Disclosure under Unawareness: An Experiment*

Ying Xue Li† Burkhard C. Schipper‡

March 31, 2025

Abstract

We consider a disclosure game between a seller and a buyer. The seller knows the quality of a good, while the buyer does not. Before the buyer decides how many units to purchase, the seller can disclose verifiable information about the good. The better the information, the more the buyer is inclined to buy. The information about the good is two-dimensional. We design two experimental treatments: In the unawareness treatment, the buyer is uncertain about the first dimension, but unaware of the second. Here, unawareness refers to a lack of conception rather than lack of information. In the control treatment, the buyer is aware of both dimensions, but uncertain about them. The theory predicts unraveling of information in the control treatment but not in the unawareness treatment. Our experimental findings are consistent with this prediction. However, a closer examination reveals that this outcome is driven by buyers becoming confused when sellers naively raise awareness of the second dimension.

Keywords: Disclosure of information, disclosure games, verifiable information, unawareness, unknown unknowns, unraveling, rationalizability, experimental games.

JEL-Classifications: D83, C72, C92, D82.

*Ying Xue gratefully acknowledges financial support from the National Natural Science Foundation of China (♯72003147). We thank Kalyani Chaudhuri for helpful comments.

†Jinhe Center for Economic Research, Xi'an Jiaotong University, and School of Economics and Management, Xinjiang University, liyxjinhe@xjtu.edu.cn

‡Department of Economics, University of California, Davis, bcschipper@ucdavis.edu

1 Introduction

Beginning with the seminal works of Grossman and Hart (1980), Grossman (1981), Milgrom (1981), Jovanovic (1982), Verrecchia (1983), Dye (1985), and Milgrom and Roberts (1986), disclosure games have been used to examine the disclosure of verifiable information across a range of economic, political, and legal contexts (see Milgrom, 2008, for a comprehensive review). The striking result in the literature is unraveling of information. This appears to contradict casual empirical observations suggesting that informed parties may not fully disclose relevant information, or that recipients fail to fully deduce the information contained in (non)-disclosure.

Various assumptions have been introduced to circumvent the unraveling result. For instance, senders may only learn the information after they have somehow committed to a disclosure strategy, and this may lead to partial disclosure in equilibrium (Kamenica and Gentzkow, 2011). Alternatively, costs of disclosure may hamper information disclosure (Verrecchia, 1983, Dye, 1985). Here we advance an alternative explanation: Receivers of information may be unaware of certain aspects of the information. Unawareness refers to the lack of conception rather than lack of information (see Heifetz, Meier, and Schipper, 2006). When the sender remains silent about an aspect of the information that the receiver is unaware of, the receiver cannot infer anything from this silence, as they are not even capable of thinking about that dimension. This prevents unraveling, particularly with regard to unfavorable information that the receiver is unaware of. For a detailed exposition of this argument, see Heifetz, Meier, and Schipper (2021). Schipper and Woo (2019) apply these ideas to political awareness among voters and electoral campaigning, while Francetich and Schipper (2025) explore a principal-agent problem in which the principal is unaware of factors affecting the agent's costs. In their model, the agent can disclose these factors before the principal designs a menu of contracts for screening the agent.

We present an experiment to test this prediction. Specifically, we compare unraveling in a disclosure game with full awareness to unraveling in an analogous game where the receiver is unaware of a dimension of the information. We find that the frequency of unraveling in the game with unawareness is significantly lower than that with full awareness, in line with the theoretical prediction. However, this result is driven by buyers becoming confused after sellers naively raise awareness — despite theory predicting that they should not raise awareness.

Our experiment contributes to a growing body of literature on experimental tests of disclosure games (see Forsythe, Isaac, and Palfrey, 1989, King and Wallin, 1991, Benndorf, Kübler, and Normann, 2015, Hagenbach and Perez-Richet, 2018, Li and Schipper, 2020, Jin, Luca, and Martin, 2021, 2022, Deversi, Ispano, and Schwardmann, 2021, Sheth, 2021, Farina and Leccese, 2024, Farina et al., 2024, Penczynski, Koch, and Zhang, 2025). However, none of these studies account for the potential limits to unraveling posed by unawareness.

We also contribute to the small but growing literature on experiments with unawareness. In an early study, Blume and Gneezy (2010) show that players in coordination games form beliefs about the opponent's awareness of a coordination opportunity and try to signal their own awareness of this opportunity. Charness and Sontuoso (2023) study experimentally the awareness of visual attributes of actions in coordination games. Heterogeneous awareness hampers coordination, while limited awareness and common awareness enhance coordination. We are not aware of other experiments on unawareness in games. Yet, there are experiments on unawareness in single-person decision making. Ma and Schipper (2017) and Araujo and Piermont (2023) analyze experimentally whether risk preferences are affected by exposure to unawareness (see also Mengel, Tsakas, and Vostroknutov, 2016, for an earlier related study). Becker et al. (2025) experimentally test reverse Bayesianism, a constraint on updating beliefs upon becoming aware.

The paper is organized as follows: In the next section, we outline the model and theoretical predictions. This is followed in Section 3 with an exposition of the experimental design and the hypothesis. The analysis is presented in Section 4. Finally, we conclude in Section 5. The instructions, questionnaire, and screenshots (incl. translations) are relegated to an online appendix accessible from `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp_appendix_complete.pdf`. The programs, data, and Stata-do file are available from `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp.do`.

2 Model

We consider a two-player disclosure game between a seller (she) and a buyer (he). The seller possesses a good with multiple attributes. Specifically, we consider two attributes, each of which may be present or absent independently of the other. As a result, the good can exhibit one of four possible attribute combinations. The seller has full knowledge of the attribute combination of their good, whereas the buyer initially does not. The true attribute combinations are important for the buyer to decide how many units to purchase. Before the buyer makes his decision, the seller can disclose verifiable information about the good's attributes to the buyer. The seller can be vague, in the sense of disclosing a range of attribute combinations, but she is not allowed to lie about the true attribute combination of the good. That is, no matter what set of attribute combinations the seller discloses to the buyer, she cannot rule out the true attribute combination of the good.

For the sake of concreteness, we call the first attribute "quality" and the second "feature". The quality can be either 2 or 3. We denote the quality by q. The feature can be either a or b (e.g., we can think of a feature being "present" or "not present"). If nature chooses quality $q \in \{2, 3\}$ and feature $f \in \{a, b\}$, then the seller's set of messages is $\mathcal{M}(q, f) := \{M \mid M \in 2^{\{2,3\}}, q \in M\} \cup \{M \mid M \in 2^{\{2,3\}\times\{a,b\}}, (q, f) \in M\}$.[1] That is,

[1]To simplify the design of the experiment, we restricted the seller's set of messages in such a way

messages are verifiable but can be vague. In particular, they can be silent on the feature.

