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# Reducing Polarization by Observing Others' Actions: Laboratory Experiments

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# Reducing Polarization by Observing Others' Actions: Laboratory Experiments※

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Abstract

This study investigates whether revealing others' actions can reduce polarization in the decontextualized settings of laboratory experiments. Despite wealth of studies on polarization, it has not been examined rigorously with varying treatments in laboratory settings. Theoretically, if people can infer others' private information through their actions, polarization should reduce for a policy that has common interests. To this end, we have conducted a novel laboratory experiment with a set of treatments theoretically derived. Our experiments show the following implications. First, when others' actions were revealed only once, polarization reduced in the short run, but increased in the long run. Second, when others' actions were revealed in all rounds, polarization reduced and almost disappeared. However, if participants thought that others had insufficient information, polarization persisted—even when others' actions were revealed in all rounds. In addition, a reduction in polarization is not necessary to increase participants' welfare since they may converge in the wrong direction. We apply our findings to real-world political issues including COVID-19 vaccination and cross-cutting views on social media and extend our discussions.

Keywords: belief polarization, laboratory experiments, asymmetric information

JEL classification: C92, D72, D82, D83

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# 1. Introduction

Ideological polarization, which has recently increased substantially in many countries, seems to have been even further accelerated since the outbreak of the COVID-19 pandemic. In speaking of ideological polarization, let us clarify what is meant by the terminology widely used nowadays. We reckon that there are two types of ideological polarization: "preference polarization", which derive from conflicts of interest (i.e., when two groups have diverging preferences), and "belief polarization", which may happen in situations where common interests exist. Belief polarization may arise when two people strengthen these prior beliefs after observing the same data. That is, although people have access to the same information, they still draw diametrically opposed implications.

Based on the above distinctions between preference polarization and belief polarization, we address the following two questions in this study: (i) how belief polarization can be reduced, and (ii) whether our welfare is improved by reducing belief polarization. One way to reduce such belief polarization, among others, is to show people others' actions and allow them to infer the private information held by others. The rationale is as follows: people typically choose the same action when they have the same information and common interests. If they can infer others' private information through their actions, polarization should reduce and ultimately disappear in situations in which common interests exist. Thus, this study primarily investigates the extent to which revealing others' actions affects and eventually reduces polarization.

In case of preference polarization, when people have the divergent preferences, the source of polarizations is rooted in themselves and people do not care about others' actions since their different actions suggest different preferences rather than different information. In contrast, our study focuses on belief polarization, when others' actions should influence rational choice under the situations where people have perfectly common interests.

Although many of policy issues have common interests to the whole society, it is also true that any real policy issue contains conflicted interests among people. Therefore, rather than using the contextualized settings in the experiments, this study employs the decontextualized settings of laboratory experiments to represent a situation in which only common interests exist and investigates whether polarization can be reduced by observing others' actions. To the best of our knowledge, as we will see below, polarization has not been examined rigorously with varying treatments as we do in our study. We aim to facilitate a deeper understanding of the nature of polarization. Although polarization arises in different contexts, it shares common features, and the laboratory experiments without specific contexts based on the formal model used in this study should help explain them.

Many formal models have shown that belief polarization can occur rationally (Dixit and Weibull, 2007; Bullock, 2009; Kondor, 2012; Acemoglu, Chernozhukov, and Yildiz, 2016). Our experiments are based on those of Andreoni and Mylovanov (2012), who simplify the belief polarization model and establish decontextualized settings of laboratory experiments (see Section 3); furthermore, we add the following new treatments to better elucidate the mechanisms how belief polarization occurs and/or reduces. In both Andreoni and Mylovanov's (2012) and our baseline sessions, the participants are informed about others' actions at the aggregated level in the final roundto see the information annihilates belief polarization. However, if the participants react to others' actions, polarization may reduce by observing others' actions in an earlier round. Thus, in our experiments, we provide information on others' actions in an earlier round instead of in the final round. In previewing our findings, we find that polarization reduces in the short run and increases again in the long run, but, crucially, not because the participants forget information in later rounds. We also test an alternative treatment in which we show the private signals observed by others instead of actions that others make in the early rounds based on the private signals they receive. With this treatment, we find that polarization reduces not only in the short run but also in the long run. This means that participants do not rely on others' actions as much and react to others' actions only in the short run, but others' signals in the long run.

We also allow the participants to observe others' actions in all the rounds and find that polarization reduces over the rounds and almost disappears, suggesting that information on others' actions must be repeatedly provided to reduce polarization. However, polarization re-emerges with the additional treatment in which some participants cannot observe the private signal. This finding shows that if participants think that other participants lack sufficient information, polarization persists even though others' actions are revealed in all rounds. Thus, to reduce polarization, it is important for people to believe that others have sufficient information.

