta)$

   Notation: $\bar{\omega} = (\omega_1, \ldots, \omega_N) \in \Omega^N$ sender's "*type*"

3. Sender discloses at most K signals from the N she obtained
   - Given $\bar{\omega}$, sender chooses $m \in M(\bar{\omega})$

3. Sender discloses at most K signals from the N she obtained
   - Given $\bar{\omega}$, sender chooses $m \in M(\bar{\omega})$:

$$M(\bar{\omega}) := \Big\{ m \in \Omega^k \mid k \leq K \text{ and } \exists \text{ injective } \rho : \{1, ..., k\} \to \{1, ..., N\} \text{ s.t. } m = (\omega_{\rho(1)}, ..., \omega_{\rho(k)}) \Big\} \cup \{\varnothing\}.$$

3. Sender discloses at most K signals from the N she obtained
   - Given $\bar{\omega}$, sender chooses $m \in M(\bar{\omega})$:

$$M(\bar{\omega}) := \Big\{ m \in \Omega^k \mid k \leq K \text{ and } \exists \text{ injective } \rho : \{1, ..., k\} \to \{1, ..., N\} \text{ s.t. } m = (\omega_{\rho(1)}, ..., \omega_{\rho(k)}) \Big\} \cup \{\varnothing\}.$$

4. Receiver observes m, takes an action, payoff realizes
   - Receiver's action $a \in A$ and payoffs are:

$$u_S(\theta, a) = a \qquad u_R(\theta, a) = -(a - \theta)^2$$

Summing Up

Three parameters will generate our **exogenous** variation

- f, the technology that generates signals
- N, the number of available signals
- K, the number of reportable signals

Three parameters will generate our **exogenous** variation

- f, the technology that generates signals
- N, the number of available signals
- K, the number of reportable signals

Technical assumptions:

- Θ and Ω finite subsets of $\mathbb{R}$; $A = \mathbb{R}$
- f satisfies **MLR property**: For $\theta' > \theta$, $\dfrac{f(\omega|\theta')}{f(\omega|\theta)}$ strictly increasing in ω

Summing Up

Three parameters will generate our **exogenous** variation

- f, the technology that generates signals
- N, the number of available signals
- K, the number of reportable signals

Technical assumptions:

- Θ and Ω finite subsets of $\mathbb{R}$; $A = \mathbb{R}$
- f satisfies **MLR property**: For $\theta' > \theta$, $\dfrac{f(\omega|\theta')}{f(\omega|\theta)}$ strictly increasing in ω

discussion

A Simple Example

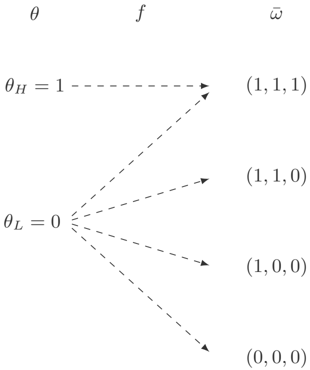
- Suppose $N = 3$, $K = 1$

θ

$\theta_H = 1$

$\theta_L = 0$

- Suppose $N = 3$, $K = 1$

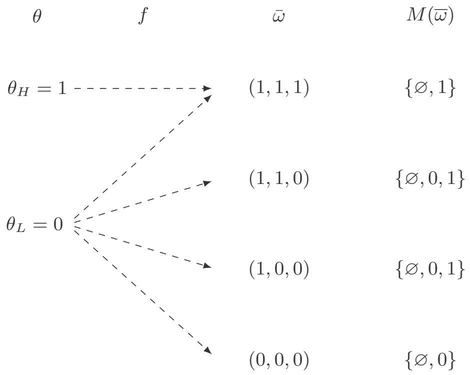


- Suppose $N = 3$, $K = 1$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1\}$
		$(1,1,0)$	$\{\varnothing, 0, 1\}$
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1\}$
		$(0,0,0)$	$\{\varnothing, 0\}$

A Simple Example

- Suppose $N = 3$, $K = 1$



- Suppose $N = 3$, $K = 1$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1\}$	1
		$(1,1,0)$	$\{\varnothing, 0, 1\}$	1
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1\}$	1
		$(0,0,0)$	$\{\varnothing, 0\}$	0

A Simple Example

- Suppose $N = 3$, $K = 1$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m	a
$\theta_H = 1$	$\dashrightarrow$	$(1,1,1)$	$\{\varnothing, 1\}$	1	$\frac{1}{3}$
		$(1,1,0)$	$\{\varnothing, 0, 1\}$	1	$\frac{1}{3}$
$\theta_L = 0$	$\dashrightarrow$	$(1,0,0)$	$\{\varnothing, 0, 1\}$	1	$\frac{1}{3}$
		$(0,0,0)$	$\{\varnothing, 0\}$	0	0

- Suppose $N = 3$, $K = 2$

$$
\begin{tikzcd}
\theta & f & \bar{\omega} \\
\theta_H = 1 \arrow[rr, dashed] & & (1,1,1) \\
& & (1,1,0) \\
\theta_L = 0 \arrow[rruu, dashed] \arrow[rru, dashed] \arrow[rr, dashed] \arrow[rrd, dashed] & & (1,0,0) \\
& & (0,0,0)
\end{tikzcd}
$$

- Suppose $N = 3$, $K = 2$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1)\}$
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1)\}$
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0)\}$
		$(0,0,0)$	$\{\varnothing, 0, (0,0)\}$

A Simple Example

- Suppose $N = 3$, $K = 2$

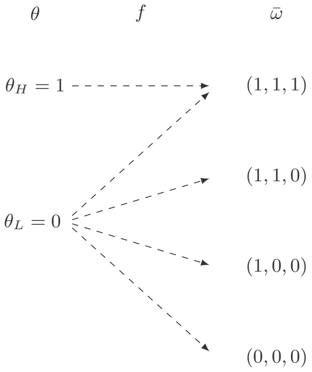
θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1)\}$	$(1,1)$
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1)\}$	$(1,1)$
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0)\}$	1
		$(0,0,0)$	$\{\varnothing, 0, (0,0)\}$	0

A Simple Example

- Suppose $N = 3$, $K = 2$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m	a
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1)\}$	$(1,1)$	$\frac{1}{2}$
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1)\}$	$(1,1)$	$\frac{1}{2}$
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0)\}$	1	0
		$(0,0,0)$	$\{\varnothing, 0, (0,0)\}$	0	0

- Suppose $N = 3$, $K = 3$



A Simple Example

- Suppose $N = 3$, $K = 3$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$
$\theta_H = 1$, $\theta_L = 0$	$\dashrightarrow$	$(1,1,1)$	$\{\varnothing, 1, (1,1), (1,1,1)\}$
$\theta_L = 0$	$\dashrightarrow$	$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1), (1,1,0)\}$
$\theta_L = 0$	$\dashrightarrow$	$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0), (1,0,0)\}$
$\theta_L = 0$	$\dashrightarrow$	$(0,0,0)$	$\{\varnothing, 0, (0,0), (0,0,0)\}$

