Lying Aversion and Vague Communication: An Experimental Study

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Abstract

An agent may strategically employ a vague message to mislead an audience's belief about the state of the world, but this may cause the agent to feel guilt or negatively impact how the audience perceives the agent. Using a novel experimental design that allows participants to be vague while at the same time isolating the internal cost of lying from the social identity cost of appearing dishonest, we explore the extent to which these two types of lying costs affect communication. We find that participants exploit vagueness to be consistent with the truth, while at the same time leveraging the imprecision to their own benefit. More participants use vague messages in treatments where concern with social identity is relevant. In addition, we find that social identity concerns substantially affect the length and patterns of vague messages used across the treatments.

Keywords: Lying; Vagueness; Communication; Experiments; Behavioral Economics

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1 Introduction

Communication has been studied extensively in economics in recent decades. In particular, the types of messages sent by an agent in the communication process and their impact on an audience's beliefs have been important subjects of game theory. Standard economic models predict that a sender will choose a message that yields the greatest benefit from the receiver's action, even when such a message is a lie. It has however been observed that senders often choose to be evasive or use vague messages instead of telling maximal lies despite the possibility that doing so will yield a lower benefit than lying would. This raises two questions regarding why and when a sender prefers using a vague message over telling a maximal lie. This issue is crucial to achieving a unified understanding of misleading behavior in many applications, including problems associated with public good provision (Serra-Garcia, Damme, and Potters 2011), sender-receiver disclosure games (Hagenbach and Perez-Richet 2018), and persuasion games (Deversi, Ispano, and Schwardmann 2021).

To answer these questions we must carefully examine the behavioral aspects of lying and vague communication. First, as demonstrated by recent developments in the literature on lying behavior (Serra-Garcia 2018; Fischbacher and Föllmi-Heusi 2013; Abeler, Nosenzo, and Raymond 2019), most people exhibit a non-trivial degree of lying aversion. If an agent intrinsically prefers being honest, then the internal cost of lying should inhibit the use of lies and encourage the use of vague yet relatively truthful messages. Second, a message affects not only an audience's belief about the state of the world but also their belief about how honest an agent is. When the agent cares about their social identity as an honest person, this external concern should impact the message they choose to communicate. After all, "a vague belief has a much better chance of being true than a precise one, because there are more possible facts that would verify it" (Russell 1923). The nontrivial cost of lying suggests that communication is no longer cheap talk and the misleading messages may bear strategic significance as a credible signal to the audience about the agent's behavioral types. On the other hand, such a strategic incentive may also influence behavior. Thus, a rational agent must balance the degree of truthfulness and vagueness of the message communicated.

In this paper, we present a model of a cheating game in which an agent may report a vague (set-valued) message or a precise (single-valued) message to an audience after privately observing the state of the world. The agent's utility depends on the monetary payoff and their truth-telling preferences. The monetary payoff is determined solely by the reported message. We study two separable motivations for honesty: the internal motivation for being honest and an external concern related to social identity for being *seen as* honest. We isolate the two costs by employing an anonymous environment where the audience cannot identify an agent with a message. Based on the model, we hypothesize that people use vague messages to reduce their internal guilt and increase their monetary payoffs. The absence of the social identity concern in the anonymous environment should lead to more straightforward profit-maximizing message choices, while the prediction is more opaque in the non-anonymous environment because of the multiplicity of equilibria introduced in a richer message space.

To test hypotheses pertaining to vague communication with lying aversion, we compare treatments from an online experiment in which subjects face a variant of the Fischbacher and Föllmi-Heusi (2013) type of reporting task (hereafter "FFH"). In this experiment, subjects privately observe an integer drawn randomly from a uniform distribution ranging from 1 to 10. The subjects are asked to report the number to the experimenter, and their monetary payment increases with the reported number. The basic idea of the experiment is that the discrepancy between the maximum numbers they could have reported and the actual numbers reported should capture subjects' aversion to lying or, by the same token, their preferences for truth-telling. We generalize the FFH model by allowing subjects to transmit set-valued messages to understand the effect of vagueness in communication. In our setup, we allow subjects to be vague by reporting multiple numbers. The experimenter then chooses one number randomly from the reported numbers and pays the subject accordingly.

We use a 2x2 experimental design to test the predictions and, in particular, to separate the intrinsic cost of lying from the social identity cost of appearing dishonest. First, there are two types of experimental sessions that represent the variation in the anonymity of agents. In the anonymous session, the responses are recorded under screen names so that the experimenter cannot map a subject's identity to their response. In the non-anonymous session, on the other hand, the experimenter knows each subject's response. The social identity cost should not affect their responses in the anonymous treatment. Therefore, the difference in behavior between anonymous and non-anonymous treatments enables us to capture the impact of the social identity cost. Second, a subject confronts two reporting tasks within each session. The observation process is identical and independent for the two tasks. When the subject reports, however, the set of available messages differs between the two tasks. In the task with restricted communication, the set is restricted to single-valued messages only. In the task with unrestricted communication, the subjects are allowed to use both single-valued and set-valued messages.

The experimental data indicate that most subjects use vague messages and that the means of the numbers they report are higher on average when vague messages are allowed but the way they use vague messages differs across the treatments. First, in the anonymous treatments, we observe less frequent lying behavior when vague messages are allowed compared with when they are not allowed. As anonymity should suppress subjects' concern with social identity, the reduction in lying behavior suggests that a vague yet truthful message reduces the internal cost of lying. Yet, at the same time, they report higher numbers on average. That is, subjects exploit vagueness to avoid uttering falsehoods while leveraging the imprecision to their own benefit. Second, subjects use vague messages in the non-anonymous treatment more often than in the anonymous counterpart. The increased frequency of vague messages and the relevance of the concern with social identity suggest that a message's vagueness affects message choices through both the internal and external costs of lying. Furthermore, we find that the pattern of reported messages differs substantially between the two types of sessions. When subjects use vague messages in the anonymous treatment, most do not refrain from the most obvious forms: that is, they report a combination of their true observations and the maximum number (10). We find, however, that only a much smaller fraction of subjects using vague messages employ such obvious messages in the non-anonymous treatment. It is possible that, in the non-anonymous treatments, subjects may expect those obvious messages to be interpreted by the audience as lies, which will discredit their social identities.

Our paper bridges the literature on lying behavior with a broader set of studies that involve vague communication. Existing literature on vague communication focuses on the strategic use of vague messages without considering the behavioral aspect of lying aversion. For instance, Serra-Garcia, Damme, and Potters (2011), analyzing a public-goods provision game between two agents with information asymmetry, assume that a set-valued vague message would incur a much lower lying cost than a precise, single-valued outright lie. Our experiment tests this assumption and provides further insight into the cost of lying with respect to the social identity concern as well. Agranov and Schotter (2012) show that, in coordination games with multiple equilibria, it might be beneficial for a benevolent sender to use vague communication. Zhang and Bayer (2022) show that, in a delegation game, social welfare is higher when messages are intervals. Wood (2022) concludes that transmitted information is more accurate when senders have the option to send either precise or vague messages. Deversi, Ispano, and Schwardmann (2021) study the strategic use of vagueness in a voluntary disclosure game. They allow subjects to send an interval that contains their type, and this formal message structure is similar to that in our design. Yet, there are two distinctive features that separate our design from theirs. First, we provide subjects with greater flexibility in choosing messages by allowing them to choose any subset of the state space. We also add a between-subject variation on anonymity. This flexibility and the variation of anonymity allow us to explore the extent to which attitudes toward lying and misleading behavior affect the use of vague messages in conjunction with strategic motives.

Conceptually, we view lying behavior as an optimization process in which a rational agent chooses the optimal degree of dishonesty, by balancing the marginal monetary benefit of lying with the non-monetary costs that depend on the likelihood that an individual is found to be lying. In a more specific context involving the nature of lying behavior, Sobel (2020) provides a comprehensive framework in which to understand lying and deception in games. He distinguishes between three properties —the form, the interpretation, and the consequence —of a message, and our model closely follows the framework suggested in that paper. We would like to particularly mention the notions of malleable lies in Turmunkh, Assem, and Dolder (2019) and deniable lies in Tergiman and Villeval (2022) which are closely related to our empirical findings pertaining to the use of vague messages. However, while the definitions of malleable and deniable lies hinge on their interpretations, we define lying strictly by reference to the formal property of a message: a message is a lie only when it does not represent the true state of the world. The agents in our model face both monetary and, potentially, psychological consequences for their message choices. Furthermore, through an analysis of equilibrium strategies, we model how the interpretation of a message affects an agent's decision. This structure allows us to decompose the internal cost of lying from the concern for social identity.

Structurally, we study lying behavior within the framework of signaling games. Since Crawford and Sobel (1982), a stream of research has tested the assumption that lying is costless, which implies that individuals will lie whenever there is a material incentive to do so. The empirical evidence continues, however, to make the case against this notion (e.g. Dickhaut, McCabe, and Mukherji (1995), Blume et al. (1998), Gneezy (2005), Sánchez-Pagés and Vorsatz (2007), Shalvi et al. (2011) and many more). Many studies argue that individuals clearly express aversion to lying and accept significantly lower payoffs than the theories have predicted.

An empirical consensus regarding the FFH experiments is that people do not lie to the extent that they could, preferring to tell only minor lies, potentially because lying is costly. As the monetary payoff in such an experiment is independent of the drawn number, subjects should report non-maximal numbers only if aversion to lying is present, for otherwise this becomes a simple case of a cheap-talk game. Abeler, Nosenzo, and Raymond (2019) combine data from 90 such experiments that describe the average reporting behavior. They find that the behavior is indeed bounded away from the maximal report but also departs from a complete truth-telling scenario. In addition, by ruling out other explanations for truth-telling which are popular in the literature (e.g. inequality aversion or seeking a reputation for not being greedy), they conclude that a preference for being seen as honest and a preference for being honest are the main motivations. As Abeler, Nosenzo, and Raymond (2019) note in their conclusion, however, the FFH paradigm has focused on subjects reporting a single number and excludes lies by omission or vagueness. Our paper extends the FFH paradigm by allowing vague communication using set-valued messages and contributes to our knowledge of how a message space in communication plays a role in an agent's reporting decision when lying entails a cost.

The studies that are closest to our work are Gneezy, Kajackaite, and Sobel (2018) and Khalmetski and Sliwka (2019). In these studies, an agent cares not only about obtaining a monetary payoff but also about whether lying takes place as well as how others interpret their report, a finding that is consistent with the empirical findings of the aforementioned study by Abeler, Nosenzo, and Raymond. These papers adopt the FFH paradigm and simplify the sender/receiver structure of a signaling game into a cheating game between reporting agents and an observing audience. This idea, in conjunction with the assumption of a non-atomic game, minimizes the role of the receiver and allows a sharper focus on that of the sender. Moreover, this simplification makes it possible to develop a unique characterization of off-path beliefs in the context of mild conditions. While we inherit their assumptions of these assumed motivations for truth-telling —internal guilt and the external concern with one's social identity —extending the message space to include set-valued messages yields more opaque predictions with multiple equilibria and off-path beliefs. We overcome this difficulty by introducing an anonymous environment to hold the impact of social identity constant.