Finally, we show that a reduction in polarization is not necessary to improve participants' welfare because all participants sometimes have the wrong beliefs even when they are informed about others' actions repeatedly. This represents the situation in which most citizens in a society may go in the wrong direction.

The rest of this paper proceeds as follows. The next subsection reviews the relevant literature and Section 2 presents the theoretical background of belief polarization. Section 3 outlines the experimental design. Section 4 describes the results and Section 5 applies them to real-world political issues including COVID-19 vaccination and cross-cutting views on social media. Section 6 concludes.

## 1.1 Literature Review

The model and experiments used in our study mainly analyze the ideological polarization of citizens. However, another type of polarization, affective polarization, is investigated, especially in the United States (e.g. Iyengar et al, 2019; Finkel et al., 2020; Wagner, 2021; Bell et al., 2022). Affective polarization is the difference between positive in-group bias toward the party one supports and negative out-group bias toward other parties. People tend to have stronger negative partisanship for the out-group party than positive partisanship for the in-group party (Levendusky, 2018; Abramowitz, 2018) and Democrats tend to have affective polarization, while Republicans tend to have ideological polarization (Grossman and Hopkins, 2016). Supposing that a private signal concerns which party (e.g., Democrats or Republicans) is not trustworthy and people observe the messages sent by the members of each party (i.e., public signals), our model and experiments can be applied to affective polarization. However, people usually have biased information processing such as confirmation bias under affective polarization. This means that they do not behave in a Bayesian manner and their belief updating is biased, which are not considered in our model. As this study mainly considers the "rational" reasons behind polarization to identify the effects of observing others' actions, such "emotional" aspects of polarization are outside our focus.

Conspiracy theories can also emerge when two people with opposing prior beliefs strengthen their beliefs after observing the same data. People who believe in conspiracy theories consume the same information as others, but their beliefs become extreme. That is, believing conspiracy theories is a type of belief polarization. Several survey experiments have investigated how people adopt conspiracy theories.[1] These experiments have relied heavily on contextualized settings. For example, Crocker et al. (1999) show that black Americans are far more likely to endorse theories about conspiracies by the U.S. government against blacks than white Americans. Galliford and Furnham (2017) show that conservatists are more likely to believe political and medical conspiracies than liberalists. Radnitz and Underwood (2015) show that people who have anxiety are more likely to believe the fictional conspiracy theory that the government is hiding the cause of a mysterious illness afflicting a small Midwestern town. By contrast, our study uses the decontextualized settings of laboratory experiments to understand the common features of polarization and conspiracy theories.

Belief polarization experiments have revealed various effects of private and public signals as well as others' actions to participants. This is similar to Anderson and Holt's (1997) information cascade experiments that show that participants overweight their private information relative to the publicly observable choices of others (Nöth and Weber, 2003; Goeree et al., 2007; Weizsäcker, 2010). In our experiments, the participants also tend to follow their private signals when others' actions are revealed only once. However, they assign greater weight to others' actions when they are revealed repeatedly. The major difference between information cascade and belief polarization is the point at which others' actions are revealed: information cascade experiments reveal them sequentially, whereas belief polarization experiments reveal them simultaneously. In information cascade experiments, one participant receives a private signal and decides in each period. Thus, participants gradually and sequentially observe others' actions. By contrast, in belief polarization experiments, participants can observe the actions chosen by all other participants simultaneously (although the data are aggregated). This implies that people

[1] Conspiracy beliefs are stronger among people who perceive patterns in randomness (e.g., van Prooijen, Douglas, and De Inocencio, 2018), are believers in paranormal and supernatural phenomena (e.g., Bruder et al., 2013), have lower levels of analytic thinking (e.g., Swami et al., 2014) and intelligence (e.g., Stieger et al., 2013), tend to link to the conjunction fallacy (Dagnall et al, 2017), have feelings of powerlessness (e.g., Abalakina-Paap et al., 1999) and anxiety (e.g., Radnitz and Underwood, 2017), are narcistic (Cichocka, Marchlewska, and Golec de Zavala, 2016), are the member of low-status groups such as black Americans (Crocker et al., 1999), have lower levels of education (e.g., Bogart and Bird, 2003), are male, unmarried, less educated, and earn less (e.g., Freeman and Bentall, 2017), and are at the political extreme (e.g., Krouwel et al., 2017), especially conservatives (Galliford and Furnham, 2017). Additional references can also be found in Douglas et al. (2019).

assign more weight to others' actions when they are revealed simultaneously, but not when they are revealed sequentially.