The buyer can purchase $x \in X := \{1, 2, 3, 4\}$ units of the good. We denote by x the amount purchased. The price of each unit is fixed to \$4. The buyer's payoff depends on the true attribute combination of the good and the number of units he buys as shown in Table 1.

Table 1: Payoffs to the Buyer under Full Awareness

		Attribute combination			
		$(2, a)$	$(2, b)$	$(3, b)$	$(3, a)$
	$x = 1$	14	10	8	7
Units	$x = 2$	8	16	12	11
purchased	$x = 3$	4	10	18	14
	$x = 4$	1	7	12	20

We observe that feature a is useful to the buyer if and only if the quality is 3. Feature b is useful if and only if the quality is 2. Moreover, we also observe that the order of optimal quantities for the buyer matches the order of attribute combinations in the table. I.e., it is determined by the main diagonal of Table 1.

We neglect the cost of production. Thus, the payoff to the seller is simply price times quantity, $\$4 \cdot x$.

We now consider two versions of this game that will feature in one treatment each. The first version is defined as above – this is an example of a standard disclosure game with full awareness.

In the second version, the seller is aware of both dimensions (i.e., quality and feature), while the buyer is initially only aware of the quality. Intuitively, unawareness of the feature means that the buyer does not even conceive of the existence or non-existence of the feature (i.e., a or b); see Heifetz, Meier, and Schipper (2006) for an epistemic characterization of the notion of unawareness used in our setting. It means that the feature is essentially out of the buyer's mind. Consequently, if the seller does not make him aware of the existence of the feature with her verifiable message before the purchase, the buyer can contemplate only about the quality of the good but not about the presence of the feature. We assume that in this case the buyer views his payoffs as given by Table 2. That is, payoffs are determined as if the feature is not present (i.e., the second dimension takes on value b). Such a setting is realistic especially if the good is an experience good whose features are only discovered by the buyer once consumed. In any case, whenever the seller discloses information, the information must be truthful in the sense of not ruling out the true state.

as to not allow her to select messages pertaining only to the feature. I.e., we exclude messages in $\{M \mid M \in 2^{\{a,b\}}, f \in M\}$.

Table 2: Payoff to the Buyer with Unawareness of the Feature

		Quality	
		2	3
	$x = 1$	10	8
Units	$x = 2$	16	12
purchased	$x = 3$	10	18
	$x = 4$	7	12

This second setting defines an instance of a game in extensive form with unawareness (see Heifetz, Meier, and Schipper, 2013, 2021, Schipper, 2021). Nature moves first, and determines the quality of the good and whether or not the feature is present. Each move of nature leads to a singleton information set of the seller. At this information set, the seller can choose a message consistent with the move of nature. I.e., if the move of nature is (q, f), then the seller's set of messages is $\mathcal{M}(q, f)$ defined above. If the seller chooses a message in $\{M \mid M \in 2^{\{2,3\}\times\{a,b\}}, (q, f) \in M\}$, then the buyer becomes aware of the existence of the feature. Consequently, the buyer's state of mind is represented by an information set in the game tree containing histories consistent with the message of the seller. If the seller chooses a message in $\{M \mid M \in 2^{\{2,3\}}, q \in M\}$, i.e., she remains silent on the feature, then the buyer remains unaware of the feature. Consequently, her state of mind is given by an information set in a less expressive game tree, where nature initially chooses between qualities in $\{2, 3\}$ followed by the seller selecting a message in $\{M \mid M \in 2^{\{2,3\}}, q \in M\}$ (assuming that nature chooses quality q in this less expressive tree). The less expressive game tree represents the buyer's view of the strategic situation when he remains unaware of the feature. This disclosure game with unawareness involves two game trees, one similar to the case of full awareness and one less expressive tree where moves of nature and messages of the seller are restricted to mentioning qualities only and anything having to do with the feature is erased. In the more expressive tree, at any history in which the seller is silent on the feature, the corresponding information set of the buyer is a subset of histories of the less expressive tree, signifying that the buyer remains unaware of the feature.[2]

To discuss the solution concept, we need both strategies and beliefs. As usual in games in extensive form, strategies map information sets into actions available at those information sets. In the game with unawareness, note that both players have information sets in both the more- and the less-expressive game trees.

For the seller, the quality and the kind of feature selected by nature represent the information sets. A strategy σ_s of the seller maps her information sets (in both trees, in case of unawareness) to the set of messages consistent with the information set. E.g.,

[2]See Heifetz, Meier, and Schipper (2021) for a graphical depiction of a disclosure game with unawareness.

if (q, f) is the information set of the seller, then $\sigma_s(q, f) \in \mathcal{M}(q, f)$. In the case of unawareness, in the less expressive tree, if q is the information set of the seller, then $\sigma_s(q) \in \{M \mid M \in 2^{\{2,3\}}, q \in M\}$. The information sets of the buyer are identified with the messages sent by the seller. The strategy of the buyer σ_b maps his information sets (in both trees) to quantities in X. For each player $i \in \{b, s\}$, we denote by Σ_i player i's set of strategies. Disclosure games with unawareness also have a notion of partial strategy, namely a strategy restricted to the less expressive tree.

A belief system β_s of the seller is a profile of beliefs, one for each of her information sets. Each belief is about the strategies of the buyer. In the case of unawareness, the seller's belief at an information set in the less-expressive game tree, is about the partial strategies of the buyer.

Analogously, a belief system β_b of the buyer is a profile of beliefs, one for each of her information sets. Each belief is about (partial) strategies of the seller and moves of nature. At each information set, it assigns probability 1 to combinations of moves of nature and strategies of the seller, such that the seller's strategy and move of nature reaches this information set.