A Simple Example

- Suppose $N = 3$, $K = 3$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1), (1,1,1)\}$	$(1,1,1)$
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1), (1,1,0)\}$	$(1,1)$
$\theta_L = 0$				
		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0), (1,0,0)\}$	1
		$(0,0,0)$	$\{\varnothing, 0, (0,0), (0,0,0)\}$	0

- Suppose $N = 3$, $K = 3$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	m	a
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1), (1,1,1)\}$	$(1,1,1)$	1
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1), (1,1,0)\}$	$(1,1)$	0
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0), (1,0,0)\}$	1	0
		$(0,0,0)$	$\{\varnothing, 0, (0,0), (0,0,0)\}$	0	0

DISCUSSION

When $K = N$, information is **fully verifiable**

- $\bar{\omega} \in M(\bar{\omega})$, ubiquitous assumption $\rightsquigarrow$ unraveling $\rightsquigarrow$ no frictions

Discussion

When $K = N$, information is **fully verifiable**

- $\bar{\omega} \in M(\bar{\omega})$, ubiquitous assumption $\rightsquigarrow$ unraveling $\rightsquigarrow$ no frictions

When $K < N$, information is **partially verifiable**

- $\bar{\omega} \notin M(\bar{\omega})$, Sender can only prove so much about herself
- Scope for imitation via **selective disclosure**
- Failure of unraveling $\rightsquigarrow$ frictions

Discussion

When $K = N$, information is **fully verifiable**

- $\bar{\omega} \in M(\bar{\omega})$, ubiquitous assumption $\rightsquigarrow$ unraveling $\rightsquigarrow$ no frictions

When $K < N$, information is **partially verifiable**

- $\bar{\omega} \notin M(\bar{\omega})$, Sender can only prove so much about herself
- Scope for imitation via **selective disclosure**
- Failure of unraveling $\rightsquigarrow$ frictions

Hybrid framework btw **cheap-talk** games and **disclosure** games

Discussion

When $K = N$, information is **fully verifiable**

- $\bar{\omega} \in M(\bar{\omega})$, ubiquitous assumption $\rightsquigarrow$ unraveling $\rightsquigarrow$ no frictions

When $K < N$, information is **partially verifiable**

- $\bar{\omega} \notin M(\bar{\omega})$, Sender can only prove so much about herself
- Scope for imitation via **selective disclosure**
- Failure of unraveling $\rightsquigarrow$ frictions

Hybrid framework btw **cheap-talk** games and **disclosure** games

Plan, Revisited

Changing K and N our tool to introduce variation in degree of verifiability

- $N \uparrow$, Sender has more signals about her type
- $K \uparrow$, Sender can report more signals

This generates rich and asymmetric comparative statics, which inform our experimental design

We then test qualitative predictions against observed behavior

Question overlooked by experimental literature

Rich experimental literature on communication

Disclosure:

- Jin, Luca and Martin (2022, AEJ: Micro) – failure of unravelling and why
- Hagenbach and Perez-Richet (2018, GEB) – preference alignment
- Li and Schipper (2020, GEB) – vague disclosure

Cheap Talk:

- Cai and Wang (2006, GEB) – overcommunication wrt the theory

Rich experimental literature on communication

Disclosure:

- Jin, Luca and Martin (2022, AEJ: Micro) – failure of unravelling and why
- Hagenbach and Perez-Richet (2018, GEB) – preference alignment
- Li and Schipper (2020, GEB) – vague disclosure

Cheap Talk:

- Cai and Wang (2006, GEB) – overcommunication wrt the theory

Closest in the approach:

- Frechette, Lizzeri, Perego (2022, Ecma) – Persuasion
    - Commitment as a core ingredient of theories of communication
    - Partial commitment and develop novel comparative statics
    - Test these qualitative predictions

Rich experimental literature on communication

Disclosure:

- Jin, Luca and Martin (2022, AEJ: Micro) – failure of unravelling and why
- Hagenbach and Perez-Richet (2018, GEB) – preference alignment
- Li and Schipper (2020, GEB) – vague disclosure

Cheap Talk:

- Cai and Wang (2006, GEB) – overcommunication wrt the theory

Closest in the approach:

- Frechette, Lizzeri, Perego (2022, Ecma) – Persuasion
  - Commitment as a core ingredient of theories of communication
  - Partial commitment and develop novel comparative statics
  - Test these qualitative predictions

Partially Verifiable Disclosure

- Burdea, Montero, Sefton (2022) – test of Glazer, Rubinstein ('04, '06)

Theory Literature

Closest papers that feature partially verifiable information, $\bar{\omega} \notin M(\bar{\omega})$

The Basic Setting:

- Milgrom (1981, Bell), example to showcase MLRP
- Fishman and Hagerty (1990, QJE), optimal amount of discretion

Mechanism-Design Approach:

- Glazer and Rubinstein (2004, Ecma) – Receiver's Verification, $K = 1$
- Glazer and Rubinstein (2006, TE) – Sender's verification

Richer Settings: Uknown N or Endogenous K

- Shin (2003, Ecma)
- Dziuda (2011, JET)

equilibrium

Main Outcome Variable

We study the effects of changing (f, N, K)

Our main **outcome** of interest is "informativeness"

- How informative is communication? That is, how effectively receiver learns state θ

Main Outcome Variable

We study the effects of changing (f, N, K)

Our main **outcome** of interest is "informativeness"

- How informative is communication? That is, how effectively receiver learns state θ

In the data, we can compute "informativeness" in several ways:

- Correlation between θ and a
- Receiver's expected payoff

Main Outcome Variable

We study the effects of changing (f, N, K)

Our main **outcome** of interest is "informativeness"

- How informative is communication? That is, how effectively receiver learns state θ

In the data, we can compute "informativeness" in several ways:

- Correlation between θ and a
- Receiver's expected payoff

Preview of comparative statics:

- Informativeness increases in K
- Informativeness increases/decreases in N depending on f

First, fix any (f, N, K)

Proposition Milgrom (1981)

A sequential equilibrium exists where sender reports the K **most favorable** signals in $\bar{\omega}$.

First, fix any (f, N, K)

Proposition Milgrom (1981)

A sequential equilibrium exists where sender reports the K **most favorable** signals in $\bar{\omega}$.

Selective Disclosure: Two predictions about sender's behavior

1. Sender discloses K signals
2. When $K < N$, sender discloses most favorable signals

First, fix any (f, N, K)

Proposition Milgrom (1981)

A sequential equilibrium exists where sender reports the K **most favorable** signals in $\bar{\omega}$.