We observe that, as long as a message can remain even remotely truthful, most agents exhibit no hesitation in increasing their monetary payoff. This observation is analogous to behavior reflecting "moral wiggle room" (Dana et al. 2007), the notion that people engage more resolutely in self-interested behavior when excuses for selfish actions are available. On the other hand, there exists a group of truth-tellers in our experiment whose reports are not only truthful but also precise, thus possibly relinquishing opportunities to obtain monetary gains. The non-trivial size of this group suggests another motivation for truth-telling in addition to internal and external concerns regarding honesty. Candidates might include a concern for the consequences of choices made or concern with good intentions.

The remainder of the paper is organized as follows. In Section 2 we define our terms and present the model setting. Section 3 provides theoretical analysis, while in Section 4 we present the experiment hypotheses based on the theoretical predictions. In Section 5 we describe our experiment design, in Section 6 we summarize the experimental outcomes, and Section 7 concludes. We list all the proofs and additional details regarding the experiment in the appendices.

2 Model

2.1 A model of lying aversion with vague communication

We study lying aversion with vague communication by considering a variant of the Fischbacher and Föllmi-Heusi cheating game with a population of agents and one audience. An agent privately observes the state of the world $i \in \Omega$, where $\Omega = \{1, 2, \ldots, N\}$ is finite. We assume i is drawn i.i.d. from a uniform distribution over Ω across agents. Each agent has a private type t that represents their intrinsic aversion to lying. We also assume t is i.i.d. across agents. Its CDF $F(t)$ is strictly increasing, continuous, and has support $[0, T]$. Denote an agent who observes the state i and has the intrinsic aversion type t as a type (i, t) agent.

An agent reports a message J to the audience after observing the true state of the world i. This reporting takes place only once and there are no repeated interactions. Like Gneezy, Kajackaite, and Sobel (2018)(GKS) and Khalmetski and Sliwka (2019)(KS), we assume that an agent's utility consists of three components: a monetary payoff, an internal concern with being honest, and a social identity for being seen as honest. We use the term 'social identity' to distinguish it from the typical understanding of reputation in a dynamic game, as we are modeling a one-shot game. Formally, we write a type (i, t) agent's utility for reporting a message J as:

$$U(i, J, t) = \underbrace{\bar{\pi}(J)}_{\text{monetary payoff}} \underbrace{- \mathbb{1}(i \notin J)[t + c(\pi(\{i\}), \bar{\pi}(J))]}_{\text{internal guilt}} + \underbrace{\gamma \rho(J)}_{\text{external social identity}} . \tag{1}$$

The message J is a nonempty[1] subset of the state space: $J \in M^{\Omega} \equiv 2^{\Omega} \setminus \emptyset$. An important distinction between our model and GKS and KS is that in our model the message space admits set-value messages instead of being isomorphic with the state space. This generalization allows messages to be categorized in multiple ways. We define the relevant terms below.

Definition 1. A message J is truthful if $i \in J$. A message is a lie if it is not truthful.

[1] An empty set is often interpreted as silence and plays an interesting role in the literature on vague communication. We abstract away from silent messages to compare cases where lying aversion is accompanied by vague language with cases where lying aversion is accompanied by precise language.

Definition 2. A message is called precise if it is a singleton set; otherwise it is vague.

Let $M_P^\Omega \equiv \{\{1\},\{2\},\ldots,\{N\}\}$ and $M_V^\Omega \equiv M^\Omega \setminus M_P^\Omega$ denote the sets of precise messages and vague messages, respectively. For example, if $\Omega = \{1,2,3\}$, the set of possible precise messages is $\{\{1\},\{2\},\{3\}\}$, and the set of possible vague messages is $\{\{1,2\},\{2,3\},\{1,3\},\{1,2,3\}\}$.[2] Note that our definition of lying depends purely on the form of a message, as in the framework proposed in Sobel (2020). The consequences of a message choice are reflected through effects on the components of the agent's utility.

The monetary payoff for an agent maps a message to the agent's utility: $\pi : M^\Omega \to \mathbb{R}$. For simplicity, we assume that $\pi(J)$ is a uniform draw over J and that the agent is a risk-neutral, expected-utility maximizer. Let us denote $\bar{\pi}(J) = E[\pi(J)]$. Note that, when a message is precise, i.e. $J = \{x\}$ with $x \in \Omega$, the monetary payoff $\pi(J)$ is simply x.

In addition to receiving a monetary payoff, the agent also has two distinct motivations for being honest. First, the agent has an internal motivation for being honest. When the agent's report J is not truthful, that is, $i \notin J$, the dishonesty incurs an internal cost, $t + c(\pi(\{i\}), \bar{\pi}(J))$. The agent's private type t captures their sensitivity to the intrinsic (fixed) cost of lying. The function $c(\pi(\{i\}), \bar{\pi}(J)) : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ represents the variable cost of lying depending on the size of the lie. The size of the lie is measured as the ex-ante difference between the monetary payoff for a report J and that of the true and precise report $\{i\}$. We assume that i) $c(\cdot) \geq 0$; ii) $c(\pi(\{i\}), \pi(\{i\})) = 0$; iii) $c(\pi(\{i\}), \bar{\pi}(J))$ is weakly increasing in $|\pi(\{i\}) - \bar{\pi}(J)|$; iv) $c(\pi(\{i\}), \pi(\{i\}) + 1) < 1$;[3] and v) $c(\pi(\{i\}), \bar{\pi}(J)) + c(\bar{\pi}(J), \bar{\pi}(K)) \geq c(\pi(\{i\}), \bar{\pi}(K))$.

The agent also has an external motivation to be ascribed a social identity for being seen as honest; that is, the agent's utility depends on the audience's belief about how honest the agent is. We assume that the audience is a rational Bayesian who forms a posterior belief based on the agent's report J. This belief, in turn, depends on the agent's mixed strategy in equilibrium.

Definition 3. A type (i, t) agent's mixed strategy is a mapping $\sigma : \Omega \times [0, T] \to [0,1]^{2^N - 1}$

[2]The fully vague message $\Omega \in M^\Omega$ is analogous to the notion of evasive lying in Khalmetski, Rockenbach, and Werner (2017) by which the sender falsely states to have not observed the state of the world.

[3]This assumption excludes the trivial case where the variable cost of lying is so high that no agent chooses to lie.

such that

$$\sigma(i,t) = \left(\sigma_{it}^{\{1\}}, \sigma_{it}^{\{2\}}, \ldots, \sigma_{it}^{\{1,2,\ldots,N\}}\right) \tag{2}$$

where σ_{it}^{J} is the probability which the intrinsic aversion type t agent with true observation i assigns to the report $J \in M_\Omega$.

In equilibrium, the audience's posterior belief about whether an agent's report J is truthful is computed using Bayes' rule:

$$\rho(J) = \frac{P(\text{agent is honest} \wedge \text{agent reports } J)}{P(\text{agent reports } J)} = \frac{\sum_{k\in J}(\int_0^T \sigma_{kt}^{J} df(t))}{\sum_{k=0}^{N}(\int_0^T \sigma_{kt}^{J} df(t))} \tag{3}$$

We normalize the posterior belief ρ in terms of the agent's utility by parameter γ. The parameter measures the agent's sensitivity to their social identity reflected in reporting message J. We further assume that i) γ is homogeneous across agents and is common knowledge; moreover, ii) $N + \gamma < T$. The latter condition ensures that $F(N+\gamma) < 1$, or there always exists a positive mass of agents who will be truth-telling for any observation i.

Because the agent's payoff depends on the audience's belief, we adopt the notion of sequential equilibria in an induced psychological game in the sense of Battigalli and Dufwenberg (2009) and Geanakoplos, Pearce, and Stacchetti (1989).

An equilibrium is a set of mixed strategies and beliefs satisfying the following conditions:

$$\forall (i,J,t) : \sigma_{it}^{J} > 0 \text{ only if } J \in \underset{J'}{\operatorname{argmax}}\, U(i,J',t), \tag{4}$$

$$\forall (i,t) : \sum_{J\in M^{\Omega}} \sigma_{it}^{J} = 1, \tag{5}$$

$$\forall J : \rho(J) = \frac{\sum_{k\in J}(\int_0^T \sigma_{tk}^{J} df(t))}{\sum_{k=0}^{N}(\int_0^T \sigma_{tk}^{J} df(t))}. \tag{6}$$

As noted by GKS, the existence of an equilibrium follows Schmeidler (1973) in treating each type (i,t) as a player.

2.2 The communication environment and the anonymity of agents

The baseline model assumes no restriction on message space M^{Ω}. If we restrict message space to M_P^{Ω}, on the other hand, we obtain a model with restricted communication. We refer to the baseline model as the model with unrestricted communication. At the risk of abusing the notation, let us denote a message as j in the model with restricted communication.

Furthermore, for a more comprehensive understanding of the relationship between the use of vague messages and the costs of lying, it is helpful to isolate their effects on internal guilt from their effects on external social identity. We can achieve this by employing an anonymous environment where the audience cannot identify an agent with a message. This implies that the agent's report does not alter the audience's belief, and hence the agent's social identity remains constant independent of their reporting choice in the anonymity-preserving environment. On the other hand, we call an environment non-anonymous when the audience can associate a message with its sender. Formally, we write an agent's utility in the anonymous environment as:

$$U_A(i, J, t) = \bar{\pi}(J) - \mathbb{1}(i \notin J)\left[t + c(\pi(\{i\}), \bar{\pi}(J))\right]. \tag{7}$$

We thus create four distinct environments by varying the restriction on the message space and the anonymity of the agents. In these environments, the agent is non-anonymous with restricted (precise only) communication (NA-R), non-anonymous with unrestricted (potentially vague) communication (NA-UR), anonymous with restricted communication (A-R), and anonymous with unrestricted communication (A-UR). Note that the NA-R environment corresponds to the standard FFH model where an agent can send only precise messages and the audience can identify a message's sender.

	Non-anonymous	Anonymous
Restricted	NA-R	A-R
Unrestricted	NA-UR	A-UR

Table 1: Four environments

3 Analysis

In this section we describe the equilibria and agents' behavior in each of the four environments as defined above. We begin by arguing that we should expect to observe vague messages used at positive probabilities in any equilibrium.

Proposition 1. *In any equilibrium under unrestricted communication, there exist types of agents who use at least one vague message with positive probability in their mixed strategies.*

Proof. See Appendix A. □

The intuition behind Proposition 1 is that there exist agents with moderately high intrinsic lying aversion type t who would prefer to be truthful while increasing the monetary payoff. Therefore, in their messages, they include higher numbers apart from their true observations. For these agents, such messages strictly dominate any precise lie.

In comparison with the unrestricted communication environment in which we are interested, a particularly useful element when analyzing a restricted communication environment is the assumption that there always exists a positive mass of truth-tellers for each observation i. While this assumption is sufficiently plausible in many contexts, it aids us especially in eliminating less interesting equilibria by uniquely characterizing off-path beliefs. Thus, we are able to make sharp equilibrium predictions even in the case of the non-anonymous environment. This, however, is unfortunately not the case when we relax the message space to allow vague messages: the richer message space induces multiplicity in agents' reporting strategies and the audience's off-path beliefs. We illustrate this point with the following examples.