While standard disclosure games with full awareness are typically solved using sequential equilibrium or perfect Bayesian equilibrium, we use prudent rationalizability (Heifetz, Meier, and Schipper, 2021, Schipper and Woo, 2019, Li and Schipper, 2020). This is a version of extensive-form rationalizability incorporating an admissibility criterion. It is strategy-equivalent to iterated admissibility applied to the associated normal form of this game (Meier and Schipper, 2024). The advantage of using prudent rationalizability is two-fold: First, the solution concept applies to both versions of the game. That is, prudent rationalizability can naturally be applied to games with unawareness while the notion of sequential equilibrium is problematic in games with unawareness. The reason is that equilibrium is often motivated as a steady-state of a learning process. Yet, in games with unawareness, a ready-made steady-state is initially elusive when the buyer becomes aware of the feature. See Schipper (2021) for a discussion. Second, since prudent rationalizability is an iterative solution concept, it provides predictions for any finite level of reasoning about the rationality of the opponent. Thus, similar to the literature on level-k models, we are able to learn about levels of reasoning of players. More precisely, we learn about mutual k-level cautious strong belief in rationality; see Li and Schipper (2020) for an experiment on disclosure games partially identifying levels of reasoning and Schipper and Zhou (2024) for a comparison of level-k-thinking with prudent rationalizability. In the limit, it identifies strategies consistent with common cautious strong belief in rationality. Finally, in disclosure games without unawareness, prudent rationalizability slightly refines pure sequential equilibrium strategies.

We say that strategy σ_i of player i is rational with belief system β_i at the player's information set, if σ_i maximizes expected payoffs with respect to the belief prescribed by β_i at that information set.

Prudent rationalizability is now defined inductively: For each player $i \in \{b, s\}$, all strategies are level-0 prudent rationalizable, $\Sigma_i^0 = \Sigma_i$. For each $k \geq 1$, the set B_s^k of level k beliefs of the seller are all the belief systems β_s that assigns strict positive probability to each level $k-1$ strategies of the buyer, Σ_b^{k-1}, and probability zero to any other strategy.

The set of level k prudent rationalizable strategies of the seller, Σ_s^k, are all level $k-1$ prudent rationalizable strategies of the seller, Σ_s^{k-1}, such that, for each strategy $\sigma_s \in \Sigma_s^k$, there exists a level k belief system $\beta_s \in B_s^k$ with which the strategy σ_s is rational at every of her information sets.

For each $k \geq 1$, the set B_b^k of level k belief systems of the buyer is the set of belief systems β_b such that for each of his information sets, if there exists a move of nature and a level $k-1$ prudent rationalizable strategy of the seller such that this strategy reaches this information set, then the support of the belief at this information set is the set of level $k-1$ prudent rationalizable strategies of the seller and moves of nature that reach this information set.

The set of level k prudent rationalizable strategies of the buyer, Σ_b^k, are all level $k-1$ prudent rationalizable strategies of the buyer, Σ_b^{k-1}, such that, for each strategy $\sigma_b \in \Sigma_b^k$, there exists a level k belief system $\beta_b \in B_b^k$ with which the strategy σ_b is rational at each of his information sets.

The set of prudent rationalizable strategies of player $i \in \{b, s\}$ is $\Sigma_i^\infty := \bigcap_{k=1}^\infty \Sigma_i^k$. See Heifetz, Meier, and Schipper (2021) for a detailed exposition.

A strategy survives k levels of the prudent rationalizability procedure, if there exists a full support belief on the k-level prudent rationalizable strategies of the other player and - in the case of the buyer - feasible moves of nature for which the strategy is rational at every information set of the player. The prudence or cautiousness is captured by full support beliefs. It means that at each level, a player does not completely exclude any of the opponent's remaining strategies and feasible moves of nature. Relevant to disclosure games, this includes the worst possible quality-feature combinations (or, in the case of not raising awareness, the worst possible quality) consistent with the message observed by the buyer. Hence, skepticism about messages comes for free through prudence/cautiousness. Note that when the buyer is unaware of the feature, he cannot be skeptical when the seller is silent about the feature because he does not even think about the feature. Heifetz, Meier, and Schipper (2021) and Meier and Schipper (2024) provide further discussions of the solution concept, including an existence proof for finite games in extensive form and a proof of equivalence to iterated admissibility based on Pearce (1984, Lemma 4). Schipper and Woo (2019) apply it to a disclosure game in an electoral campaign framework. Most relevant, Li and Schipper (2020) solve a disclosure game with four quality levels using prudent rationalizability and partially identify levels of reasoning in experiments on disclosure games (without unawareness). Battigalli (2006) applies a closely related rationalizability concept with belief restrictions to a standard disclosure game without unawareness.

To see how prudent rationalizability operates in disclosure games, consider first a disclosure game with two quality levels $Q = \{2, 3\}$. (Such a game is actually played by our participants in the first 15 rounds of our experiment.) At the first level, a buyer receiving a singleton message from the seller knows the true quality (since information is verifiable and thus the seller cannot lie). Hence, he best-responds by choosing the quantity equal to the quality level disclosed. At the second level, the seller forms full-support beliefs about first-level prudent rationalizable strategies of the buyer. If her quality is 3, then she happily discloses it to the buyer, because otherwise she runs the risk of the buyer buying less than 3 (since she entertains full-support beliefs). At the third level, the buyer forms full-support beliefs over second-level prudent rationalizable strategies of the seller. In particular, if he does not hear the message $\{3\}$ from the seller then he knows that the seller does not have quality 3 since any second-level prudent rationalizable seller with quality 3 would have happily disclosed this fact to him. At this point, information unravels with respect to qualities. The buyer deduces complete information about the quality from the seller's message, even if the message itself is vague because a seller with quality 2 may say $\{2, 3\}$.

To define unraveling more formally, let $\preceq$ be a binary relation on moves of nature that reflect the buyer's preferences, assuming that he chooses the optimal quantity under complete information (see the main diagonals in Tables 1 and 2. I.e., $(2, a) \preceq (2, b) \preceq (3, b) \preceq (3, a)$ as well as $2 \preceq 3$. Given a message M and the awareness of the buyer, we denote by $\min_{\preceq} M$ the minimum quality-feature (in the case of awareness of the buyer) or minimum quality (in the case of unawareness of the buyer) consistent with the message. For instance, if $M = \{2\}$ then $\min_{\preceq} M = \{(2, a)\}$ if the buyer is aware of the feature. Otherwise, if the buyer is unaware of the feature, then $\min_{\preceq} M = \{2\}$.

Definition 1 (Unraveling) *We say that a strategy profile is unraveling (in terms of information and awareness) if*

(i) for each move of nature $(q, f) \in \{2, 3\} \times \{a, b\}$, the seller sends a message $M \in \mathcal{M}(q, f)$ such that $\min_{\preceq} M = \{(q, f)\}$.

(ii) for each message M of the seller, the buyer purchases quantity $x \in X$ that maximizes the buyer's payoff at $\min_{\preceq} M$.

We say that a player's strategy is unraveling if it is part of the unraveling strategy profile.

Note that in the case of disclosure games with unawareness, unraveling requires making the buyer aware of the feature, otherwise, he cannot deduce anything from silence about the feature. It is important to note that in the game with full awareness, message $\{2\}$ can be unraveling whereas it is not in the game with unawareness. We will return to this issue when we analyze our data.