Selective Disclosure: Two predictions about sender's behavior

1. Sender discloses K signals "quantity"
2. When $K < N$, sender discloses most favorable signals "quality"

First, fix any (f, N, K)

Proposition Milgrom (1981)

A sequential equilibrium exists where sender reports the K **most favorable** signals in $\bar{\omega}$.

Selective Disclosure: Two predictions about sender's behavior

1. Sender discloses K signals "quantity"
2. When $K < N$, sender discloses most favorable signals "quality"

Our analysis focuses on this equilibrium (outcome) more later

- $N = 3$, $K = 2$

θ	f	$\bar{\omega}$	$M(\overline{\omega})$	$\sigma^*(\bar{\omega})$
$\theta_H = 1$		$(1,1,1)$	$\{\varnothing, 1, (1,1)\}$	$(1,1)$
		$(1,1,0)$	$\{\varnothing, 0, 1, (1,0), (1,1)\}$	$(1,1)$
$\theta_L = 0$		$(1,0,0)$	$\{\varnothing, 0, 1, (0,0), (1,0)\}$	$(1,0)$
		$(0,0,0)$	$\{\varnothing, 0, (0,0)\}$	$(0,0)$

Changing K

Now fix any (f, N)

How does an increase in K affect information transmission?

Now fix any (f, N)

How does an increase in K affect information transmission?

Proposition

The equilibrium informativeness increases in K.

Now fix any (f, N)

How does an increase in K affect information transmission?

Proposition

The equilibrium informativeness increases in K.

Intuition: Easier to send messages that others cannot imitate $\Rightarrow$ Less pooling $\Rightarrow$ More information transmitted

Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 1$

θ	$\bar{\omega}$	$M(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	$(1, 1, 1)$	$\{\varnothing, 1\}$	1
	$(1, 1, 0)$	$\{\varnothing, 0, 1\}$	1
θ_L	$(1, 0, 0)$	$\{\varnothing, 0, 1\}$	1
	$(0, 0, 0)$	$\{\varnothing, 0\}$	0

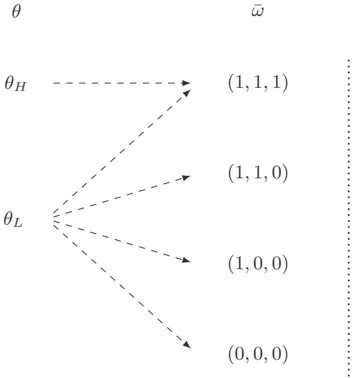
Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 1$

θ	$\bar{\omega}$	$M(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	$(1,1,1)$	$\{\varnothing, 1\}$	1
	$(1,1,0)$	$\{\varnothing, 0, 1\}$	1
θ_L			
	$(1,0,0)$	$\{\varnothing, 0, 1\}$	1
	$(0,0,0)$	$\{\varnothing, 0\}$	0

Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 2$



Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 2$

θ	$\bar{\omega}$	$M(\bar{\omega})$
θ_H, θ_L	$(1, 1, 1)$	$\{\varnothing, 1, (1, 1)\}$
θ_L	$(1, 1, 0)$	$\{\varnothing, 0, 1, (1, 0), (1, 1)\}$
θ_L	$(1, 0, 0)$	$\{\varnothing, 0, 1, (0, 0), (1, 0)\}$
θ_L	$(0, 0, 0)$	$\{\varnothing, 0, (0, 0)\}$

Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 2$

θ	$\bar{\omega}$	$M(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	$(1, 1, 1)$	$\{\varnothing, 1, (1, 1)\}$	$(1, 1)$
	$(1, 1, 0)$	$\{\varnothing, 0, 1, (1, 0), (1, 1)\}$	$(1, 1)$
θ_L	$(1, 0, 0)$	$\{\varnothing, 0, 1, (0, 0), (1, 0)\}$	$(1, 0)$
	$(0, 0, 0)$	$\{\varnothing, 0, (0, 0)\}$	$(0, 0)$

Back to Example: Increasing K

- Binary state $\Theta = \{\theta_L, \theta_H\}$ and binary signals $\Omega = \{0, 1\}$
- "Conclusive bad news": $f(\omega = 1|\theta_H) = 1$ and $f(\omega = 1|\theta_L) \in (0, 1)$
- $N = 3$, $K = 2$

θ	$\bar{\omega}$	$M(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	$(1, 1, 1)$	$\{\varnothing, 1, (1, 1)\}$	$(1, 1)$
	$(1, 1, 0)$	$\{\varnothing, 0, 1, (1, 0), (1, 1)\}$	$(1, 1)$
θ_L	$(1, 0, 0)$	$\{\varnothing, 0, 1, (0, 0), (1, 0)\}$	$(1, 0)$
	$(0, 0, 0)$	$\{\varnothing, 0, (0, 0)\}$	$(0, 0)$

Now fix (f, K)

How does an increase in N affect information transmission?

CHANGING N

Now fix (f, K)

How does an increase in N affect information transmission?

A nontrivial tradeoff:

- $+$ Higher $N \rightsquigarrow$ sender can find better signals to prove her type
- $-$ Higher $N \rightsquigarrow$ sender can be more selective of what signals to disclose

Now fix (f, K)

How does an increase in N affect information transmission?

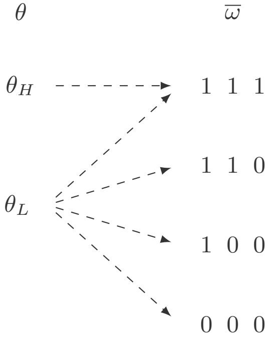
A nontrivial tradeoff:

+ Higher $N \rightsquigarrow$ sender can find better signals to prove her type
− Higher $N \rightsquigarrow$ sender can be more selective of what signals to disclose

Depending on f, an increase in N can increase or decrease informativeness see DiTillio, Ottaviani, Sorensen (2021, Ecma)