Example 1. Consider the case where $\gamma > \frac{N-1}{2}$. Then this case in which all agents report the vaguest messages $\{1, 2, \ldots, N\}$, such that $\rho(J) = 1$ only when $J = \{1, 2, \ldots, N\}$ and 0 otherwise, is an equilibrium.

This example describes the scenario in which agents care greatly about social identity and are forced to stick to the (exogeneously) given norm of full vagueness. While this specific example is similar to situations that might occur in the real world,[4] an important implication is that there can exist a multiplicity of equilibria depending on the combination of γ and the off-path beliefs. Consider the following example.

Example 2. All agents report a message in the form of an interval: $[i,N] = \{i, i+1, \ldots, N-1, N\}$, and the audience assigns a positive posterior belief only to those interval-messages and zero to all other messages. We need the following conditions to hold to constitute such equilibria:

- truth-tellers: $\frac{i+N}{2} + \gamma\rho(J) > U(i, \{i, x^*, x^*+1, \ldots, N\}, t)$[5] for all i and an interval message J
- liars: $\frac{k+N}{2} - \mathbb{1}(i \neq k)(t + \bar{\pi}(J)) + \gamma\rho(J) > U(i, J', t)$ for any non-interval message J'

The conditions hold trivially when $\gamma \to \infty$, and the signaling game becomes isomorphic with the NA-R scenario, where each message i is simply replaced with the interval $[i,N]$. The ending sequence conveys no information to the audience, and the equilibrium follows that of the NA-R.

The multiplicity of equilibria obscures our understanding of the agents' behavior regarding vague communication. We thus first turn our attention to anonymous environments to delineate the relationship between one's internal cost of lying and vague messages.

Because we are now free of the social identity component, we can utilize the fact there is a clear mapping between an agent's type (i,t) and the resulting behavior. That is, fixing the observation i, one's lying behavior simplifies to a monotone function of t in the A-R environment: the agent reports $j > i$ when $(j-i) + c(i,j) > t$. Thus, there exists a threshold t_i^* for each observation i below which the agent reports a lie and above which the agent tells the truth. This threshold, however, becomes much higher

[4]For instance, we may imagine a group of politicians all replying with the same vague message to a politically sensitive question because they know that any message other than a fully vague message will be interpreted as a lie and hurt their social identity. Many similar examples can arise in situations where agents value their social identity highly. We appreciate Brian Rogers for suggesting this interpretation of the equilibrium.

[5]This message maximizes the expected payoff conditional on including the true state i. We later define this kind of message as an optimally vague message.

in the A-UR environment because now the agent is equipped with vague messages that allow them to remain truthful while increasing the expected payoff. This fact leads to the following observations.

Observation. *If a type (i, t) agent reports truthfully after observing state i in the A-R environment, then the agent also reports truthfully when observing i in the A-UR environment.*

Observation. *For each observation $i < N$, there exists a positive mass of agents who lie in the A-R environment but report truthfully in the A-UR environment.*

The immediate corollary of these two observations is the following proposition, which states that the mass of liars is greater when communication is restricted in the anonymous environments.

Proposition 2 (A-R/A-UR)**.** *The set of types (i,t) of agents who lie in equilibrium in the A-UR environment is a subset of liar types in any equilibrium in the A-R environment. The expected monetary earnings are greater on average when the communication is not restricted.*

Another implication of the anonymous environment worth noting is that the absence of the social identity concern simplifies the problem into a straightforward comparison between the solutions to truth-telling-constrained and unconstrained optimizations. That is, for each type (i, t) agent, there exists both $\max_{J:i\in J} U(i, J, t)$ and $\max_{J\in M^\Omega} U(i, J, t)$, and the agent reports truthfully only if the two maximums coincide.

We can add structure to the constrained optimization. Intuitively, this maximum has the form of a union of the true observation i and some ending sequence $x, x+1, \ldots, N$. We can solve the optimization problem to find the threshold $x^* = \lceil (N+2) - \sqrt{2N - 2i + 3} \rceil$. [6]

Definition 4. The optimal vague message (OVM) for each true observation i is defined as

$$OVM_i \equiv \{i, x^*, x^* + 1, \ldots, N\}, \tag{8}$$

where x^* the threshold above which including the values maximizes.

[6] We can simplify the optimization problem by approximating it with a continuous uniform distribution: $\text{argmax}_x \int_i^{i+1} \frac{u}{N-x+2} du + \int_x^N \frac{u}{N-x+2} du$

Then $OVM_i \in \text{argmax}_{J:i\in J} U(i,J,t)$ and weakly dominates all truthful messages. This allows us to make the following inferences in the A-UR environment:

Proposition 3. *In the A-UR environment, all truth-tellers use the optimal vague messages.*

Corollary. *In the A-UR environment,*

i. no agent's message contains a number below the true observation.

ii. no precise message except $\{N\}$ is truthful.

Lastly, we conclude this section by comparing the behavior of an agent in the non-anonymous environment with that of an agent in the anonymous environment. A thought experiment that involves choosing an agent and comparing their behavior in the two environments easily leads to the conjecture that the absence of the social identity concern should only encourage more lies. The following lemma shows that this is indeed the case under restricted communication.

Lemma 1. *If a type (i,t) agent lies in an equilibrium in the NA-R environment, then the agent lies in the A-R environment.*

Proof. See Appendix A. □

Using the above lemma, we now generalize the argument to compare the probability that an arbitrarily chosen agent lies in the two environments.

Proposition 4 (NA-R/A-R)**.** *The set of types (i,t) of agents who lie in an equilibrium in the NA-R environment is a subset of the set of liar types in any equilibrium in the A-R environment. The expected monetary earnings are higher on average in the A-R environment.*

Proof. See Appendix A. □

4 Hypotheses

In this section, we have transformed our theoretical analysis into specific hypotheses that can be tested in an experiment. The results of the experiment, which will be discussed in the following section, will be based on these hypotheses.

Hypothesis 1. *In both the NA-UR and A-UR environments, agents use vague messages.*

Hypothesis 1 is a consequence of Proposition 1.

Hypothesis 2 (A-R/A-UR)**.** *In the anonymous environment,*

i. more agents lie when communication is restricted (precise): $lie_{A-R} \geq lie_{A-UR}$*;*

ii. an agent who is truthful in A-R is also truthful in A-UR conditional on the same observation;

iii. some agents who lie in A-R report truthfully in A-UR conditional on the same observation;

iv. agents earn higher monetary payoffs on average when communication is not restricted (vague): $earning_{A-R} \leq earning_{A-UR}$*.*

Hypothesis 2 is a consequence of Proposition 2 and the above observations about behavior in the A-UR environment.

Hypothesis 3. *In the A-UR environment,*

i. all truth-tellers in A-UR use OVM;

ii. no message contains a number below the true observation;

iii. no precise message except $\{N\}$ *is truthful.*

Hypothesis 3 is a consequence of Proposition 3 and its corollary.

Hypothesis 4 (NA-R/A-R)**.** *Under restricted communication, agents earn higher monetary payoffs on average in the anonymous environment:* $earning_{NA-R} \leq earning_{A-R}$*.*

Hypothesis 4 is a consequence of Proposition 4.

5 Experimental Design

We vary the experimental treatments along two dimensions: 1) we consider precise or vague messages, and 2) we vary the experimenter's ability to identify responses to an individual subject. We represent variation in the anonymity of subjects in two types of experiments. Within each session, a subject confronts two stages of reporting tasks that represent the availability of vague messages. In each stage, subjects are incentivized to observe a random number and later report the number to the experimenter. Their earnings depend on the number or numbers they report.

In the anonymous session, responses are recorded under screen names so that the experimenter cannot map a subject's identity to their response. As the subjects are instructed that the experiment prohibits such mapping by design, this treatment should establish the effect of suppressing the social identity concern and emulate the environment where $\gamma \to 0$. In the non-anonymous (identifiable) session, on the other hand, the experimenter knows each subject's response.

The 'stage' is our basic unit of observation. In each stage, subjects first observe the realization of a random integer uniformly distributed between 1 and 10 and later are asked to report the number. In the anonymous treatment, the number is generated within the experimental software so that the experimenter knows both the true observation what each subject reports. In the non-anonymous treatment, subjects use an external website to generate the random number so that the experimenter cannot know the true observation.[7] The experimenter is unable to identify whether a particular individual has lied or not in any of the treatments. This design choice derives from the idea that an environment in which the experimenter can detect cheating at the individual level is overly artificial; as result, subjects' discomfort with lying behavior may be exaggerated in such an environment.

The observation process for the two tasks is identical and independent but the set of available messages differs between the two tasks. In the restricted stage, the set is restricted to single-valued messages only. In the unrestricted stage, subjects are allowed to use both single-valued and set-valued messages. In the restricted stage, the subjects

[7] We provided a link to a Google search result for the phrase "random number between 1 and 10."

are paid the equivalent in dollars of the number they report divided by 2. In the unrestricted stage, when they report a single number, they are paid the equivalent in dollars to the number they report divided by 2, while when they report multiple numbers, the computer will randomly choose one of the numbers and they are paid the equivalent in dollars of this number divided by 2. To emulate the one-shot game structure of our model, we asked subjects to participate only once in each of the stages and we randomized the order of precise and vague stages within a session.[8]

The combination of these between-subject and within-subject variations yields four treatments in our experiment: NA-R,[9] NA-UR, A-R, and A-UR.

We recruited 176 student subjects from the subject pool of the Missouri Social Science Experimental Laboratory (MISSEL) at Washington University in St. Louis. For recruitment and experiment management, we used the ORSEE system (Greiner 2015). Students were invited to participate in a virtual Zoom meeting where the experimenter read the instructions and provided a link to the main experiment web page. The main experiment was implemented using the Qualtrics online survey platform.

We conducted 18 sessions and each session lasted for approximately 30 minutes, including the instructions read during Zoom meetings, a screening quiz to make sure that subjects understood the experimental procedures, and two stages of the main experiment task via Qualtrics. [10] In all cases, subjects received a $2 show-up fee, so the total amount they could earn ranged from $2 to $12, with an average total fee, including the show-up fee, of $9.84. No subject participated in more than one session. See Appendix D for our experimental instructions and procedural details.

6 Results

We present basic summary statistics in Table 2. There were 8 anonymous sessions and 10 non-anonymous sessions, with an average of 12.3 and 8.2 participants, respectively,

[8]Using OLS regressions, we find that there is no order effect on the average report.

[9]The NA-R treatment is equivalent to the original experiment conducted by Fischbacher and Föllmi-Heusi (2013).

[10]The first 11 sessions were conducted from August 2020 to October 2020, while the remainder were conducted in September 2022. The results of a logit regression show no significant differences in the probability of lying between the two groups of sessions.

in each session.[11]. In the unrestricted communication treatments, we used the mean of the numbers included in each subject's report when calculating the average report. We computed the average length of vague messages using the average number of numbers included in the messages.

	Restricted	Unrestricted			Observations
	Average	Average	Vague (%)	Length	
Anonymous	7.619	8.132	48%	2.103	97
Non-anonymous	7.000	8.282	75%	2.810	79

Table 2: Data summary

We report first that the majority of subjects used vague messages in both treatments.