Belief polarization was traditionally recognized as an "irrational" phenomenon under which people do not act in a Bayesian manner. For example, "irrational" belief polarization can occur because of confirmation bias (Rabin and Schrag, 1999; Fryer, Harms, and Jackson, 2019), ambiguity aversion (Baliga, Hanany, and Klibanoff, 2013), and bounded memory, which means that individuals make decisions based on some past experiences (Wilson, 2014). Gerber and Green (1999) also show that "biased" Bayesian updating, where people resist or ignore information inconsistent with their prior views or partisan predispositions, can explain belief polarization.

However, recent studies show that belief polarization can also be a "rational" phenomenon with Bayesians (Dixit and Weibull, 2007; Bullock, 2009; Andreoni and Mylovanov, 2012; Kondor, 2012; Acemoglu, Chernozhukov, and Yildiz, 2016). They indicate that when the dimensionality of information exceeds that which describes the state of the world, belief polarization occurs. Suppose the state of the world is one-dimensional, but the uncertainty around it is two-dimensional and both dimensions are important to identify the state of the world. Then, even if people commonly observe many public signals about one dimension, polarization may persist when they observe different private signals on the other. In such cases, these different private signals induce diverging posterior beliefs, as public signals provide information on only one dimension and people continue to have different information on the other. As our main interest is in how a person reacts to others' actions when they contain the information held by others, we use the "rational" framework in this study.

Most previous experiments of polarization adopt the contextualized setting of survey experiments. The seminal study by Lord, Ross, and Lepper (1979) shows that participants who already have differing views on the death penalty are driven further apart after reading a study suggesting that it deters serious crime. Similarly, studies have also examined such contexts as the death penalty (Houston and Fazio, 1989; Schuette and Fazio, 1995), presidential debates (Katz and Feldman, 1962; Sigelman and Sigelman, 1984), and the economy (Kinder and Mebane, 1983). On the contrary, Andreoni and Mylovanov (2012) investigate belief polarization in the decontextualized settings of laboratory experiments. The experiments based on this setting are replicated in this study as the baseline session.

# 2. Background

## 2.1 Basic Model

This subsection formally shows the application of belief polarization to the politics example. The following model is based on the decontextualized model developed by Andreoni and Mylovanov (2012). Suppose that the implementation of a drastic reform policy such as radically deregulating the market, engaging in war, or joining/leaving an international union is a controversial issue in a society. Formally, suppose policy $x \in \{0,1\}$, where $x = 0$ is no reform and $x = 1$ is reform.[2] While the implementation of such a reform policy is not necessary to induce a desirable consequence for (the majority of) citizens. There are two states of the world, $\theta \in \{g, b\}$. Both citizens and the government have preferences for the policy represented by $u_{\theta x}$ and $v_{\theta x}$, respectively, when policy $x \in \{0,1\}$ is implemented in state $\theta \in \{g, b\}$. Suppose that both obtain zero from the status quo policy regardless of the state: $u_{\theta 0} = v_{\theta 0} = 0$ for any $\theta \in \{g, b\}$. Reform is good for citizens in state $\theta = g$, but undesirable for citizens in state $\theta = b$: i.e., $u_{g1} > 0$ and $u_{b1} < 0$. On the contrary, there are two types of the government, $\gamma \in \{c, d\}$, where $\gamma = c$ means that the government is the congruent type whose interests coincide with those of citizens. That is, $v_{g1} > 0$ and $v_{b1} < 0$ for the congruent type. The dissonant type, $\gamma = d$, means that the government have the different policy preference from the citizen's preference because of, for example, the strong relation with special interest groups. That is, $v_{g1} < 0$ and $v_{b1} > 0$ for the dissonant type. Citizens do not know the state of the world and the prior probability of each state is 50%. If citizens can guess the state of the world, they can also know whether the reform policy is desirable for them. Thus, they try to infer the state of the world to decide whether they support the policy.

While citizens cannot observe the state of the world, the government is expected to have more information about it. Suppose that the government receives an imperfect signal

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[2] We considered the reform policy here, but any type of political decision, not only with reference to a reform policy, can be considered as $x$ as other possible interpretations.

about the state of the world, $s \in \{g', b'\}$, such that $Pr(\theta = g|s = g') = Pr(\theta = b|s = b') = p \in (0.5, 1)$. That is, signal $g'$ $(b')$ means that the state of the world is more likely to be $g$ $(b)$. After receiving the signal, the government sends a public message to citizens, $m \in \{0,1\}$, where $m = 0$ means that they do not support the reform and $m = 1$ means that they support it. However, the government may be the dissonant type. Suppose that the politician supports their preferred policy in their message. That is, when $s = g'$, the congruent type supports the reform $(m = 1)$, while the dissonant type does not and recommends keeping the status quo $(m = 0)$.