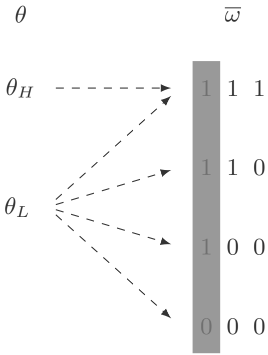
Example 1: Where Increasing N is Bad

Example 1: Where Increasing N is Bad

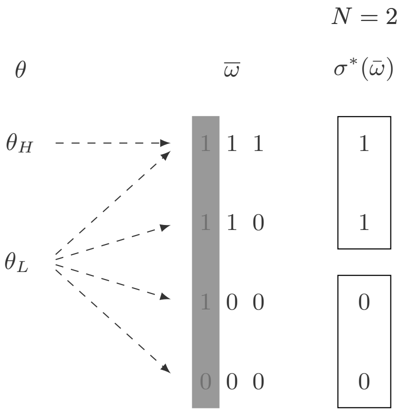


Example 1: Where Increasing N is Bad

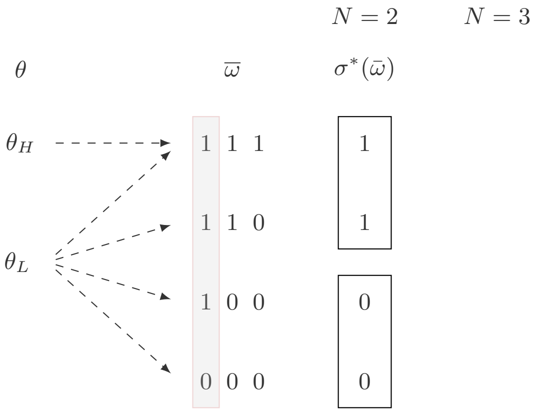
$N = 2$



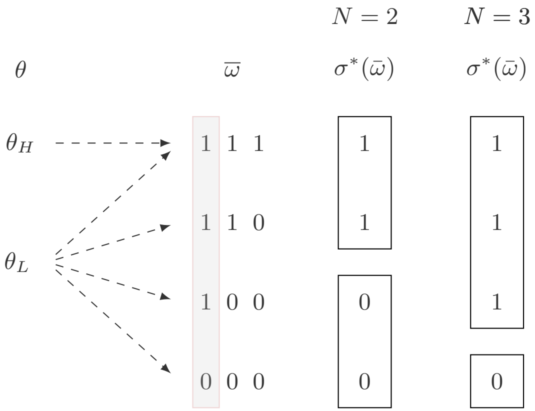
Example 1: Where Increasing N is Bad



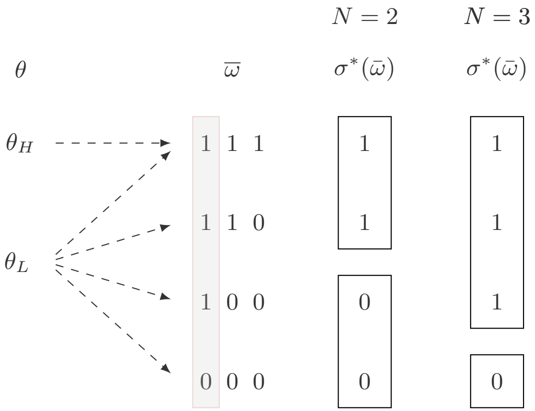
Example 1: Where Increasing N is Bad



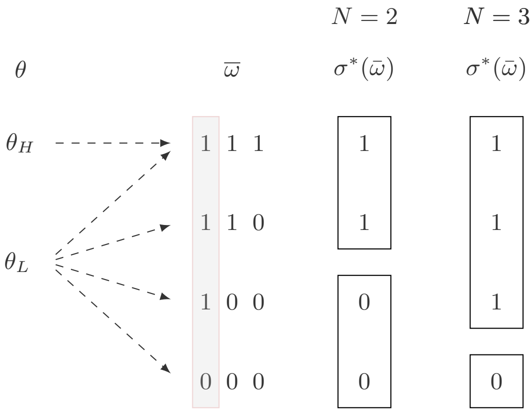
Example 1: Where Increasing N is Bad



Example 1: Where Increasing N is Bad



Example 1: Where Increasing N is Bad

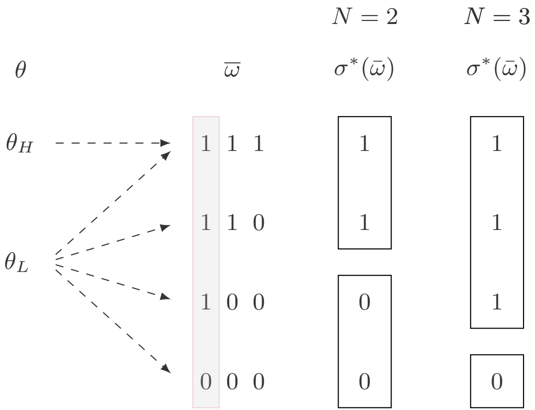


$N \uparrow \rightsquigarrow$ more likely that θ_L can imitate θ_H $\rightsquigarrow$ informativeness $\downarrow$

Example 1: Where Increasing N is Bad

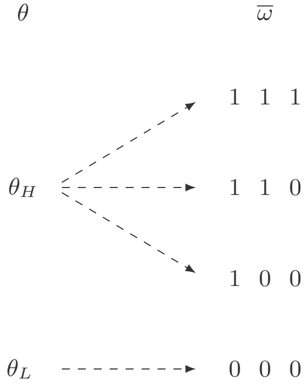
Conclusive bad news

$(f(\omega = 1|\theta_H) = 1 \text{ and } f(\omega = 1|\theta_L) \in (0,1))$



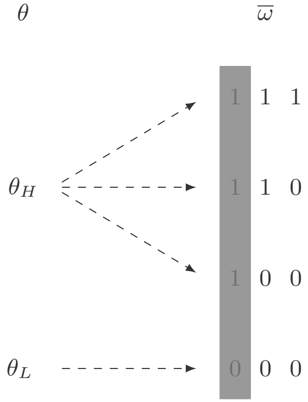
$N \uparrow \;\rightsquigarrow\;$ more likely that θ_L can imitate $\theta_H \;\rightsquigarrow\;$ informativeness $\downarrow$