Result 1. *In the NA-UR environment, 59 of 79 participants (74.7%) used vague messages. In the A-UR environment, 47 of 97 participants (48.4%) used vague messages.*

This result supports Hypothesis 1.

In the anonymous treatment, the numbers reported for the restricted and unrestricted treatments average 7.619 and 8.132, respectively, while in the non-anonymous treatment, the numbers reported average 7 and 8.282, respectively. These reported numbers are significantly lower than those in the profit-maximizing reports and are in line with findings reported in the literature that have highlighted agents' preference for truth-telling. Overall, we find that allowing vague messages increased the mean of numbers reported. We also find that the probability of lying is independent of gender in both the restricted and unrestricted treatments. Additional details regarding the logit regression outcomes are available in Appendix B. In addition, we find that the impact of anonymity on average reports is statistically not significant. Finally, we show that the introduction of non-anonymity significantly affects the choice to send vague messages. In the treatment where social identity concern is relevant, subjects use vague and longer messages more often.

Result 2. *In the anonymous environment,*

[11]Participants chose time blocks voluntarily, and we provided the anonymous version of the software in larger sessions.

1. *more participants lied when communication was restricted (43.3% in A-R and 30.9% in A-UR);*

2. *almost all participants who were truthful in A-R remained truthful in A-UR;*[12]*;*

3. *52.58 % of subjects reported truthfully under both A-R and A-UR, 26.80% always lied, while 16% switched from lying to truth-telling when they were allowed to be vague;*

4. *participants reported higher numbers on average when communication was not restricted (7.619 in A-R and 8.282 in A-UR).*

A comparison between the results obtained with restricted and unrestricted communication in anonymous sessions confirms Hypothesis 2. More subjects lied in the restricted than in the unrestricted treatment and their behavior can be classified into three types: truth-tellers (reported truthfully under both treatments), conditional liars (switched from lying to truth-telling when they were allowed to be vague) and liars (lied under both treatments). This is in line with previous work on lying aversion (Gneezy, Kajackaite, and Sobel (2018), Khalmetski and Sliwka (2019), among others). An interesting point is that 15 of the 16 participants who switched from lying to truth-telling reported picking the number 10 in A-R, yet they chose vague and truthful messages when the expected earnings were lower than 10. This finding supports our conjecture that the internal cost of lying depends on the inclusion of true states in the reported messages.

Table 3 presents the average numbers reported in the A-R and A-UR treatments for truth-tellers, conditional liars, and liars. We find that truth-tellers report on average 1.282 higher numbers when they are allowed to be vague. This result is significant at the 1% significance level and is consistent with the model's prediction that truth-tellers seek payoff maximization conditional on including true observations in their reports. Conditional liars reported on average 1.156 lower numbers when they were allowed to be vague. This result is significant at the 1% significance level and supports Hypothesis 2. We interpret this result as implying that subjects with moderate t prefer to use vague

[12]Four subjects were truthful in the A-R and lied in the A-UR, but their true observations were much larger in the A-UR than in the A-R treatments. It is likely that the counterfactual would be consistent with our prediction conditional on observing similar numbers in both treatments.

messages and include true states to reduce the internal cost of lying. Consistent with our expectation regarding agents with higher t, we did not find a significant impact of unrestricted communication on liars as reflected in their average reports. In addition, t-tests of the difference between subjects' true observations and their reports show over-reporting across all three types in the A-UR treatment. This result is also in line with Hypothesis 2, which states that agents earn higher monetary pay-offs under unrestricted communication. Likewise, we also find that a true observation has a negative effect on the probability of lying in the restricted treatment, while it has no effect in the unrestricted one. Table 4 presents the estimated coefficients of the logit model of the effect of true observations on the probability of lying. This result is intuitive, as a subject who randomly drew a low observation can increase their payoff only by lying when the communication is restricted to precise messages. These subjects can, however, always employ a vague yet truthful message in the unrestricted environment; hence the true observation has no effect.

	Restricted	Unrestricted	Differences in means	Observations
Truth-tellers	5.608	6.890	1.282	51
	(0.416)	(0.293)	(0.464)	
Conditional liars	9.875	8.718	-1.156	16
	(0.125)	(0.316)	(0.370)	
Liars	10	9.962	0.038	26
		(0.027)	(0.027)	
Test (Report = True)				
Truth-tellers	0	1.953		51
		(0.267)		
Conditional liars	5.000	1.531		16
	(0.791)	(0.432)		
Liars	5.462	5.076		26
	(0.521)	(0.543)		

Table 3: Anonymous Treatment

	Observation (Restricted)	Observation (Unrestricted)
Lying dummy	-0.138	-0.081
	(0.072)	(0.081)

Table 4: Logit model of the probability of lying

Result 3-1. *In the A-UR environment,*

1. (a) *28.4% (19 of 67) of truth-tellers reported the optimal messages (either the OVM or the honest 10), 26.9% (18 of 67) reported a pair of true observations and 10;*

   (b) *23.9% (16 of 67) of truth-tellers used a precise message below* {10}*;*

2. *only 2 of 97 subjects included a number below the true observation in the report;*

3. *all precise messages reporting numbers below* {10} *were truthful.*

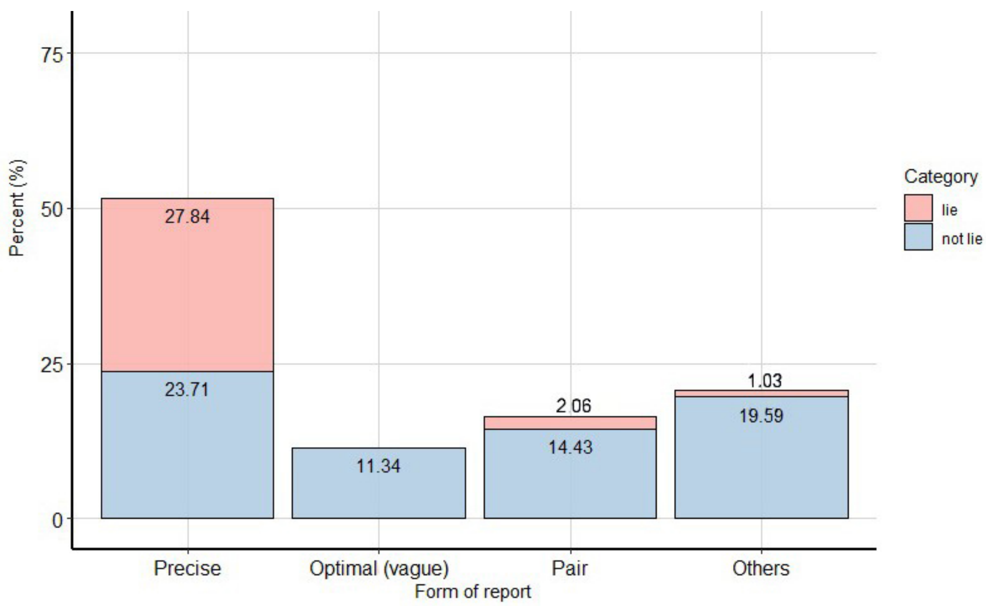

Figure 1: Message types used in A-UR treatments

This result partially supports Hypothesis 3. Figure 1 summarizes the types of messages used in A-UR treatments. Overall, 51.5% (50 of 97) of participants used precise messages, while 48.5% (47 of 97) used vague messages. Among the 50 precise messages, 54% (27 of 50) were lies and 46% (23 of 50) were not lies. All the liars reported drawing the maximum of 10. Among the 23 precise truth-tellers, 7 observed 10 and reported so.

The model predicts that all truth-tellers seek payoff maximization conditional on including true observations in their reports. If we combine both optimal vague messages (including honest 10 as the optimal message) and the pair-type messages into a broader set of payoff-increasing truthful messages, we find that the majority (55.2%) of truth-tellers maximized their monetary payoffs conditional on being honest.[13] Yet there remains a noticeable number of precise truth-tellers who reported drawing a number below 10, which contradicts our hypothesis. This may suggest the possibility of other motivation for truth-telling that is not captured by our model.

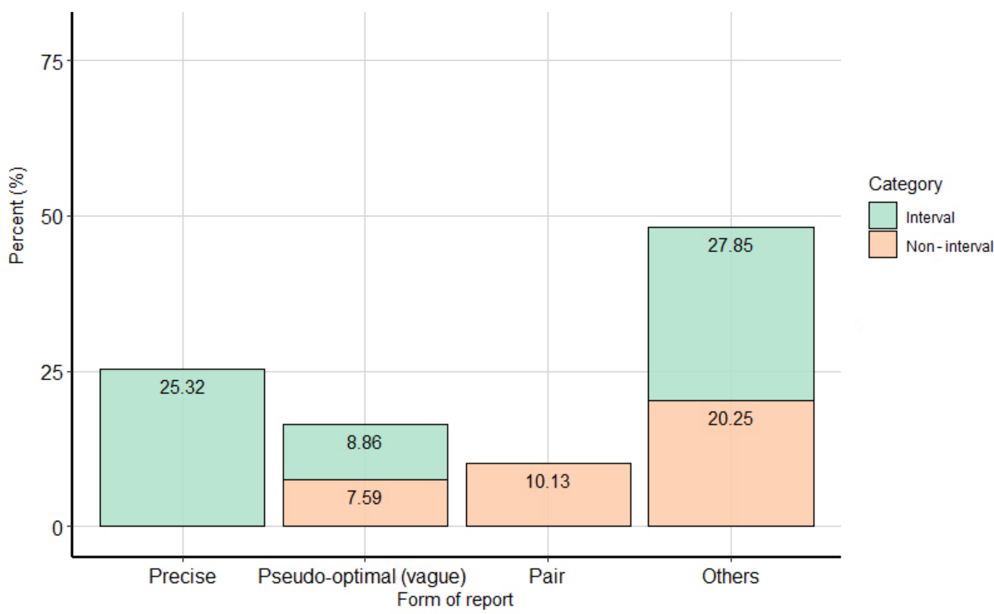

Figure 2: Message types used in NA-UR treatments

Comparing behaviors across the A-UR and the NA-UR treatments, it is interesting to note that a higher percentage of participants used vague messages in the non-

[13]When a message is both optimal and precise, namely $\{10\}$, we count it as an optimal message. Likewise, when a message is both optimal and contains two numbers, like $\{8, 10\}$, we label it 'Optimal.' We classify sub-optimal messages using two numbers as 'Pair.'

anonymous environment. Overall, 25.3% (20 of 79) of participants used precise messages while 74.7% (59 of 79) used vague messages. This difference might reflect the fact that some maximal liars in the anonymous case lie by reporting 10 in the absence of any concern with social identity. Also, it is worth noting that vague messages were longer in the non-anonymous treatments (2.81 numbers reported on average) compared with what occurred in the anonymous environment (2.10 numbers reported on average). The difference is significant at the 1% significance level and could reflect the impact of vague messages on the external cost of lying. To further compare the effect of social identity on vague communication, we categorized vague messages into the following three categories: 'Pseudo-optimal,' 'Pair,' and 'Others.' While we do not know the true observation of each subject in the non-anonymous treatments, we classified optimal-looking messages as 'Pseudo-optimal' in a similar manner to how we defined the OVM in Definition 8, using the minimum reported numbers in the messages as pseudo-true-observations. For example, a report consisting of $\{6, 9, 10\}$ is considered pseudo-optimal because this message would maximize the expected payoff if the true observation was 6. A report $\{6, 7, 8, 9, 10\}$, on the other hand, is not classified as pseudo-optimal.[14] Figure 2 summarizes the types of messages used in NA-UR treatments.