Proposition 1 *In the disclosure game with full awareness, any prudent rationalizable outcome is an unraveling outcome.*

The proof follows directly from Li and Schipper (2020, Proposition 1) upon noting that the four quality levels 1, 2, 3, and 4 in their game map bijectively to $(2, a), (2, b), (3, b)$, and $(3, a)$, respectively.

The unraveling prediction under full awareness contrasts with prudent rationalizable outcomes when the buyer is initially unaware of the feature. If the move of nature selects the quality-feature combination $(2, a)$, then in any prudent rationalizable outcome the seller remains silent about the feature (i.e., chooses a message that is silent on a or b). The buyer remains unaware of the feature and views the game as given by the less expressive tree. In this tree, there are just two quality levels, 2 and 3. Since the buyer is unaware of the feature, he cannot deduce from the fact that the seller remains silent on it that the good has feature a. In fact, he does not consider the feature at all. That is, information unravels with respect to the quality of the good but not with respect to the feature.

Proposition 2 *In the disclosure game where the buyer is initially unaware of the feature, in any prudent rationalizable outcome the seller does not fully reveal the quality-feature combination if nature selects* $(2, a)$*. In this case, the seller is silent on the feature.*

The observation is due to Heifetz, Meier, and Schipper (2021, Proposition 3). It also proved in an application by Schipper and Woo (2019).

3 Experimental Design and Hypothesis

We conducted experiments both at the University of California, Davis, and later at Xi'an Jiaotong University. The experiment run at UC Davis was programmed in zTree (Fischbacher, 2007) except for a paper-based questionnaire on demographics. The later experiments, run at Xi'an Jiaotong University, were programmed in o-tree (Chen et al., 2016) so that text could be displayed in Chinese. At both locations, the questionnaire (see the Online Appendix under `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp_appendix_complete.pdf`.) was distributed only at the end of the experimental session. Subjects were recruited on both campi using the ORSEE recruitment system by Greiner (2004). In China, we also used WeChat to recruit subjects.

Upon arrival in the lab, participants received written instructions for the experiment (see the Online Appendix under `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp_appendix_complete.pdf`.). They were given sufficient time to read the instructions. After the experimenter went over the written instructions in front of the participants, they were able to ask questions about the instructions and the experiment. These questions were answered by the experimenter in public. The same experimenter conducted all sessions in the US and in China.

Each session ran one of the following two treatments:

Treatment A: Participants played 15 rounds of a disclosure game with two quality levels, $\{2, 3\}$. Then, in the 16th round, *both* the seller and the buyer were notified about the dimension of the feature, $\{a, b\}$, and participants played the disclosure game with both the quality and feature dimensions. This treatment serves as the control treatment. The game in the 16th round represents the disclosure game with full awareness discussed in the prior section.

Treatment U: Participants played 15 rounds of a disclosure game with two quality levels, $\{2, 3\}$. Then, in the 16th round, *only the seller* was notified about the dimension of the feature, $\{a, b\}$, and participants played the disclosure game with both quality and feature dimensions, with the buyer being initially unaware of the existence of the feature-dimension. The game in the 16th round represents the disclosure game with unawareness discussed in the prior section.

Each participant was allowed to participate in only one session, and was assigned to one of the two treatments. Thus, we have a between-subject experimental design. In the US, none of the participants of a prior experimental disclosure game reported in Li and Schipper (2020) were allowed to participate in present experiment.

At the beginning of each session, participants were randomly assigned into matching-groups of six participants. Each participant stayed in the same matching-group throughout the session. Participants were unaware of matching-groups. At the beginning of each round, each participant was (re-)randomly matched to another participant from the same matching-group. The resulting pair of participants played the disclosure game together for one round, one participant being randomly assigned to the role of the seller and the other being the buyer. Participants were randomly rematched within their matching-group after each round. The random rematching should minimize repeated-games effects over the 16 rounds, while the matching groups allows us to collect a sufficient number of independent observations. Each matching group is an independent observation.

Due to random assignment of participants to the role of the buyer or seller, a participant may find herself in the role of a seller in one round and in the role of a buyer in another. This change of roles should facilitate interactive reasoning. Participants may find it easier to reason about the other player once they have been in a similar role.

In each round, first the seller receives information about the move of nature (i.e, quality in rounds 1 to 15 and the quality-feature combination in round 16). The move of nature was private information to the seller and was not observed by the buyer. Then the seller chose a message to send to the buyer. After receiving the seller's message, the buyer decided on the quantity to purchase. Finally, both the buyer and seller were informed about their own payoffs. For screenshots, see the Online Appendix under `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp_appendix_complete.pdf`.

In the 16th round of the treatment with full awareness (treatment A), both the seller and the buyer were notified of the existence of the second dimension along with the new payoff table for the buyer (see the screenshots for the seller and the buyer).

However, only the seller received information about the quality level and feature selected by nature. Different from previous rounds, the message set of the seller is extended by eight additional messages involving the second dimension.

In the 16th round of the treatment with unawareness (treatment U), only the seller was notified of the existence of the second dimension along with the new payoff table for the buyer. Upon receiving information on the quality level and the feature selected by nature, the seller then decided on a message. Recall that the set of available messages also contains messages that are silent on the dimension of the additional feature (see seller's screenshots in the Online Appendix under `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp_appendix_complete.pdf`.). If the message received by the buyer did not contain information about the feature, but at most information about the quality, then the buyer simply chooses a quantity to purchase as in the first 15 rounds. If the message received by the buyer did contain information about the feature, then, before making the decision, the buyer was notified about the second dimension along with the new payoff table.

After the disclosure games, participants received and answered a paper-based questionnaire about demographics. The questionnaire was not incentivized, and this was known to participants upfront.[3] At the end of the session, participants were paid a show-up fee plus earnings from the disclosure games. For each participant, one disclosure game was randomly and independently selected for payment. For the experiments in the US, the payoffs in the disclosure games are already denominated in US dollars. For the experiments in China, the payoff numbers of the games in Section 2 were multiplied by two and used for payment in Ren Min Bi (RMB).