Citizens do not know the government's type and the prior probability of being each type is 50%. They obtain a private signal about the type of the government, $t \in \{c', d'\}$, such that $Pr(\theta = c|t = c') = Pr(\theta = d|t = d') = q \in (0.5, 1)$. That is, signal $c'$ $(d')$ means that the government is more likely to be the congruent (dissonant) type. This private signal can be interpreted as citizens' evaluations of the government based on their past experiences. Each citizen should have different experiences of the government as well as check different news media. These different experiences and information provided by the media lead to their different evaluations of the government. Here, we called these past cumulative experiences and information the private signal.

Citizens want to infer the state of the world (a consequence of the reform) from the government's public message. However, without knowing the government's type, they cannot infer it from this message since they do not know whether the government is announcing citizens' preferred policy or not. That is, the state of the world is one-dimensional (the reform is good or bad), whereas the uncertainty around it is two-dimensional (the government's type and the government's signal). The timing over which citizens obtain each piece of information is as follows:

Period 1: A citizen obtains a private signal about the politician's type.
Period 2: The government sends a message.

Suppose that the government announces that they support reform $(m = 1)$ in the second period. Then, a citizen who observed $t = c'$ in the first period believes that the state of the world is more likely to be $\theta = g$. More precisely, the probability of $\theta = g$ is

$\Pr(\theta = g|t = c', m = 1) = qp + (1 - q)(1 - p) > 0.5$. On the contrary, a citizen who observed $t = d'$ believes that the state of the world is $\theta = b$ with probability $\Pr(\theta = b|t = c', m = 1) = qp + (1 - q)(1 - p)$. Therefore, belief polarization emerges—even though both citizens observe the same message from the government—because they have different private signals.

## 2.2 Multiple Public Signals

The previous subsection supposes that a citizen observes the government's message only once. Here, suppose that a citizen can observe the government's messages several times. It may be strange that the government sends several (possibly different) messages to citizens. In this case, there are two possible reinterpretations of the above story as follows. First, there are several politicians belonging to the government party who observe different signals about the state of the world. Hence, they send a message sequentially according to their observed signal, and citizens who receive $t = c'$ ($t = d'$) believe that each politician is the congruent (dissonant) type with probability $q \in (0.5, 1)$. Second, there are several media outlets which observe different signals about the state of the world. Each media outlet sends a message sequentially through reporting news according to their observed signal, and citizens who receive $t = c'$ ($t = d'$) believe that each media outlet has high (low) ability and was able to get the correct (incorrect) signal with probability $q \in (0.5, 1)$.

In these cases, citizens' posterior beliefs depend only on the difference between the number of realizations of different messages, but not their order. Let $n$ be the number of messages sent by the politicians (or media outlets) and $k$ be the number of messages equal to one ($m = 1$). Then,

$$\delta = 2k - n.$$

If $\delta = 0$, the number of messages is equal at $m = 0$ and $m = 1$. More politicians (media outlets) support the reform policy when $\delta > 0$, whereas more politicians (media outlets) support the status quo policy when $\delta < 0$. Define $\Pr(\theta = g|t, \delta)$ as the posterior probability that the state of the world is $g$ (the reform policy is desirable for citizens) given a private signal and $\delta$. There is **disagreement** in a society when $\Pr(\theta = g|t = c', \delta) \neq \Pr(\theta = g|t = d', \delta)$. When $\delta = 0$, $\Pr(\theta = g|t = c', \delta) = \Pr(\theta = g|t = d', \delta) = 0.5$, and there is no disagreement. By contrast, when $\delta \neq 0$, there exists disagreement. If the number of messages ($n$) is odd, $\delta \neq 0$ in all cases; hence, disagreement always occurs. The **probability of disagreement** defines the ex-ante probability that disagreement occurs in each period. Then, the following result is derived directly from Proposition 1 of Andreoni and Mylovanov (2012, p. 215).

**Result 1**: *The probability of disagreement is*

*(i) One if the number of public messages ($n$) is odd.*

*(ii) Positive and increasing with $n$ if $n$ is even.*

As a measure of the **value of disagreement**, we consider the absolute value of the difference between the beliefs about the state of the world conditional on different private signals, namely, $|\Pr(\theta = g|t = c', \delta) - \Pr(\theta = g|t = d', \delta)|$. Then, the following result is derived directly from Proposition 2 of Andreoni and Mylovanov (2012, p. 216).