Result 3-2. *In the NA-UR environment,*

1. *22.0% (13 of 59) and 13.6% (8 of 59) of vague messages are pseudo-optimal and pairs, respectively; and*
2. *49.2% (29 of 59) of vague messages take the form of an interval.*

Note that, compared with the results observed in the anonymous treatment, as displayed in Figure 1, participants used fewer precise and pair-type messages. Conditional on using vague messages, only 36.6% are either pseudo-optimal or pairs in the NA-UR treatment. This ratio differs starkly from the 53.2% observed in the A-UR treatment. In addition, we see that the vast majority of the messages now fall into the 'Others' category. Among the 'Others' messages, half take the form of intervals, which was not the case in the anonymous treatments. In particular, 49.1% of vague messages reported in the

[14]When a message is both pseudo-optimal and pair, like $\{8, 10\}$, we count it as 'Pseudo-optimal,' similar to how we classified vague messages in the A-UR treatments. Only sub-optimal messages using two numbers are labeled 'Pair.'

NA-UR treatment used intervals, while only 37.2% did in A-UR. We can infer from the forms of the reported messages that subjects understood that pseudo-optimal and pair messages are obvious and can negatively affect the audience's belief in an equilibrium.

The distribution of the lengths of messages also indicates that there is a significant difference in reporting patterns between the A-UR and the NA-UR treatments. In Figure 3 we report the cumulative distribution of message lengths for the A-UR and NA-UR treatments. The figure shows that subjects use vague and longer messages more often in the NA-UR treatment. Together with the frequent use of interval messages in the non-anonymous treatment, we interpret this pattern as indirect evidence of the impact of vagueness on the external cost of lying.

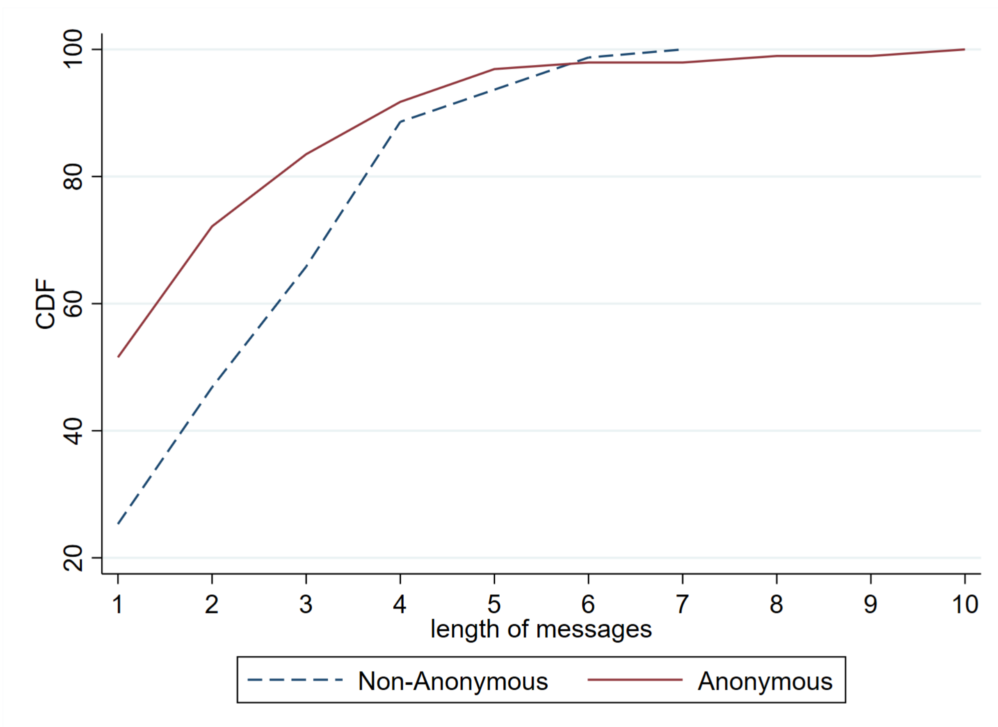

Figure 3: The cumulative distribution of lengths of vague messages in the A-UR and NA-UR treatments

Result 4. *Comparison between the A and NA environments*

1. *The average numbers reported in A-R and NA-R are 7.619 and 7, respectively;*

2. *the average numbers reported in A-UR and NA-UR are 8.132 and 8.232, respectively.*

We do not find statistically significant differences between average numbers reported in the anonymous and non-anonymous treatments. Our results do not reject the null hypotheses under either restricted or unrestricted communication, with p-values 0.185 and 0.562, respectively. While these results run against our Hypothesis 4 prediction, they are in line with Fries et al. (2021), who find a similarly perplexing outcome according to which increasing the anonymity of a report has no effect on average numbers reported or lying behavior. One possible explanation is that the impact of anonymity on behavior creates only a minuscule difference when collapsed into an average and projected into a unidimensional space, and our sample is far from the infinitely large sample needed to provide such statistical power. The difference we documented across the restricted and unrestricted treatments makes this explanation particularly plausible. Despite the similar magnitudes of the average numbers reported, the types of messages used in the two environments differ substantially in form and length.

7 Concluding Remarks

We contribute to the literature by bridging lying behavior with studies that involve vague communication. The extensive use of vague messages among our subjects, in both anonymous and non-anonymous sessions, provides us with insights that can be applied to various communication contexts. We find that subjects exploit vagueness to be consistent with the truth, while at the same time leveraging such imprecision to their own benefit. In addition, we find that 38% of liars in the anonymous sessions switch to truth-telling when they are allowed to be vague, which supports the key conjecture that a vague and truthful message reduces the internal cost of lying. We show that subjects use vague and longer messages more often when they are concerned with social identity. The difference in the reporting patterns across the NA-UR and the A-UR sessions suggests that vagueness still plays an important behavioral role.

Overall, subjects included higher numbers in their messages more often when vague communication was allowed. This finding sheds new light on our understanding of lying aversion, suggesting that a restricted message space could be a source of the observed abstention from monetary-payoff maximization in previous experiments reported in the literature. The average numbers reported in the treatments with restricted communication in our experiment are comparable to results reported in the previous experiments, capturing approximately 70% of the maximum numbers available. Insofar, as we allow the use of vague messages, however, the average number reported increases to 8.1, reducing the degree of lying aversion from 30% of the maximum monetary payoff amount to less than 20%. In addition, our findings in the anonymous treatments indicate that our subjects lie less often as they increase their expected monetary payoffs. That is, the option to use vague messages enables the subjects to maintain their integrity by including true states in their messages at a lower monetary cost. Similarly, subjects in the non-anonymous treatments also reported higher numbers on average when vague messages were allowed. Yet, the difference in the reporting patterns —vague messages with longer and more sophisticated forms —suggests that the use of vague messages provides subjects an alternative means to retain their social identity. In other words, when subjects are given a new option to use vague messages to convey their honesty to an audience, they no longer need to sacrifice their monetary payoffs significantly to provide a credible signal.

Our finding is analogous to the "moral wiggle room" mentioned in Dana et al. 2007, where dictators care only whether they maintain an image of fairness, but without having a significant effect on their partners' payoffs. In our experiment, most subjects exhibit no hesitation in increasing their monetary payoffs as long as their messages can remain even remotely truthful. The presence of precise truth-tellers in the anonymous environment, while small, suggests however that the moral-wiggle-room argument alone may not paint the whole picture. The decomposition of the aversion to monetary-payoff maximization in our experimental design calls for a new perspective on misleading behavior by showing that the observed aversion in many individuals is independent of the consequences of their message choices. It is possible that another motivation for truth-telling, such as a concern with projecting a well-intentioned self-image. That is, although subjects might have understood that there was no external observer to judge their behavior, their moral standards may combine the honesty achieved by reporting true observations with the uprightness of reporting the most accurate messages.

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Appendices

A Proofs

Let us first begin with restating the previously known results about the NA-R environment. The main intuition is that some agents lie when they see a small number, while some others always report the truthful message. Thus, when a reported number is small, it is safe to believe that the agent is being honest. The following equilibrium results establish a baseline for comparison with the other environments.

Lemma 2 (KS LM 1)**.** *In any equilibrium in the NA-R environment, there exists a strict positive probability that agents lie.*

Proof. Suppose there exists an equilibrium in the NA-R environment where no agent lies and the audience believes $P(j \text{ is truthful}) = 1$ for any report j. The utility of an arbitrary agent with the true observation of $i < N$ and the type t is

$$U(i, j, t) = j - \mathbb{1}(i \neq j)[t + c(i, j)] + \gamma \cdot 1.$$

when the agent reports some j.

As the social identity is constant under the audience's belief that everyone is truth-telling, the agent is better off by reporting $i+1$ instead of i when

$$U(i, i+1, t) - U(i, i, t) = ((i+1) - i) - (t + c(i, i+1)) > 0.$$

Because we assumed $c(i, i+1) < 1$, there exists some $0 < t < 1 - c(i, i+1)$.

□

Lemma 3 (KS PR 4; GKS PR 2)**.** *In any equilibrium in the NA-R environment, no agent underreports.*

Proof. Suppose there exists an equilibrium where an agent lies by reporting a number j below their true observation i. Then it must be the case $\rho(j) > \rho(i)$.

It also follows that reporting j must yield a larger utility than reporting i:

$$(j-i)+\gamma(\rho(j)-\rho(i)) \geq t+c(i,j).$$

We complete the proof by showing that $\rho(i)=1$; that is, if any agent choose to report i, then it must be the case that the report is truthful.

Take another agent with the intrinsic aversion type t who observes some $i' \neq i$. We claim that $U(i',j,t') > U(i',i,t)$:

$$(j-i)+[c(i',i)-c(i',j)]+\gamma(\rho(j)-\rho(i)) \geq c(i',i)-c(i',j)+t+c(i,j) > 0$$

because of the triangular inequality assumption: $c(i,i')+c(i',j) \geq c(i,j)$. As the choice of this agent is arbitrary, this is the case for all agents who do not observe i never lies by reporting i; in turn, this implies $\rho(i)=1$, a contradiction. □

Lemma 4 (KS THM 1; GKS PR 5). *In any equilibrium in the NA-R environment,*

i. there exists a threshold $1 < l^* < N$ *such that*

$$\forall j \geq l^* \; \exists i \neq j, t \in \mathbb{R} \;\; s.t. \;\; \sigma_{it}^{j} > 0 \;\; and$$

$$\forall j < l^*, i \in \Omega, t \in \mathbb{R} \; \sigma_{it}^{j} = 0;$$

ii. all agents who observe a value above the threshold report their observed value truthfully.