Example 2: Where Increasing N is Good

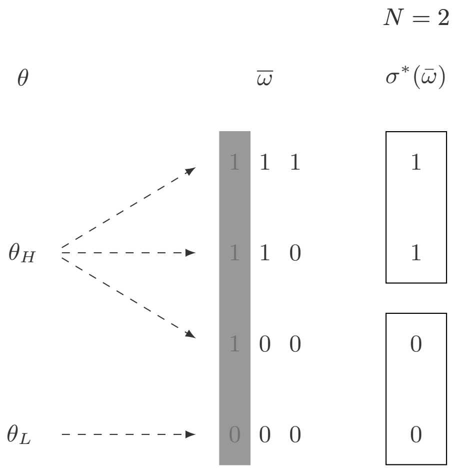


Example 2: Where Increasing N is Good

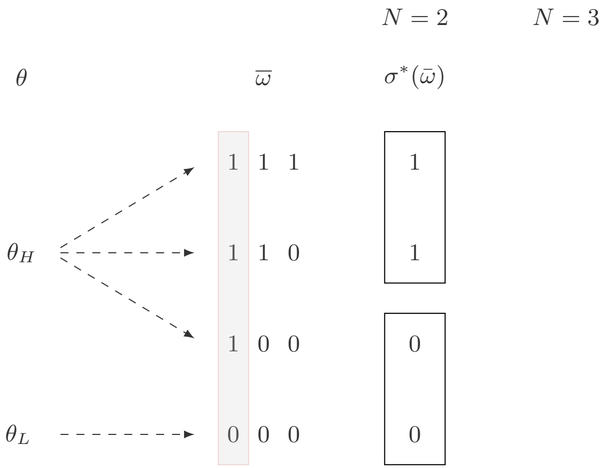
$N = 2$



EXAMPLE 2: WHERE INCREASING N IS GOOD



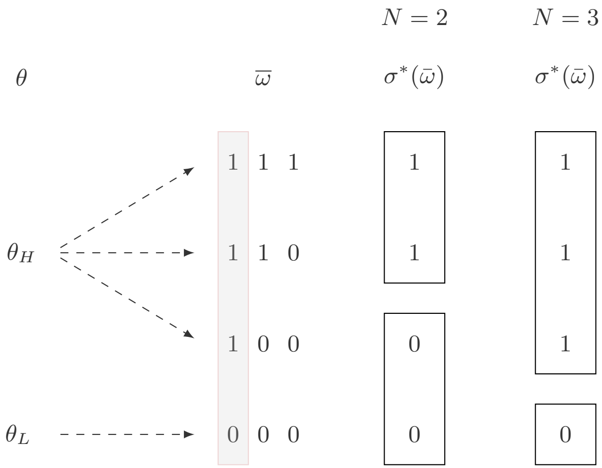
EXAMPLE 2: WHERE INCREASING N IS GOOD



Example 2: Where Increasing N is Good

		$N = 2$	$N = 3$
θ	$\overline{\omega}$	$\sigma^*(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	1 1 1	1	1
θ_H	1 1 0	1	1
θ_H	1 0 0	0	1
θ_L	0 0 0	0	0

Example 2: Where Increasing N is Good

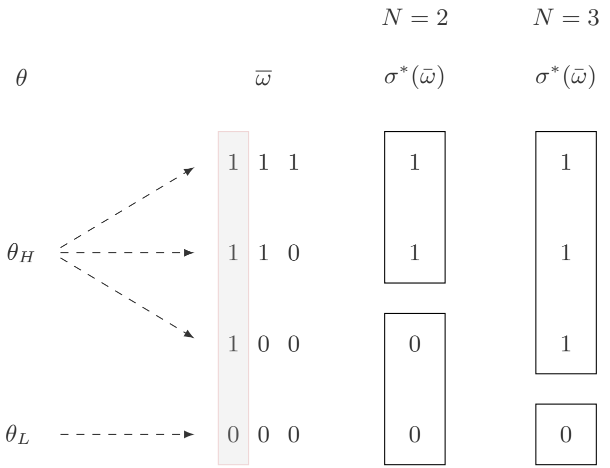


$N\uparrow$ $\rightsquigarrow$ less likely that θ_H can separate from θ_L $\rightsquigarrow$ informativeness $\uparrow$

Example 2: Where Increasing N is Good

Conclusive Good News

$f(\omega = 0|\theta_L) = 1$ and $f(\omega = 1|\theta_H) \in (0,1)$



$N \uparrow$ $\rightsquigarrow$ less likely that θ_H can separate from θ_L $\rightsquigarrow$ informativeness $\uparrow$

When f is conclusive, we obtain the following comparative statics:

Proposition

Let Θ and Ω be binary. Fix any K. As N increases, the receiver's payoff

- Increases if f has conclusive good news
- Decreases if f has conclusive bad news

When f is conclusive, we obtain the following comparative statics:

Proposition

Let Θ and Ω be binary. Fix any K. As N increases, the receiver's payoff

- Increases if f has conclusive good news
- Decreases if f has conclusive bad news

We do not have a more general result at this point but we will need it

When f is conclusive, we obtain the following comparative statics:

Proposition

Let Θ and Ω be binary. Fix any K. As N increases, the receiver's payoff

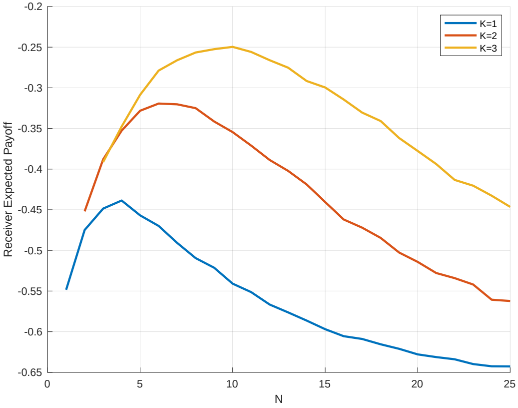
- Increases if f has conclusive good news
- Decreases if f has conclusive bad news

We do not have a more general result at this point but we will need it

Conjecture

As N increase, informativeness increases until $N^{\star}$ and then decreases

Changing N



Receiver Expected Payoff
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
0
5
10
15
20
25
N
K=1
K=2
K=3

experiment

Let $\Theta = \{1, 2, 3\}$, uniformly distributed

Let $\Omega = \{A, B, C\}$

Let $\Theta = \{1, 2, 3\}$, uniformly distributed

Let $\Omega = \{A, B, C\}$

A $2 \times 2 \times 2$ factorial design:

Let $\Theta = \{1, 2, 3\}$, uniformly distributed

Let $\Omega = \{A, B, C\}$

A $2 \times 2 \times 2$ factorial design:

- Two levels for $N \in \{4, 20\}$

Experimental Design

Let $\Theta = \{1, 2, 3\}$, uniformly distributed

Let $\Omega = \{A, B, C\}$

A $2 \times 2 \times 2$ factorial design:

- Two levels for $N \in \{4, 20\}$
- Two levels for $K \in \{2, 4\}$

Let $\Theta = \{1, 2, 3\}$, uniformly distributed

Let $\Omega = \{A, B, C\}$

A $2 \times 2 \times 2$ factorial design:

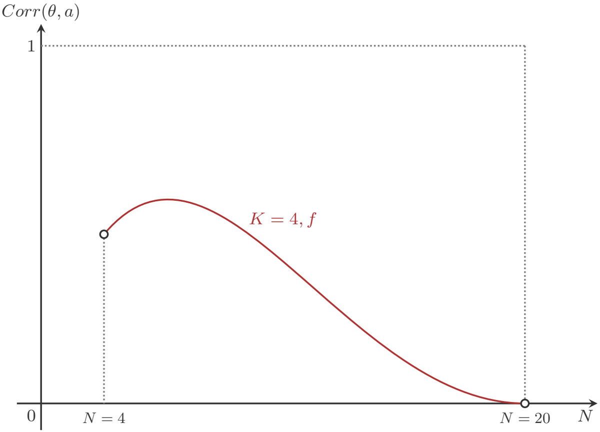
- Two levels for $N \in \{4, 20\}$
- Two levels for $K \in \{2, 4\}$
- Two kinds of f's:

f': "Good News"