For our analysis, we are not interested in the first 15 rounds. They just allow participants to gain familiarity with a simpler version of the task. We are solely concerned about decisions in round 16. In particular, we focus on whether outcomes in treatment A differ significantly from outcomes in treatment U. It allows us to compare unraveling in disclosure games with full awareness with unraveling in disclosure games with unawareness. The theory predicts unraveling in the former, but failure of unraveling in the latter, particularly in the case where nature chooses $(2, a)$. In line with the theoretical predictions, we hypothesize the following:

Hypothesis 1 *The relative frequency of unraveling outcomes when nature selects* $(2, a)$ *in treatment A is significantly higher than that in treatment U.*

[3]For the experiments conducted in the US, participants also completed an unincentivized 30-question Raven's progressive matrices test at the computer. Each question consisted of a graphic pattern in which one piece is missing. Participants needed to select the missing piece out of 8 options in order complete the pattern. We will not analyze the data here as we did not collect the data for the China samples. We did not collect the data for the China samples because we observed that participants spent a lot of time on this unincentivized task and we do not have a hypothesis w.r.t. the data from the Raven's progressive matrices test beyond what we already analyzed in disclosure games with full awareness in Li and Schipper (2020).

4 Result

The first set of experimental sessions of was conducted in a computer lab at the University of California, Davis, USA, in May 2016 and February to March 2017. The next set of sessions was conducted in a computer lab at Xi'an Jiatong University, China, in November 2021, December 2021, and May to June, 2022. The delay between the sessions is due to one of coauthors moving back to China for her first academic appointment and the Covid pandemic that generally interrupted laboratory experiments. For reasons we will explain shortly, we report on two samples collected in China, which we call "China" and "China*". The entire data set and the Stata-do file are available from `https://faculty.econ.ucdavis.edu/faculty/schipper/unawpgexp.do`. The demographic details are summarized in Table 3.

Table 3: Demographics of Our Samples

	USA May 2016 & Feb.-Mar. 2017			China Nov. 2021			China* Dec. 2021 & May-June 2022		
Variable	Count	Mean	Std. Dev.	Count	Mean Dev.	Std.	Count Dev.	Mean	Std.
Sessions Treatm. A	9			6			11		
Sessions Treatm. U	9			6			11		
Total Sessions	18			12			22		
Participants Treatm. A	192			78			150		
Participants Treatm. U	186			78			120		
Total Participants	378			156			270		
Female	235	0.62		63	0.4		130	0.48	
Age	378	20.71	2.50	156	20.14	2.86	270	20.20	2.71
Average GPA	373	3.22	0.47	135	83.81	6.72	263	83.81	6.31
Economics	85	0.22		15	0.10		22	0.08	
Math	8	0.02		8	0.05		4	0.01	
Engineering	43	0.11		67	0.43		154	0.57	

Table 4 shows the payments and duration for all three samples. As mentioned in Footnote 3, for the China and China* samples, we did not add the Raven's progressive matrices task, which substantially shortened the experiment.

Table 4: Incentives

	USA	China	China*
Mean	$17.96	RMB 36.58	RMB 35.44
Max	$ 25.00	RMB 50.00	RMB 46.00
Min	$ 9.00	RMB 24.00	RMB 12.00
Std. Dev.	3.86	7.63	8.50
Av. Duration	60 min	30 min	30 min

While the remuneration of participants in China is lower than that in the US ($1.00 is about RMB 7.23), the duration of the experiments in China is about half. Moreover,

	USA		China		China*		Pooled	
	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U
Unravel.	24	8	18	14	36	14	78	36
Non-unravel.	38	34	8	12	22	50	68	96

Table 5: Counts of Unraveling/Non-unraveling Outcomes by Treatment and Sample upon Nature Selecting $(2, a)$

purchasing power in China is larger. We believe that, overall, the incentives are comparable. In both countries, we gauged the expected payments with the wages a student could earn when working for the duration of the experiment.

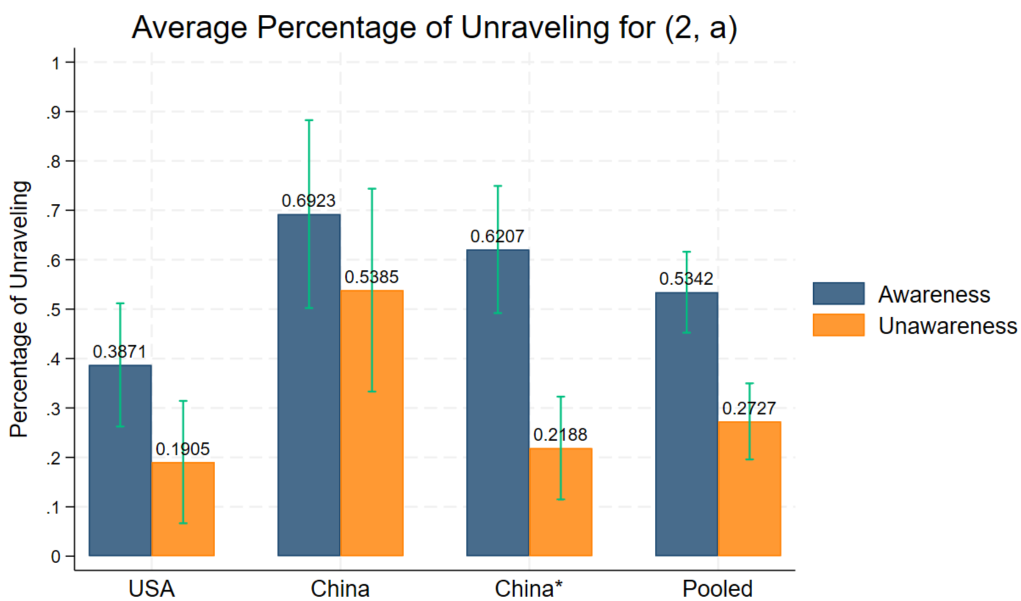

Figure 1: Relative Frequency of Unraveling upon Nature Selecting $(2, a)$

Figure 1 visualizes the relative frequencies of unraveling in both treatments upon nature choosing $(2, a)$. The blue bars indicate treatment A, the orange ones represent treatment U. We report histograms for all three samples separately as well as for the pooled data. All samples show a higher frequency of unraveling in treatment A than in treatment U. The green bars indicate 95% confidence intervals. We apply the one-sided Fisher's Exact Test for 2×2 tables with two independent samples (Siegel and Castellan, 1988) to the count data in Table 5. We find that the difference in unraveling between treatments A and U is statistically significant for the USA sample ($p = 0.0263$), statistically insignificant for the China sample ($p = 0.1964$), and statistically significant for the China* sample ($p = 0.0000$).