Proof. Let $L_P^\Omega \subseteq M_P^\Omega$ be the set of messages that liars use to lie with positive probability. Let $l^* = \min L_P^\Omega$. By Lemma 2, L_P^Ω is nonempty and l^* is well-defined. Also, by the no-underreporting condition, we can deduce that $\rho(1)=1$ and $1 < l^*$.

We now show $L_P^\Omega = \{l^*, l^*+1, \ldots, N\}$ by contradiction: suppose there exists some elements of Ω greater than l^* which is not an element of L_P^Ω. Let n be the minimum of such elements, so that $n-1 \in L_P^\Omega$. As $\rho(n)=1$, we can see that any agent who lies by reporting $n-1$ is strictly better off by reporting n instead:

$$\begin{aligned} U(i,n,t)-U(i,n-1,t) &= (n-(n-1))-(c(i,n)-c(i,n-1))+\gamma(\rho(n)-\rho(n-1)) \\ &> c(n-1,n)-(c(i,n)-c(i,n-1))+\gamma(\rho(n)-\rho(n-1)) \geq 0. \end{aligned}$$

Now it remains to show that the agents who observe $i \in L_P^\Omega$ reports truthfully. Suppose there exists $j, j' \in L_P^\Omega$ such that some agent observing j instead chooses to report j'. That is,

$$U(j,j',t)-U(j,j,t) = (j'-j)-(t+c(j,j'))+\gamma(\rho(j')-\rho(j)) \geq 0$$

for any intrinsic aversion type t. This implies that any agent who lies by reporting j is strictly better off by reporting j' instead:

$$\begin{aligned} U(i,j',t)-U(i,j,t) &\geq (j'-j)+(c(i,j)-c(i,j'))+\gamma(\rho(j')-\rho(j)) \\ &\geq t+c(j,j')+(c(i,j)-c(i,j')) > 0 \end{aligned}$$

for any intrinsic aversion type t and any true observation $i \neq j$. Therefore, all agents who observe $i \in L_P^\Omega$ reports truthfully. □

Based on the three results, we bring a simple comparison of the behavior of an agent in the NA-R environment to that in the A-R environment. A thought experiment of choosing an agent and comparing their behavior in the two environments easily leads to a conjecture that the absence of the social identity concern should only facilitate more lies. Applying these observation to the unrestricted communication leads to Proposition 1. We also obtain Lemma 1 from these three lemmas, which we will use to prove Proposition 4.

Proof of Proposition 1.

Case 1. Anonymous environment: as shown in Proposition 3, all truth-tellers use the optimal vague message.

Case 2. Non-anonymous environment: suppose there exists an equilibrium where no agent uses a vague message. Let $\rho(j) = 0$ for all $j \in M_V^\Omega$. Given that all messages used with positive probability are precise, we know all precise messages are used with positive probability in this equilibrium. We use Lemma 2 and 3 to argue that there exists a positive probability that agents lie upward. Let l^* be the threshold defined in Lemma 4.

Let us first argue that there exists agents who observe l^*-1 and lie by reporting l^*. Suppose not. Then there must exist some $l > l^*$ such that

$$U(l^*-1, l, t) - U(l^*-1, l^*, t) = (l - l^*) + (c(l^*-1, l^*) - c(l^*-1, l)) + \gamma(\rho(l) - \rho(l^*)) > 0.$$

Note that $c(l^*-1, l^*) - c(l^*-1, l) \leq 0$ because $l > l^*$ and c is increasing in the distance between the two arguments. Also, $c(l^*-1, l^*) - c(l^*-1, l) \leq c(i, l^*) - c(i, l) \leq 0$ for all $i < l^*$ because of the triangular inequality assumption. This implies that for all agents whose true observation is below l^* is better off by reporting l instead of l^*. As no agent would lie by reporting l^*, this is a contradiction to the definition of threshold.

Now consider the agent who observes l^*-1 and lies by reporting l^*. The agent receives the utility of

$$U(l^*-1, l^*, t) = l^* - (t + c(l^*-1, l^*)) + \gamma\rho(l^*).$$

However, if the agent reports $\{l^*-1, l^*+1\}$ instead, the agent receives

$$U(l^*-1, \{l^*-1, l^*+1\}, t) = l^*.$$

That is, the agent is better off by reporting $\{l^*-1, l^*+1\}$ when

$$t > \gamma\rho(l^*) - c(l^*-1, l^*),$$

which happens with a positive probability. Furthermore, the above analysis is valid for all $\rho(\{l^*-1, l^*+1\}) \geq 0$. This is a contradiction to the assumption of an equilibrium with no vague messages. Therefore, there exists a positive probability that agents use a vague message in any equilibrium in the NA-UR environment.

□

Proof of Lemma 1. Let $j > i$ be a part of an equilibrium strategy for an (i,t)-agent in the NA-R environment:

$$U(i,j,t) = j - [t + c(i,j)] + \gamma\rho(j) \geq U(i,j',t) \quad \forall j' \in M_P^{\Omega}.$$

We can infer that

$$j - [t + c(i,j)] + \gamma\rho(j) \geq i + \gamma\rho(i),$$

or

$$(j - i) - [t + c(i,j)] \geq \gamma(\rho(i) - \rho(j)).$$

As no agent underreports in the A-R environment, it suffices to show that this agent does not tells the truth in the A-R. Suppose not.

$$U_A(i,i,t) = i > U_A(i,j,t) = j - [t + c(i,j)].$$

This implies $\rho(i) < \rho(j)$, meaning the agent lied in the NA-R both because there were a monetary gain and a social identity gain.

$$(j-i) + [c(i',i) - c(i',j)] + \gamma(\rho(j) - \rho(i)) \geq c(i',i) - c(i',j) + t + c(i,j) > 0$$

because of the triangular inequality assumption: $c(i,i') + c(i',j) \geq c(i,j)$. As the choice of this agent is arbitrary, this is the case for all agents who do not observe i never lies by reporting i; in turn, this implies $\rho(i) = 1$, a contradiction. Therefore, the agent must lie in the A-R if the agent sees the same observation i. □

Proof of Proposition 4. WTS $P(\text{lie}_{NA-R}) < P(\text{lie}_{A-R})$.

We argue by the law of total probability:

$$P(\text{lie}_{NA-R}) = \sum_{i=1}^{N} P(\text{observe } i) P(\text{lie}_{NA-R} | \text{observe } i);$$
$$P(\text{lie}_{A-R}) = \sum_{i=1}^{N} P(\text{observe } i) P(\text{lie}_{A-R} | \text{observe } i).$$

Because the probability of observing some i is uniform in both environments, it suffices to show that the conditional probability of lying in A-R is greater than or equal to that in NA-R for all true observation i.

We learned that there exists some threshold $1 < l^* < N$ in Lemma 4. Thus, conditional on that an agent observing $i \geq l^*$, we have the conditional probability of the agent reporting a lie as

$$P(\text{lie}_{NA-R}|\text{observe } i) = 0;$$

for all intrinsic aversion type t, while

$$P(\text{lie}_{A-R}|\text{observe } i) > 0$$

because of the positive probability that the agent has the type t small enough to report a lie.

Now consider the case of $i < l^*$. Let T_i be a subset of $\mathbb{R}$ such that

$$P(\text{lie}_{NA-R}|\text{observe } i, t \in T_i) > 0;$$
$$P(\text{lie}_{NA-R}|\text{observe } i, t \notin T_i) = 0.$$

By Lemma 1, $P(\text{lie}_{A-R}|\text{observe } i, t \in T_i) = 1$; and $P(\text{lie}_{A-R}|\text{observe } i, t \notin T_i) \geq 0$. Thus, regardless of $P(t \in T_i)$, we have

$$P(\text{lie}_{NA-R}|\text{observe } i) \leq P(\text{lie}_{A-R}|\text{observe } i)$$

for all $i < l^*$. Therefore, $P(\text{lie}_{NA-R}) < P(\text{lie}_{A-R})$.

Also, because the monetary payment is a monotone mapping of the reports under the restricted communication, and because any lying takes the form of reporting upward, agents would earn more monetary payoff on average as the probability of lying is greater in the A-R. □

B Gender Difference

B.1 Non-anonymous Environment

In the non-anonymous environment, 28 males and 51 females attended the experiments. We do not find statistically significant differences between males and females neither on their reports nor on the length of vague messages.

Table 5: Gender difference on Reports in the Non-anonymous Environment

	Dependent variable:		
	Report_P	Exp_V	vague_size
	(1)	(2)	(3)
Gender difference	0.0553	−0.1587	0.2941
	(0.7291)	(0.2963)	(0.3582)
Constant	6.9804	8.3379	2.7059
	(0.4341)	(0.1764)	(0.2133)
Observations	79	79	79
R^2	0.0001	0.0037	0.0087

Under the unrestricted communication, male and female subjects are almost equally likely to send a precise message. Men are more likely to send a pseudo-optimal vague message, while women are slightly more likely to send a message with contains a pair or an interval.