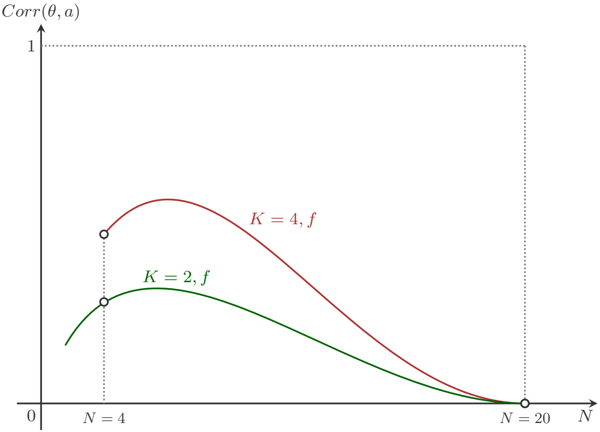
State	Signal A	Signal B	Signal C
$\theta = 3$	25%	50%	25%
$\theta = 2$	10%	30%	60%
$\theta = 1$	5%	20%	75%

f: "Bad News"

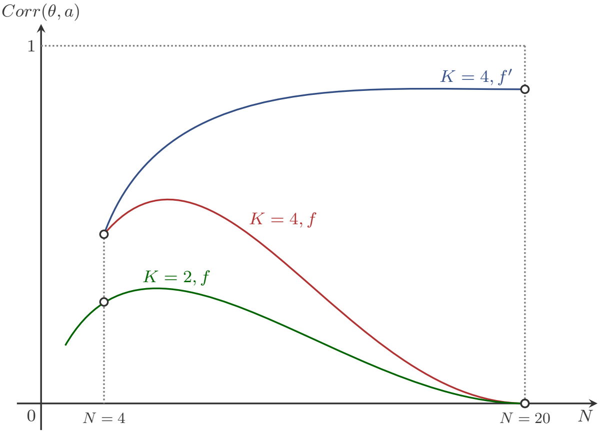
State	Signal A	Signal B	Signal C
$\theta = 3$	75%	20%	5%
$\theta = 2$	60%	30%	10%
$\theta = 1$	25%	50%	25%



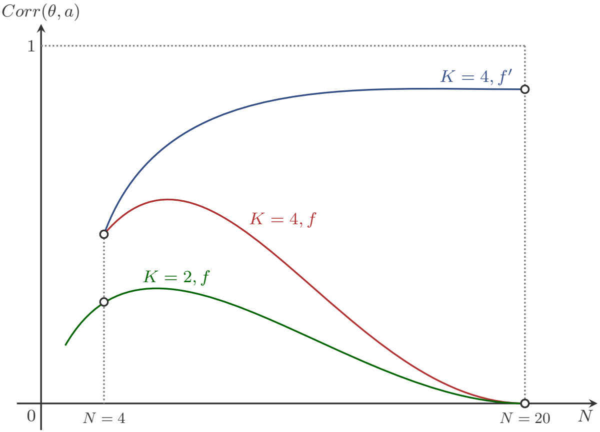
Test 1. Change in N given f (decreasing).



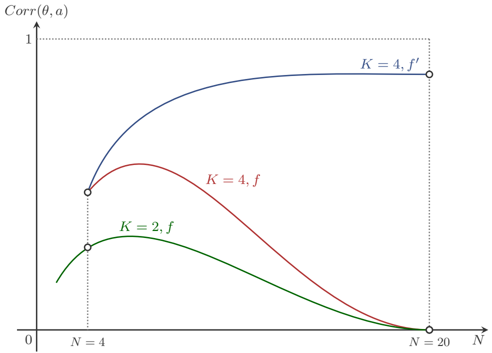
Test 2. Change in K: at $N = 4$ (gap) at $N = 20$ (nogap)



Test 3. Change in N given f' (increasing)



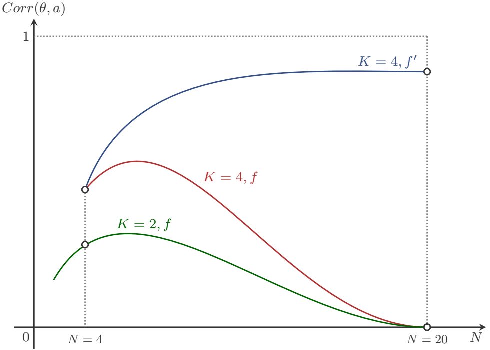
Test 4. Change f vs f' given $N = K$ (no effect)



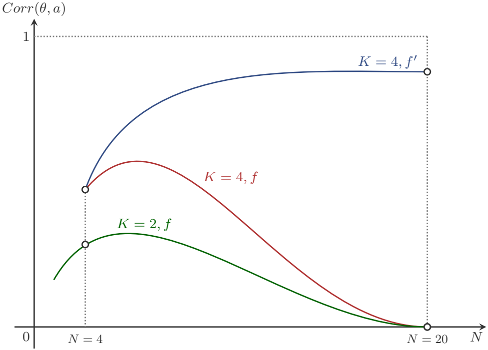
What I like:

- Each test is “identified”
- Predictions are stark, setting high bar for empirical validation
- Only aggregate outcomes here, data will be much richer

A One-Slide Summary



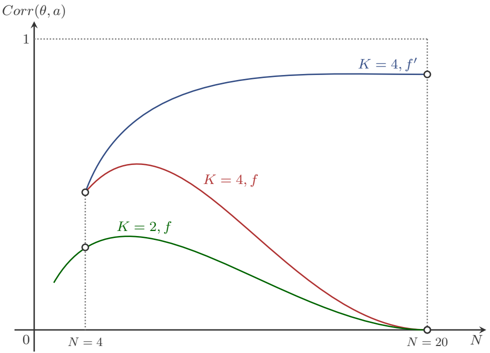
Conceptually, current narrative relies on three arguments:



Conceptually, current narrative relies on three arguments:

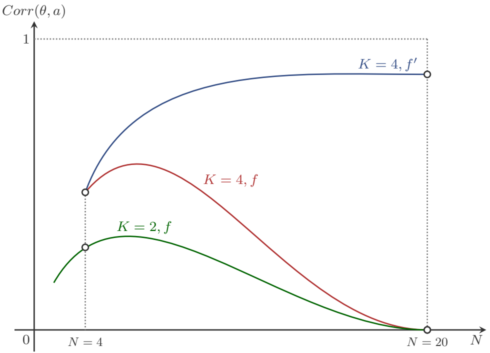
1. Verifiability is first-order ingredient of communication

A One-Slide Summary



Conceptually, current narrative relies on three arguments:

1. Verifiability is first-order ingredient of communication
2. A theory that introduces meaningful variations in verifiability



Conceptually, current narrative relies on three arguments:

1. Verifiability is first-order ingredient of communication
2. A theory that introduces meaningful variations in verifiability
3. A set of tests to challenge the theory

what’s missing

Current Challenges

1. **Equilibrium multiplicity**:
   - Unlike classic disclosure, SE outcome not unique when $K < N$

1. **Equilibrium multiplicity**:
   - Unlike classic disclosure, SE outcome not unique when $K < N$
   - So what?