What explains the differences between the samples? First of all, when continuing the experiments in China, we changed the probability distribution with which nature chooses the quality-feature combination from uniform to $(0.4, 0.2, 0.2, 0.2)$ over $((2, a), (2, b), (3, b), (3, a))$. This was motivated by increasing statistical power because we are only interested in the difference in unraveling between treatments A and U when nature selects $(2, a)$. Note that this does not affect the individual behavioral predictions of the solution concept conditional on the move of nature (for the seller) and conditional on the message received (for the buyer). Second, when collecting the China sample, we noticed from informal exit interviews that sellers did not pay attention to the fact that buyers were unaware of the feature in round 16. They essentially overlooked several facts displayed on screen before round 16 (see the appendix for screen shots):

> "Till now the buyer has no idea about the possible special feature. As before (s)he is just aware of qualities 2 and 3. With your message to the buyer, you may or may not choose to inform the buyer about the possibility of the special feature. If you inform the buyer about the feature, then (s)he will also see this table. Otherwise if you choose not to inform the buyer about the feature, then (s)he will remain unaware of it. The feature is chosen randomly as well.
>
> ...
>
> Which message would you choose to send to the buyer?"

Apparently, this paragraph contained too much text and was not read carefully. As a remedy, we changed the text for the collection of the China* sample by separating the sentences of the paragraph and adding another sentence just before asking them to choose (see the appendix for screenshots):

> "Till now the buyer has no idea about the possible special feature. As before (s)he is just aware of qualities 2 and 3.
>
> With your message to the buyer, you may or may not choose to inform the buyer about the possibility of the special feature.
>
> If you inform the buyer about the feature, then (s)he will also see this table. Otherwise if you choose not to inform the buyer about the feature, then (s)he will remain unaware of it. The feature is chosen randomly as well.
>
> ...
>
> As before, the message has to contain the true number. You can be silent on the feature but whenever the feature is mentioned, it must contain the true feature.
>
> Which message would you choose to send to the buyer?"

This is the only difference between the China and the China* samples. It highlights the fact that comprehension of instructions is extremely important for experiments, especially when the experiment is about the effect of raising awareness. It would be wrong to discount the China sample as a "pilot experiment" because at the time of running it, we did not think of it as a pilot experiment. While clearly the comprehension of instructions for the China sample was not carefully controlled, ex post we think that it allowed us to learn about the impact of small awareness raising changes in the instructions. In any case, when pooling all samples, the difference in unraveling between treatments A and U remains statistically significant ($p = 0.0000$), again using a one-sided Fisher's Exact Test.

Observation 1 *We cannot reject the hypothesis. The relative frequency of unraveling outcomes when nature selects* $(2, a)$ *in treatment A is significantly higher than that in treatment U.*

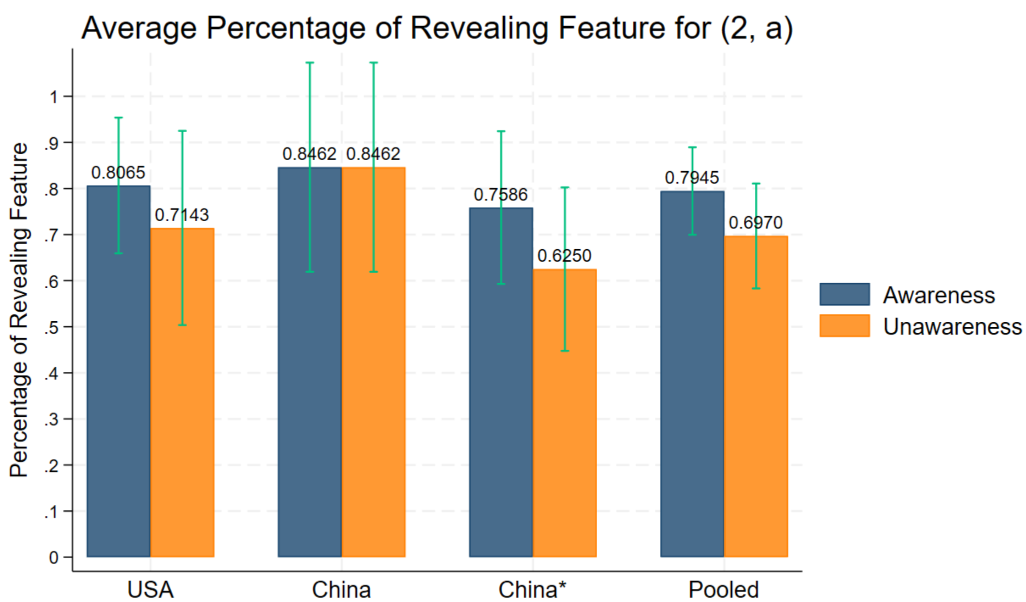

Figure 2: Relative Frequency of the Seller Revealing the Feature upon Nature Selecting (2, a)

Recall that unraveling under unawareness requires that the seller makes the buyer aware of the feature dimension when sending her message, while this is not required under full awareness. So just by choosing messages randomly and applying our definition of unraveling, we should observe less unraveling in treatment U than in treatment A. Is our result an artefact of the different implications of what unraveling represents under awareness and unawareness? To be more precise, recall that when nature selects $(2, a)$, unraveling in treatment U requires the seller to send a message raising awareness of the feature.

In treatment U, any message in $\{\{(2,a)\},\{(2,a),(2,b)\},\{(2,a),(3,a)\},\{(2,a),(3,b)\},\{(2,a),(2,b),(3,a)\}$ $\{(2,a),(2,b),(3,b)\},\{(2,a),(3,a),(3,b)\},\{(2,a),(2,b),(3,a),(3,b)\}\}$ is consistent with unraveling. In treatment A, messages in $\{\{2\},\{2,3\}\}$ are also consistent with unraveling.