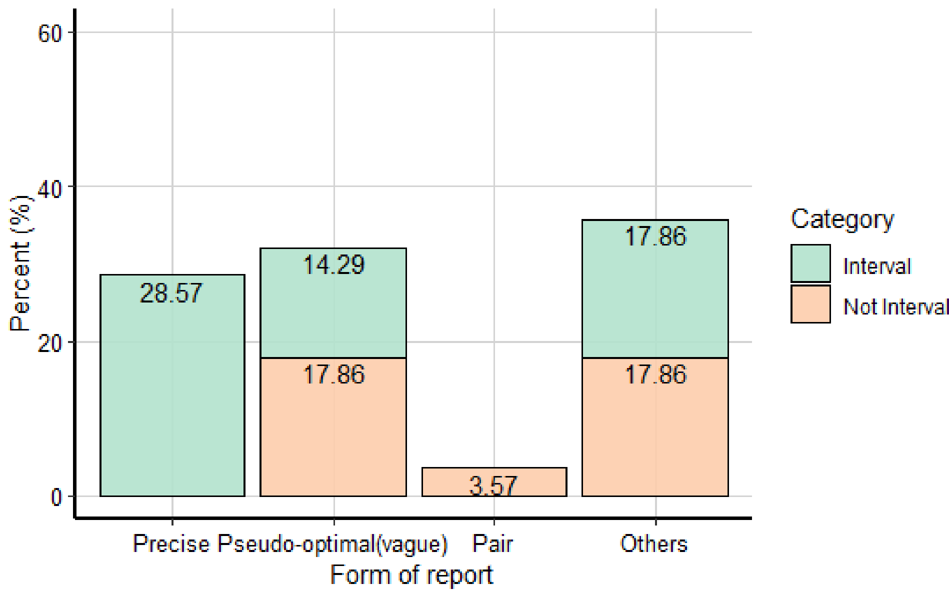

Figure 4: Message types male subjects used in NA-UR treatments

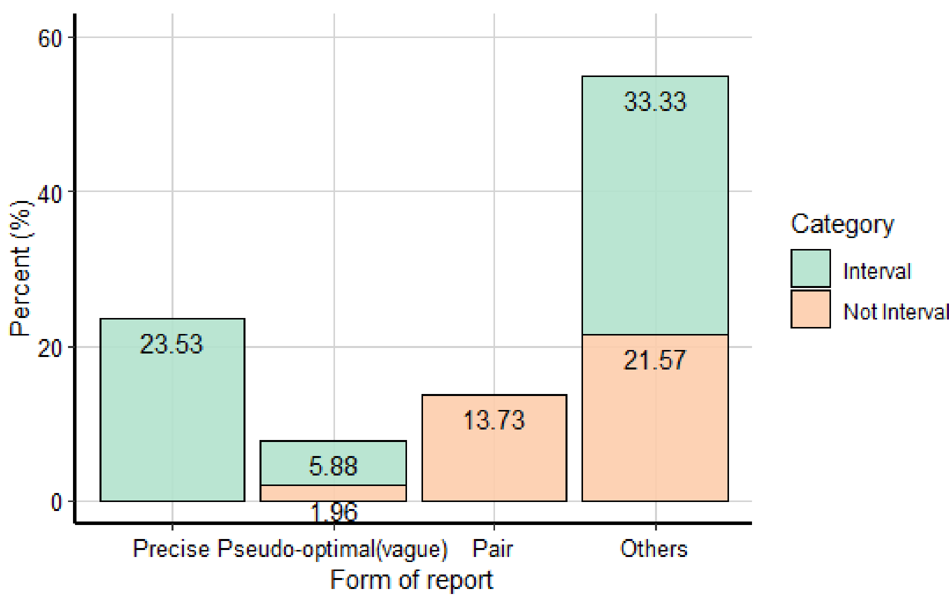

Figure 5: Message types female subjects used in NA-UR treatments

B.2 Anonymous Environment

We used only a subset of anonymous sessions to analyze the gender effect as we could not identify the participants' gender in principle. We ran four single sexed sessions (two male-only sessions and two female-only sessions) to create a gender dummy variable without interfering the anonymous property of the experiment design.

Under the restricted communication, we do not see statistically significant differences between males and females neither on their reports nor on the length of vague messages.

Table 6: Gender difference on Reports in the Anonymous Environment

	Dependent variable:		
	Report_P	Exp_V	vague_size
	(1)	(2)	(3)
Gender difference	0.1034	−0.6061	−0.4867
	(0.7107)	(0.5810)	(0.4461)
Constant	8.000	8.3290	2.3143
	(0.4784)	(0.3911)	(0.3003)
Observations	64	64	64
R^2	0.0003	0.0172	0.0030

The results show that, 34.29 % of males and 31.03% of females lied in the non-anonymous treatment. Therefore, we do not find substantial difference in the lying behavior between them. In addition, we do not see significant differences in the choice of type and length of vague messages, as shown by Figures 6 and 7.

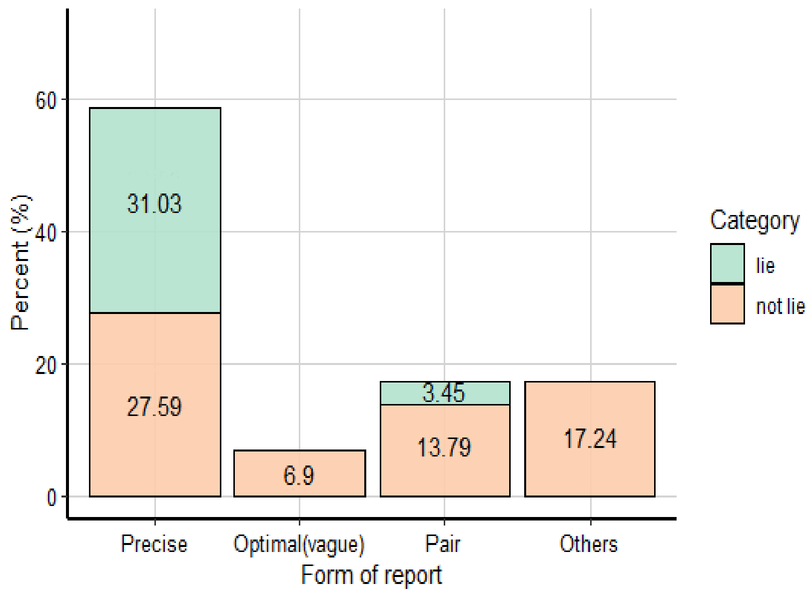

Figure 6: Message types male subjects used in A-UR treatments

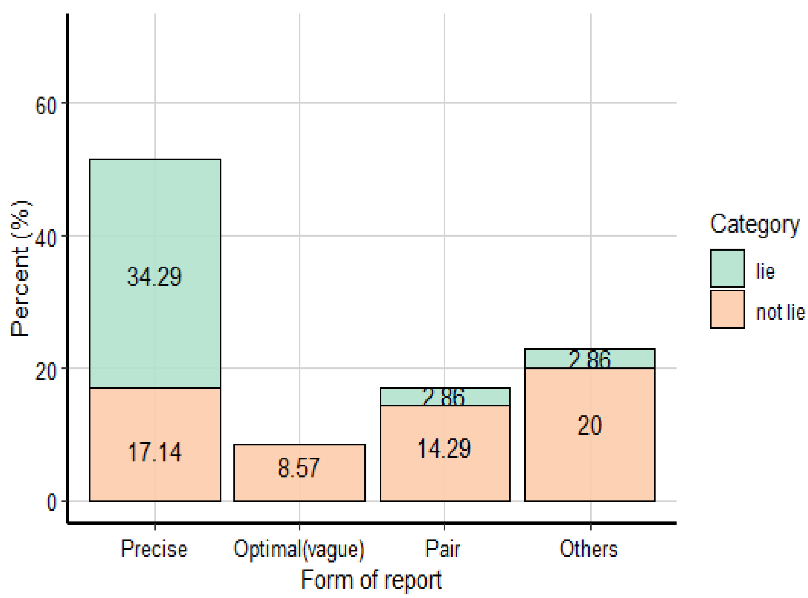

Figure 7: Message types female subjects used in A-UR treatments

C Experimental procedure

An experiment session contains the instructions, a preliminary quiz, and two stages of choice tasks. The subjects receive invitations through the Missouri Social Science Experimental Laboratory(MISSEL)'s ORSEE system. Once registered, they receive a link to a Zoom meeting. After subjects join the Zoom meeting room, the experimenter reads the instructions, followed by a preliminary quiz to ensure the understanding of the procedures. In an anonymous session, everyone including the experimenter has their video off, and the experimenter does not explicitly take attendance. In order to assure the subjects about anonymity, subjects are asked to use a screen name. The experimenter emphasizes that the screen name is used solely for data analysis and that they cannot associate the screen name with their true identity. In an non-anonymous session, on the other hand, the experimenter has their video on and asks the subjects to turn their video on as well. Also, the experimenter takes attendance with the experiment roster.

The subjects are allowed to participate in the main experiment only after successfully passing the preliminary quiz. Each subject has three chances to attempt the quiz before turned away. The experimenter provides a link to the main experiment website via the chat window of the Zoom meeting upon the successful completion of the quiz.

At the beginning of the main experiment part, subjects enter their identification information. In the anonymous treatment, subjects are asked to enter their screen name; whereas, in the non-anonymous treatment, subjects are asked their name and student ID.

After entering the identification information, the subjects observe the realization of a random integer uniformly distributed between 1 to 10 and later asked to report the number. In the anonymous treatment, the number is generated within the experiment software. In the non-anonymous treatment, subjects click on a link to a Google search result for the phrase "random number between 1 to 10."

In the reporting screen, subjects are presented with ten boxes labeled from 1 to 10 and report by selecting the numbered boxes. In a precise stage (Figure 8), which allows for precise messaging only, a subject may select only one box at a time, whereas in a vague stage (Figure 9), they may select multiple boxes. Subjects are told that this selection is deemed as a statement that the numbers represented by the selected box include the number they observed.

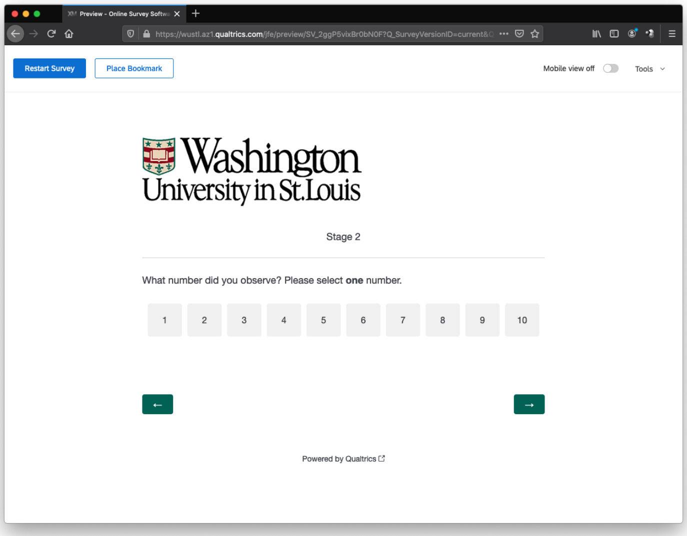

Figure 8: A screenshot of the experiment software displaying the precise-message stage

In the case of a precise message, the subject is paid the equivalent in dollars to the number she selected divided by two. In the case of a vague message, the computer randomly chooses one number from the submitted selection of numbers and pay the equivalent in dollars to the randomly chosen number divided by two.

After subjects complete both precise and vague stages, a confirmation screen reviews their compensation information. In the anonymous treatment, the experimenter bulk-purchases Amazon gift card to match the earnings for each screen name. The experimenter provides a third party (Department of Economics) with a list of the gift codes and matching screen names, excluding the amount associated with each code. The subjects visit an external website and retrieve their compensation in the form of the gift code by entering their screen name. This process is to ensure the anonymity of the experiment session. The experiment can map between responses and screen names, but not between screen names and true identities. The third party can only map between true identities and screen names, but not between true identities and their corresponding responses. In the non-anonymous treatment, they are asked to enter their email

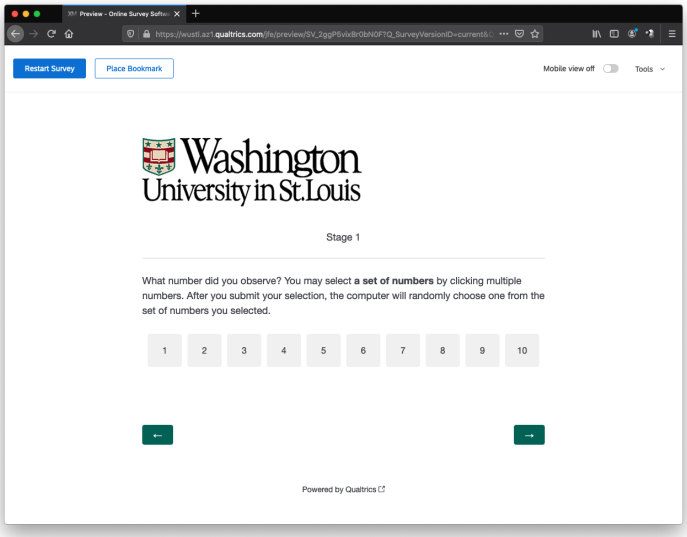

Figure 9: A screenshot of the experiment software displaying the vague-message stage

address and taxpayer information to receive the Amazon gift card directly emailed to them.