1. **Equilibrium multiplicity**:

- Unlike classic disclosure, SE outcome not unique when $K < N$
- So what?
- Our equilibrium has "nice" properties: Unique outcome surviving (a generalized version of) Neologism Proofness Farrel (1993)

  Subtle problem: Not implemented... Stronger refinement?

1. **Equilibrium multiplicity**:

   - Unlike classic disclosure, SE outcome not unique when $K < N$
   - So what?
   - Our equilibrium has "nice" properties: Unique outcome surviving (a generalized version of) Neologism Proofness — Farrel (1993)

     Subtle problem: Not implemented… Stronger refinement?
   - Ultimately, proof is in the pudding

     Yet, what observable behavior can offer some reassurance?

1. **Equilibrium multiplicity**:

   - Unlike classic disclosure, SE outcome not unique when $K < N$
   - So what?
   - Our equilibrium has "nice" properties: Unique outcome surviving (a generalized version of) Neologism Proofness — Farrel (1993)

     Subtle problem: Not implemented... Stronger refinement?

   - Ultimately, proof is in the pudding

     Yet, what observable behavior can offer some reassurance?

2. **Analytical solutions for N**

   - No analytical results for N yet. — DiTillio et al (2021)?

Current Challenges

1. **Equilibrium multiplicity**:
   - Unlike classic disclosure, SE outcome not unique when $K < N$
   - So what?
   - Our equilibrium has "nice" properties: Unique outcome surviving (a generalized version of) Neologism Proofness — Farrel (1993)

     Subtle problem: Not implemented... Stronger refinement?
   - Ultimately, proof is in the pudding

     Yet, what observable behavior can offer some reassurance?
2. **Analytical solutions for N**
   - No analytical results for N yet. — DiTillio et al (2021)?
3. **Lab Implementation**
   - Coding *ad hoc* software, Instructions, IRB

summing up

Summary

Verifiability is a pervasive ingredient in communication

Flexible framework that introduces variations in verifiability

Stark comparative statics to inform our experimental design

Test main qualitative predictions of the theory against observed behavior

- If confirmed, this is empirical validation for a core component of our theories of communication
- If not, it indicates something off in our theories

thank you

appendix

Round 1 of 4: Message Stage You are the Sender

Reminder:

Signal probabilities if the SN is 1

A	B	C
60%	30 %	10 %

Signal probabilities if the SN is 2

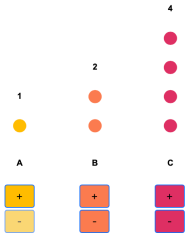
A	B	C
30 %	60 %	10 %

Signal probabilities if the SN is 3

A	B	C
10 %	30 %	60 %

Your Secret Number is 3.

Available Evidence



The evidence you are showing the receiver is:

B B C

Send

Round 1 of 4: Guessing Stage You are the Receiver

Reminder:

Signal probabilities if the SN is 1

A	B	C
60%	30 %	10 %

Signal probabilities if the SN is 2

A	B	C
30 %	60 %	10 %

Signal probabilities if the SN is 3

A	B	C
10 %	30 %	60 %

Of the 10 available pieces of evidence, the sender chose to send you the following ones:

Evidence Reported by the Sender

B B C

Use the slider below to make your guess about the Secret Number.

Your guess is 2.58

Submit Guess

Equilibrium Multiplicity

Unlike classic disclosure games, SE outcome not unique when $K < N$

Off-path beliefs can support other equilibrium outcome

Equilibrium Multiplicity

Unlike classic disclosure games, SE outcome not unique when $K < N$

Off-path beliefs can support other equilibrium outcome

$$N = 3, K = 1$$

θ	$\bar{\omega}$	$M(\bar{\omega})$	$\sigma^*(\bar{\omega})$
θ_H	$(1,1,1)$	$\{\varnothing, 1\}$	$\varnothing$
	$(1,1,0)$	$\{\varnothing, 0, 1\}$	$\varnothing$
θ_L	$(1,0,0)$	$\{\varnothing, 0, 1\}$	$\varnothing$
	$(0,0,0)$	$\{\varnothing, 0\}$	$\varnothing$

Multiplicity is a serious (albeit common) challenge for experiments

- Data will provide guidance as to which equilibrium is played

Refinements

Multiplicity is a serious (albeit common) challenge for experiments

- Data will provide guidance as to which equilibrium is played

The selective-disclosure outcome is the only one that survives certain refinements:

Multiplicity is a serious (albeit common) challenge for experiments

- Data will provide guidance as to which equilibrium is played

The selective-disclosure outcome is the only one that survives certain refinements:

- Refinements for signalling games (e.g., Cho-Kreps ’87, Banks-Sobel ’87) have no force here

Multiplicity is a serious (albeit common) challenge for experiments

- Data will provide guidance as to which equilibrium is played

The selective-disclosure outcome is the only one that survives certain refinements:

- Refinements for signalling games (e.g., Cho-Kreps ’87, Banks-Sobel ’87) have no force here
- Refinements for cheap talks: Farrel (1993)’s **Neologism Proofness**, Matthews, Okuno-Fujiwara, Postelwite (1991), and some weaker versions

Go to Credible Neologism

Remark (Existence, again)

Our equilibrium is Neologism Proof.

Moreover, Neologism Proofness delivers outcome uniqueness

An equilibrium (σ, μ) induces an outcome $x : \Omega^N \to A$,

$$x(\bar{\omega}) = \sum_{\bar{\omega}'} \mu(\bar{\omega}'|\sigma(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \qquad \forall \bar{\omega}.$$

Proposition (Uniqueness)

Let (σ^*, μ^*) be our equilibrium and (σ, μ) be any other NP equilibrium. Let x^* and x their respective outcomes. Then, $x^* = x$.