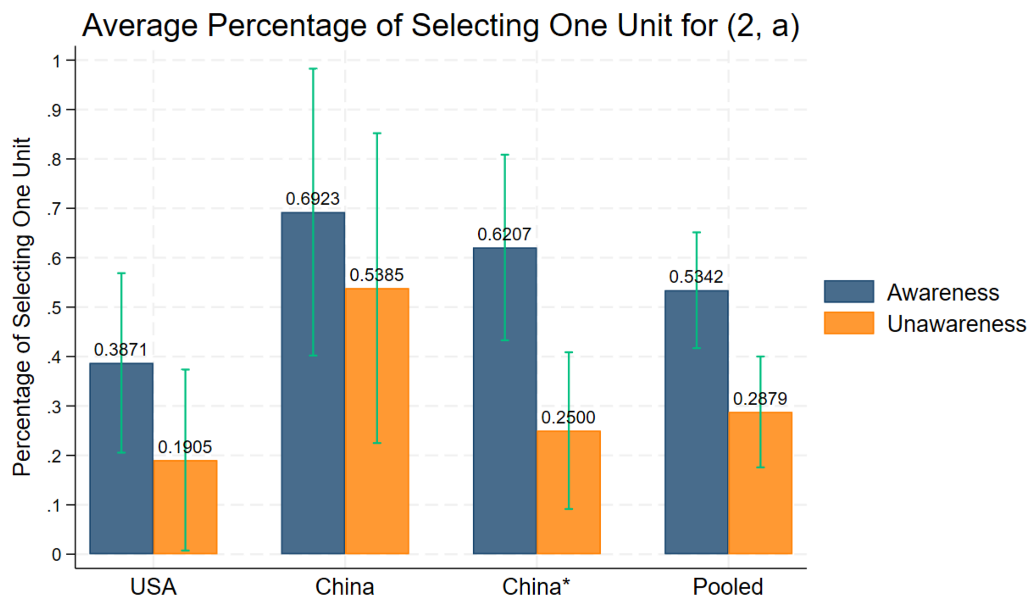

Figure 3: Relative Frequency of the Buyer Purchasing One Unit upon Nature Selecting (2, a)

We can study separately the seller's and the buyer's parts of the definition of unraveling (Definition 1). In Figure 2, we show histograms with the relative frequency of the seller revealing the existence of the feature when sending the message to the buyer upon nature selection $(2,a)$. We observe that for all samples except the China sample[4], the seller is more likely to keep silent about the feature (i.e., less likely to use a message that reveals the existence of the feature) in treatment U than in treatment A, which is consistent with the theory. However, the one-sided Fisher's test for 2×2 tables with two independent samples applied to count data in Table 6 confirms that these differences are not statistically significant (USA sample: $p = 0.3618$, China sample: $p = 0.7035$, China* sample $p = 0.1984$, Pooled sampled: $p = 0.1298$). Moreover, the relative magnitudes of revealing the feature in Figure 2 are much larger than for unraveling in Figure 1 suggesting that a substantial fraction of sellers raise the buyer's awareness of the feature when the buyer is unaware of it. Essentially, overall 70% of the sellers do not conform to theory. This suggests that the lack of unraveling under unawareness must be due to the buyer's behavior and not the seller's behavior.

[4]We believe that the fact that the relative frequencies of mentioning the feature in the China sample are equal for both treatments A and U just emphasizes our earlier claim that participants did not read carefully the instructions in the China sample.

	USA		China		China*		Pooled	
	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U
Disclose	25	15	11	11	22	20	58	46
Not discl.	6	6	2	2	7	12	15	20

Table 6: Counts of the Seller Disclosing the Feature by Treatment and Sample upon Nature Selecting $(2, a)$

	USA		China		China*		Pooled	
	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U	Treat. A	Treat. U
One	18	4	9	7	18	8	45	19
Not one	11	17	4	6	11	24	26	47

Table 7: Counts of the Buyer Purchasing One Unit by Treatment and Sample upon Nature Selecting $(2, a)$

Figure 3 displays histograms with the relative frequency of the buyer selecting quantity one, the optimal quantity in the unraveling outcome when nature selected $(2, a)$. We observe that despite 70% of the sellers raising awareness of the feature, overall only 29% of the buyers select the optimal quantity in treatment U. This is significantly less than in treatment A, suggesting that raising awareness of the feature when buyers are unaware of it confuses the buyers and induces them to choose non-optimal quantities. The one-sided Fisher's test for 2×2 tables with two independent samples applied to count data in Table 7 shows that these differences are statistically significant, except in the China sample (USA sample: $p = 0.0027$, China sample: $p = 0.3441$, China* sample $p = 0.0036$, Pooled sampled: $p = 0.0000$).

To sum up, while we cannot reject our hypothesis, it is not because our theory works as expected, but because both sellers and buyers largely do not conform to the theory. In particular, sellers naively raise awareness too often and buyers confusedly choose non-optimal quantities upon becoming aware.

Observation 2 *Contrary to the theory under unawareness, significantly more than half of the sellers raise awareness of the feature, and significantly more than half of the buyers choose non-optimal quantities upon becoming aware.*

The China* sample's behavior is closer to the theoretical prediction both in treatment A and U. This might be due to having more participants from science and engineering in the China* sample compared to the USA sample.

5 Discussion

When buyers are aware of potentially negative aspects of a good, they may become suspicious if the seller does not disclose relevant information about these aspects. In contrast, if buyers are unaware of these aspects, then they will not become suspicious if the seller is silent on these aspects. That is, skepticism presupposes awareness. Consequently, information does not unravel under unawareness as it does under full awareness. The theoretical predictions of disclosure games with and without unawareness match the above intuition. In this note, we experimentally test these predictions. In line with the theory, we observe significantly less unraveling under unawareness than under awareness. However, it seems that this is not due to the validity of the theory. In contrast to the theory, we observe sellers naively raise awareness when theory predicts that they should not, and buyers confusedly make suboptimal decisions upon becoming aware. This explains the lack of unraveling under unawareness.

While learning would allow both sellers and buyers to become more sophisticated, learning requires repetition. When a game with unawareness is repeated after awareness has been raised the first time it is played, the buyer would not be unaware anymore. Thus, we cannot observe learned behavior in a game with unawareness after awareness has been raised.

Lastly, we comment on the nature of information provided to subjects in our unawareness treatment. Since our experiment aims to measure unawareness as an explanatory variable, we as experimenters cannot disclose all relevant information to participants at the beginning. This is simply unavoidable. If we were to tell participants upfront that there is an attribute dimension of the good that has not been previously described, then we would already change the participants' mind and participants would become aware of this second dimension upfront. In some sense, we would destroy with the experimental instructions what we want to measure in the experiment. Not disclosing everything to participants in an experiment should not be confused with lying to participants. Every piece of information conveyed in the instructions is truthful and verifiable. We are just silent on some dimension of the good in period 16. In fact the information provided to participants in the experiment is akin to the notion of verifiable information, the paradigm that we test in this experiment. In almost all economic experiments in the literature, participants are not told literally everything about the experiment. Often, the very purpose of an experiment is concealed from participants for the fear that knowing purpose may affect their behavior via the experimenter demand effect. Avoiding the experimenter demand effect by withholding information from the participants just means that this very information is expected to be behaviorally relevant. In any case, we should recognize that similar to the effect of lying to participants, not disclosing everything that is relevant to the participants' decisions may lead them to mistrust our instructions in later experiments. In the language of Charness, Samek, and van de Ven (2022), our experiment must be considered to be one in the "gray area" with respect to practices that omit information or are misleading without an explicit lie being told. We mitigate these possible negative effects on future experiments by keeping track of who participated in which experiment using ORSEE (Greiner, 2004), and exclude participants in the unawareness treatment from future experiments.