D Experimental Instructions

D.1 Instructions for Anonymous session (Zoom session; no video)

Welcome to the experiment! Thank you very much for participating today, and I will first walk you through the instructions for the experiment.

We need your full attention during the experiment. If you have trouble with hearing the audio or seeing the shared screen, please let me know. Do not turn the video on during the experiment. If you have any questions during the instructions, please raise hand so that I can unmute you. Your question will be answered out loud, so everyone can hear.

The experiment you will be participating in today is an experiment in individual decision making. At the end of the experiment, you will be paid an Amazon gift card. You will receive the show-up fee of $2 for completing the experiment, with the additional amount that depends on your decisions and on chance. The details of the compensation will be described later. All instructions and descriptions that you will be given in the experiment are accurate and true. In accordance with the policy of this lab, at no point will we attempt to deceive you in any way.

I would like to first point out that we want to ensure this experiment is conducted anonymously, meaning that we cannot connect the responses recorded in this experiment to any particular individual who participated in this research. Qualtrics, the survey platform we are using, provides an option for the researchers to not collect any personal information, such as IP address or geographic location of the participants, for anonymous surveys. Also, your response will be recorded with a SCREEN NAME. You will be asked to choose a screen name that is at least 8 characters in length using letters, numbers, and underscore. This SCREEN NAME is only used in data analysis and distributing your Amazon gift card after the experiment. We cannot and will not attempt to associate SCREEN NAMEs to any particular individual.

I will now describe the main features of the experiment. First, there is a short quiz to ensure your understanding of the procedures. You will be able to repeat the quiz if you make mistakes. You will have three chances to attempt the quiz. If you fail to get all questions correct after three attempts, you may not participate in the main experiment. Even in such a case, please remain connected to the Zoom session until everyone finishes, and you will receive the show-up fee for today's experiment. The main part of the experiment after the preliminary quiz consists of two STAGES. In each STAGE you will observe a number that we ask you to remember and later report to us. The number you report to us determines how much money you will be paid. At the end of the experiment, a confirmation screen will summarize today's experiment and provide the information to retrieve your payment. I will give you more details about each step. At the end of this instructions, we will first provide a link for the preliminary quiz using the chat window. This is a screenshot of the webpage. Please choose a screen name, and make sure you keep this screen name. After you successfully complete the preliminary quiz, you will be reminded of your screen name once again. We recommend you copy and paste the screen name. We cannot recover this information for you, and you will not be able to receive your compensation without the correct screen name. Please wait while everyone else finishes the quiz. Once everyone finishes, we will provide another link for the main experiment using the chat window. This is a screenshot of the first page of the main experiment. Make sure you use the same screen name you used in the preliminary quiz. You may not receive your compensation if the screen names do not match. As previously mentioned, your main task today is to observe a number that we ask you to remember and later report to us. The observation process is identical in both STAGES. At the beginning of both STAGES, the computer will randomly draw a number between 1 to 10. The probabilities are equal across the numbers; that is, each number is chosen with the same probability of one-tenth. We ask you to remember the number and report on the next screen. However, the way you can report differs between STAGES. In one STAGE, you are allowed to select one number after you observe the draw. This is a screenshot of the experiment stage where you can select one number. By one number, we mean that you may click only one number on the screen. We will interpret this selection as a statement that the number you observed is the number you selected, and we will regard this number as your report. The number you report determines how much money you will be paid. You will be paid the equivalent in dollars to the number you report divided by 2. In other words, if you report "1", you receive 50 cents. If you report "2", you receive $1, if you report "3", you receive $1.50 and so on. A confirmation screen after your report will help you review your selection and the corresponding payment. In another STAGE, you are allowed to select a set of numbers after you observe the draw. This is a screenshot of the experiment stage where you can select a set of numbers. By a set of numbers, we mean that you may click multiple numbers on the screen. For instance, you may choose to click on four numbers, one number, two numbers, or even all ten numbers. If you select multiple numbers, we will interpret it as a statement that the number you observed is one of the numbers you selected. If you select a single number, we will interpret it as a statement that the number you observed is the number you selected. After you submit your selection, the computer will randomly choose one number from the set of numbers you selected. We will regard this randomly chosen number as your report. Again, the number you report determines how much money you will be paid. You will be paid the equivalent in dollars to the randomly chosen number from the set of numbers you selected divided by 2. If the randomly chosen number is “1”, you receive 50 cents. If “2”, you receive $1, if “3”, you receive $1.50 and so on. A confirmation screen after your report will help you review your selection and the corresponding payment.

The order of the two STAGES is randomly determined. In other words, it is equally likely that you first participate in the STAGE allowing only a single number and then participate in the STAGE allowing a set of numbers, or first participate in the STAGE allowing a set of numbers and then participate in the STAGE allowing only a single number. In any case, you will play each STAGE only once.

After the completion of both STAGES, a final review screen will provide the information to receive your Amazon gift card code. This is a screenshot of the review screen. This includes your SCREEN NAME you entered, the amount you will receive, and a randomly generated passcode. Because the experiment is anonymous, we have no means to recover this information for you. Please make sure you either print or take the screenshot of this page for your record, because it is very important when you retrieve your compensation.

In the final review screen, you will find a link of a google form. To receive your amazon gift card you have to copy and paste the link in another browser and then fill your personal information. The google form is created by a staff of the department of economics, who won’t have access to the data of this experiment.The experimenter only has a list of SCREEN NAMES and the amount associated with them. The experimenter will never be able to access your personal information. This is a screenshot of the google form which you will have to fill to receive your amazon gift card.

Washington University in St. Louis recommends student subjects to report their taxpayer identification information for tax purposes. If you are an international student and do not have the taxpayer identification information, please indicate so by entering ‘Foreign’ in the form. If you do not have or do not wish to provide the identification information, please indicate that you would like to opt out by entering ’Refuse’ in the form.

We are sorry for the inconvenience that we are not able to email you with the gift code directly. This payment process is to ensure anonymity in this experiment, and we appreciate your understanding that the anonymity of the reports constitutes a crucial component of our research.

This is the end of the instructions. If you have any questions, please raise hand. Otherwise, I will provide the link via the chat window. Please copy and paste the link to your browser to generate the SCREEN NAME.

D.2 Instructions for Non-Anonymous session (Zoom session; video)

Welcome to the experiment! Thank you very much for participating today. Before we start, I will go over the roster to take attendance to make sure I have everyone registered for the session. During the attendance please turn your video on.

I will now walk you through the instructions for the experiment. We need your full attention during the experiment. If you have trouble with hearing the audio or seeing the shared screen, please let me know. If you have any questions during the instructions, please use the hand-raising feature of Zoom and your question will be answered out loud, so everyone can hear.

The experiment you will be participating in today is an experiment in individual decision making. At the end of the experiment, you will be paid an Amazon gift card. You will receive the show-up fee of $2 for completing the experiment, with the additional amount that depends on your decisions and on chance. The details of the payment will be described later. All instructions and descriptions that you will be given in the experiment are accurate and true. In accordance with the policy of this lab, at no point will we attempt to deceive you in any way.

This is a screenshot of the first page in the main experiment. At the end of the instructions, I will provide the link to the experiment using the chat window. Please copy and paste the link to your browser. The first screen will ask your identification information – your first and last name and your student ID.

After you enter your information, you will proceed to the next screen and take a short quiz to ensure your understanding of the procedures. You will be able to repeat the quiz if you make mistakes. You will have three chances to attempt the quiz. If you fail to get all questions correct after three attempts, you may not participate in today's experiment. In such case, you will only receive the show-up fee for today's experiment.

The main part of the experiment consists of two STAGES after the preliminary quiz. In each STAGE you will observe a number that we ask you to remember and later report to us. The number you report to us determines how much money you will be paid. At the end of the experiment, a confirmation screen will summarize today's experiment and provide the information to retrieve your payment. I will give you more details about the observation, reporting, and payment processes.

The observation process is identical in both STAGES. At the beginning of both STAGES, we will provide a link to Google page that randomly generates a number between 1 and 10. The probabilities are equal across the numbers; that is, each number is chosen with the same probability of one tenth. We ask you to open the link, remember the number, close the Google page, and report the number on the next screen. This is a screenshot of an example Google page. You will see that this is a search result for 'random number between 1 and 10', and the page displays a randomly generated number that matches the search phrase. Do not click on the 'generate' button on the Google page, because the number you see is already randomly generated. Any additional generation only distorts the statistical properties of the experiment. I will now demonstrate how this Google page works. You will find this link during the experiment, and this is equivalent of opening a google page and typing in "random number between 1 and 10." When you open the link, a new window pops up. As you can see, this number is already randomly generated and you should not generate the number again.

The way you can report differs between STAGES. In one STAGE, you are allowed to select one number after you observe the randomly generated number. This is a screenshot of the experiment stage where you can select one number. By one number, we mean that you may click only one number on the screen. We will interpret this selection as a statement that the number you observed is the number you selected, and we will regard this number as your report. The number you report determines how much money you will be paid. You will be paid the equivalent in dollars to the number you report divided by 2. In other words, if you report "1", you receive 50 cents. If you report "2", you receive $1, if you report "3", you receive $1.50 and so on. A confirmation screen after your report will help you review your selection and the corresponding payment. In another STAGE, you are allowed to select a set of numbers after you observe the randomly generated number. This is a screenshot of the experiment stage where you can select a set of numbers. By a set of numbers, we mean that you may click multiple numbers on the screen. For instance, you may choose to click on four numbers, one number, two numbers, or even all ten numbers. If you select multiple numbers, we will interpret it as a statement that the number you observed is one of the numbers you selected. If you select a single number, we will interpret it as a statement that the number you observed is the number you selected. After you submit your selection, the computer will randomly choose one number from the set of numbers you selected. We will regard this randomly chosen number as your report.

Again, the number you report determines how much money you will be paid. You will be paid the equivalent in dollars to the randomly chosen number from the set of numbers you selected divided by 2. If the randomly chosen number is "1", you receive 50 cents. If "2", you receive $1, if "3", you receive $1.50 and so on. A confirmation screen after your report will help you review your selection and the corresponding payment.

The order of the two STAGES is randomly determined. In other words, it is equally likely that you either participate in the STAGE allowing a single number first and then participate in the STAGE allowing a set of numbers or participate in the STAGE allowing a set of numbers first and then participate in the STAGE allowing a single number. In any case, you will play each STAGE only once.

After the completion of both STAGES, a final review screen will summarize today's experiment. This is a screenshot of the review screen. The last screen will ask your email address to receive the Amazon Gift Code of the amount that corresponds to your responses. We will directly send you Amazon gift code to the email address you provide. Please allow us a few hours after the completion of the experiment to validate the data and send the email. In addition, Washington University in St. Louis recommends student subjects to report their taxpayer identification information for tax purposes. If you are an international student and do not have the taxpayer identification information, please indicate so by entering ‘Foreign’ in the form. If you do not have or do not wish to provide the identification information, please indicate that you would like to opt out by entering ’Refuse’ in the form.

This is the end of instructions. If you have any questions, please raise your hand. Otherwise, I will provide the link via the chat window. Please copy and paste the link to your browser and start the experiment.