Denote $\mathcal{M} = \bigcup_{\bar{\omega} \in \Omega^N} M(\bar{\omega})$ the space of all messages

Sender's Strategy

pure and θ-independent

- $\sigma : \Omega^N \to \mathcal{M}$ s.t. $\sigma(\bar{\omega}) \in M(\bar{\omega})$, for all $\bar{\omega}$

Receiver's Beliefs and Strategy

- $\mu : \mathcal{M} \to \Delta(\Omega^N)$
- $a : \mathcal{M} \to \Delta(A)$

Given μ, receiver's optimal strategy given by

$$a(m) := \arg\max_a \mathbb{E}(-(a-\theta)^2 | m) = \mathbb{E}(\theta | m)$$

Denote $\mathcal{M} = \bigcup_{\bar{\omega} \in \Omega^N} M(\bar{\omega})$ the space of all messages

Sender's Strategy

pure and θ-independent

- $\sigma : \Omega^N \to \mathcal{M}$ s.t. $\sigma(\bar{\omega}) \in M(\bar{\omega})$, for all $\bar{\omega}$

Receiver's Beliefs and Strategy

- $\mu : \mathcal{M} \to \Delta(\Omega^N)$
- $a : \mathcal{M} \to \Delta(A)$

Given μ, receiver's optimal strategy given by

$$a(m) := \arg\max_a \mathbb{E}(-(a-\theta)^2 | m) = \mathbb{E}(\theta|m) = \sum_{\bar{\omega}} \mu(\bar{\omega}|m)\mathbb{E}(\theta|\bar{\omega}) \qquad \forall m$$

Definition:

A Sequential Equilibrium is a pair (σ^*, μ^*) s.t.

1. For all $\bar{\omega} \in \Omega^N$, $\sigma^*(\bar{\omega}) \in M(\bar{\omega})$ and

$$\sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \geq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|m')\mathbb{E}(\theta|\bar{\omega}') \qquad m' \in M(\bar{\omega})$$

Definition:

A Sequential Equilibrium is a pair (σ^*, μ^*) s.t.

1. For all $\bar{\omega} \in \Omega^N$, $\sigma^*(\bar{\omega}) \in M(\bar{\omega})$ and

$$\sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \geq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|m')\mathbb{E}(\theta|\bar{\omega}') \qquad m' \in M(\bar{\omega})$$

2. For all m, supp $\mu^*(\cdot|m) \subseteq \tilde{C}(m)$.

Definition:

A Sequential Equilibrium is a pair (σ^*, μ^*) s.t.

1. For all $\bar{\omega} \in \Omega^N$, $\sigma^*(\bar{\omega}) \in M(\bar{\omega})$ and

$$\sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \geq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|m')\mathbb{E}(\theta|\bar{\omega}') \qquad m' \in M(\bar{\omega})$$

2. For all m, supp $\mu^*(\cdot|m) \subseteq \tilde{C}(m)$.

Notation:

$\tilde{C}(m) := \{\bar{\omega} \in \Omega^N : m \in M(\bar{\omega})\}$; types that could have sent m

Definition:

A Sequential Equilibrium is a pair (σ^*, μ^*) s.t.

1. For all $\bar{\omega} \in \Omega^N$, $\sigma^*(\bar{\omega}) \in M(\bar{\omega})$ and

$$\sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \geq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|m')\mathbb{E}(\theta|\bar{\omega}') \qquad m' \in M(\bar{\omega})$$

2. For all m, supp $\mu^*(\cdot|m) \subseteq \tilde{C}(m)$. In particular, if $m \in \sigma^*(\Omega^N)$,

$$\mu^*(\bar{\omega}|m) = q(\bar{\omega}|{\sigma^\star}^{-1}(m)) \quad \forall \bar{\omega}$$

Notation:

$\tilde{C}(m) := \{\bar{\omega} \in \Omega^N : m \in M(\bar{\omega})\}$; types that could have sent m

Definition:

A Sequential Equilibrium is a pair (σ^*, μ^*) s.t.

1. For all $\bar{\omega} \in \Omega^N$, $\sigma^*(\bar{\omega}) \in M(\bar{\omega})$ and
$$\sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \geq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|m')\mathbb{E}(\theta|\bar{\omega}') \qquad m' \in M(\bar{\omega})$$

2. For all m, supp $\mu^*(\cdot|m) \subseteq \tilde{C}(m)$. In particular, if $m \in \sigma^*(\Omega^N)$,
$$\mu^*(\bar{\omega}|m) = q(\bar{\omega}|{\sigma^{\star}}^{-1}(m)) \quad \forall\bar{\omega}$$

Notation:

$\tilde{C}(m) := \{\bar{\omega} \in \Omega^N : m \in M(\bar{\omega})\}$; types that could have sent m

Total Prob: $q(\bar{\omega}) = \sum_\theta p(\theta) f(\bar{\omega}|\theta)$; Conditional Prob: $q(\bar{\omega}|K)$

We refine off-path beliefs via **Neologism Proofness** (Farrel, 1993)

A **neologism** is a a pair (m, C) such that $C \subseteq \tilde{C}(m)$.

Literal meaning of (m, C) $\rightsquigarrow$ "*My type $\bar{\omega}$ belongs to C*"

We refine off-path beliefs via **Neologism Proofness** (Farrel, 1993)

A **neologism** is a a pair (m, C) such that $C \subseteq \tilde{C}(m)$.

Literal meaning of (m, C) $\rightsquigarrow$ "*My type $\bar{\omega}$ belongs to C*"

Definition

A neologism (m, C) is **credible** relative to equilibrium (σ^*, μ^*) if

$$(i) \quad \sum_{\bar{\omega}'} q(\bar{\omega}'|C)\mathbb{E}(\theta|\bar{\omega}') > \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \text{ for all } \bar{\omega} \in C,$$

$$(ii) \quad \sum_{\bar{\omega}'} q(\bar{\omega}'|C)\mathbb{E}(\theta|\bar{\omega}') \leq \sum_{\bar{\omega}'} \mu^*(\bar{\omega}'|\sigma^*(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \text{ for all } \bar{\omega} \notin C,$$

The equilibrium is **neologism proof** if no neologism is credible

Remark (Existence, again)

Our equilibrium is Neologism Proof.

Moreover, Neologism Proofness delivers outcome uniqueness

An equilibrium (σ, μ) induces an outcome $x : \Omega^N \to A$,

$$x(\bar{\omega}) = \sum_{\bar{\omega}'} \mu(\bar{\omega}'|\sigma(\bar{\omega}))\mathbb{E}(\theta|\bar{\omega}') \qquad \forall \bar{\omega}.$$

Proposition (Uniqueness)

Let (σ^*, μ^*) be our equilibrium and (σ, μ) be any other NP equilibrium. Let x^* and x their respective outcomes. Then, $x^* = x$.

In lab implementation, we may not need all these neologisms in:

$$\{(m, C) : m \in \mathcal{M}, C \subseteq \tilde{C}(m)\}$$

When Ω is binary, it is sufficient to consider these neologisms:

If m is off-path its literal meaning is "*my highest k signals are m*"

Proposition

If Ω is binary, weaker refinement guarantees outcome uniqueness.