References

[1] Araujo, F. and E. Piermont (2023). Unawareness and risk taking: The role of context, Journal of Economic Behavior and Organization 208, 61–79.

[2] Battigalli, P. (2006). Rationalization in signaling games: Theory and applications. International Game Theory Review 8, 67—93.

[3] Becker, C.K., Melkonyan, T., Proto, E., Sofianos, A., and S.T. Trautmann (2025). Revising beliefs in light of unforeseen events, Journal of the European Economic Association, forthcoming.

[4] Benndorf, V., Kübler, D., and H.-T. Normann (2015). Privacy concerns, voluntary disclosure of information, and unraveling: an experiment. European Economic Review 75, 43–59.

[5] Blume, A., and U. Gneezy (2010). Cognitive forward induction and coordination without common knowledge: Theory and evidence, Games and Economic Behavior 68, 488–511.

[6] Charness, G., Samek, A., and J. van de Ven (2022). What is considered deception in experimental economics?, Experimental Economics 25, 385–412.

[7] Charness, G. and A. Sontuoso (2023). The doors of perception: Theory and evidence of frame-dependent rationalizability, American Economic Journal: Microeconomics 15, 309-344.

[8] Chen, D.L., Schonger, M., and C. Wickens (2016). oTree - An open-source platform for laboratory, online and field experiments, Journal of Behavioral and Experimental Finance 9, 88–97.

[9] Deversi, M., Ispano, A. and P. Schwardmann (2021). Spin doctors: An experiment on vague disclosure. European Economic Review 139, 103872.

[10] Dye, R.A. (1985). Disclosure of nonproprietary information. Journal of Accounting Research 23, 123–145.

[11] Farina, A. and M. Leccese (2024). Hiding a flaw: An experimental analysis on multidimensional information disclosure, Princeton University.

[12] Farina, A., Frechette, G., Ispano, A., Lizzeri, A., and J. Perego (2024). The selective disclosure of evidence: An experiment, New York University.

[13] Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. Experimental Economics 10, 171–178.

[14] Forsythe, R., Isaac, M., and T.R. Palfrey (1989). Theories and tests of "blind bidding" in sealed-bid auctions. The RAND Journal of Economics 20, 214–238.

[15] Francetich, A. and B.C. Schipper (2025). Rationalizable disclosure and screening under unawareness. University of California, Davis.

[16] Greiner, B. (2004). The online recruitment system ORSEE - a guide for the organization of experiments in economics. Papers on Strategic Interaction 2003-10, Max Planck Institute of Economics, Strategic Interaction Group.

[17] Grossman, S. (1981). The Informational role of Walrasian and private disclosure about the product quality. Journal of Law and Economics 24, 461–483.

[18] Grossman, S. and O. Hart (1980). Disclosure Laws and Takeover Bids. Journal of Finance 35, 323–334.

[19] Hagenbach, J. and E. Perez-Richet (2018). Communication with evidence in the lab. Games and Economic Behavior 112: 139–165.

[20] Heifetz, A., Meier, M., and B.C. Schipper (2021). Prudent rationalizability in generalized extensive-form games with unawareness, B.E. Journal of Theoretical Economics 21, 525–556.

[21] Heifetz, A., Meier, M., and B.C. Schipper (2013). Dynamic unawareness and rationalizable behavior. Games and Economic Behavior 81, 50–68.

[22] Heifetz, A., Meier, M., and B.C. Schipper (2006). Interactive unawareness. Journal of Economic Theory 130, 78–94.

[23] Jin, G.Z., Luca, M., and D. Martin (2021). Is no news (perceived as) bad news? An experimental investigation of information disclosure. American Economic Journal: Microeconomics 13, 141–173.

[24] Jin, G.Z., Luca, M., and D. Martin (2022). Complex disclosure. Management Science 68, 3236–3261.

[25] Kamenica, E. and M. Gentzkow (2011). Bayesian persuasion. American Economic Review 101, 2590–2615.

[26] King, R.R., and D.E. Wallin (1991). Market-induced information disclosure: An experimental markets investigation. Contemporary Accounting Research 8, 170–197.

[27] Li Y.X. and B.C. Schipper (2020). Strategic reasoning in persuasion games: An experiment. Games and Economic Behavior 121, 329–367.

[28] Ma, W.J. and B.C. Schipper (2017). Does exposure to unawareness affect risk preferences? A preliminary result. Theory and Decision 83, 245-–257.

[29] Meier, M. and B.C. Schipper (2024). Conditional dominance in games with unawareness. University of California, Davis.

[30] Milgrom, P. (2008). What the seller won't tell you: persuasion and disclosure in markets. Journal of Economic Perspectives 22, 115–131.

[31] Milgrom, P. (1981). Good news and bad news: Representation theorems and applications. Bell Journal of Economics 12, 380–91.

[32] Milgrom, P and J. Roberts (1986). Relying on the information of interested parties. Rand Journal of Economics 107, 18–32.

[33] Pearce, D.G. (1984). Rationalizable strategic behavior and the problem of perfection. Econometrica 52(4): 1029-1050.

[34] Penczynski, S.P., Koch, C., and S.H. Zhang (2025). Disclosure of verifiable information under competition: An experimental study, University of East Anglia.

[35] Raven, J., J.C. Raven, and J.H. Court (2000). Manual for Raven's Progressive Matrices and Vocabulary Scales. San Antonio, TX: Pearson.

[36] Schipper, B.C. (2021). Discovery and equilibrium in games with unawareness. Journal of Economic Theory 198, 105365.

[37] Schipper, B.C. (2014). Unawareness - A gentle introduction to both the special issue and the literature. Mathematical Social Sciences 70, 1–9.

[38] Schipper, B.C. and H.Y. Woo (2019). Political awareness, microtargeting of voters, and negative electoral campaigning. Quarterly Journal of Political Science 14, 41–88.

[39] Schipper, B.C. and H. Zhou (2024). Level-k thinking in the extensive form, Economic Theory, forthcoming.

[40] Sheth, J. (2021). Disclosure of information under competition: An experimental study, Games and Economic Behavior 129, 158–180.

[41] Siegel, S. and N.J. Castellan (2008). Nonparametric statistics for the behavioral sciences, Second edition, McGraw-Hill.

[42] Verrecchia, R.E. (1983). Discretionary disclosure. Journal of Accounting and Economics 5, 179–194.