**Result 2**: *The expected value of disagreement*

*(i) Is unchanged by observing one more message if the number of public messages ($n$) is odd.*

*(ii) Strictly increases by observing one more message if $n$ is even.*

Therefore, both the probability of disagreement and the expected value of disagreement may increase, or at least not decrease, as the number of messages increases. In other words, polarization persists and may rise as citizens receive more public messages from politicians.

The next section explains the details of our experiments using decontextualized settings in the sense that the above story is not directly explained to participants. Hence, they are not required to choose the best of the two "policies" and do not observe messages from "politicians."

# 3. Experimental Design

## 3.1 Process of the Experiments

Eight experimental sessions were conducted at Waseda University, Japan in 2021 and 2022. There were 25 or 30 participants in each session and they engaged only once in the entire study. The participants were divided into five or six teams, each comprising five members. They played three sets of the same game in succession. Team members were randomly matched at the beginning of each set. The composition of the teams changed in each set. One set comprised several rounds and the participants made one decision per round. There were four urns, as shown in Figure 1. At the beginning of the set, one of the four urns was chosen, from which a ball was selected. The urns had two separate compartments. The first compartment contained red and green balls. Urns A and C had one red ball and three green balls. Urns B and D had one green ball and three red balls. A random draw from a compartment was equivalent to a signal informing the participants about the chosen urn. When the ball was red (green), the chosen urn was A or C with a 25% (75%) probability and B or D with a 75% (25%) probability. The second compartment contained white and black balls. Urns A and D had one black ball and three white balls. Urns B and C had one white ball and three black balls. A random draw from this compartment was equivalent to a signal informing the participants about the chosen urn. When the color of the ball was white (black), the chosen urn was B or C with a 25% (75%) probability and A or D with a 75% (25%) probability.

[Figure 1 Here]

The urns were divided into two groups. Group 1 comprised Urns A and B and Group 2 comprised Urns C and D. During the experiment, the participants had to determine whether the selected urn was from Group 1 (Urn A or B) or 2 (Urn C or D). They had to place bets on Group 1 or 2, or both, by observing the color of the ball drawn in each round. A total of 15 draws were made from the urn selected at the beginning of each set. Each urn was selected at a probability of 25%. Only the first draw was performed in front of each participant. The color of the ball drawn in front of the other members was hidden. As the draw was privately witnessed by each participant, we called it the "private draw." The first draw was from the red/green compartment only. In the other 14 draws, all team members saw the same color. As this draw was publicly observed by all the members, we called it the "public draw." Public draws were made only from the white/black compartment. A bet was placed after each draw. The process continued until the bet comprised one round. For example, the first round contained the first draw and bet. The participants had to place a bet without observing the color of the ball in a few treatments. In such cases, we counted the process until this bet as one round. Further details are presented later.

These settings are analogous to the formal model in Section 2. First, a private draw is a private signal about the government, and green means congruent ($c'$), while red means dissonant ($d'$). Second, a public draw is a message sent by the government, and white means that the government supports the reform policy ($m = 1$), while black means it does not ($m = 0$). Then, Group 1 means that the reform policy is desirable for citizens ($\theta = g$) and Group 2 means that the reform policy is undesirable ($\theta = b$). Urn A (B) represents the case in which the government is the congruent (dissonant) type, meaning it is more (less) likely to support the reform policy. On the contrary, Urn C (D) represents the case in which the government is the congruent (dissonant) type, meaning they are less (more) likely to support the reform policy.

There were 16 rounds of bets in each set. First, the participants could place bets after each of the 15 draws. After the bets on the 15th draw, the total number of bets on each group by all the team members were revealed and the participants could make bets once more. That is, in the 16th round, the summations of all the points to be bet on each group from Rounds 1 to 15 are revealed. The purpose of the bets in the 16th round was to allow the participants to update their beliefs based on the information contained in the aggregate of all the bets. If the participants were all perfectly risk-neutral Bayesians and this was common knowledge, then polarization should have disappeared in Round 16.

The entire process was run on a computer. The ball was not drawn physically. All the experiments were performed using a computer screen. We used oTree for these experiments. In each round, the participants could place between 0 and 9 bets on each of the groups of urns. After each draw, they could simultaneously make up to 18 bets (i.e., 9 or fewer bets each on Group 1 or 2). Only integers could be chosen.

We used the following quadratic scoring rule. The participants were given 10 points for every bet on the group that contained the urn selected in the set. Points that were betted for the incorrect group were not returned. We called points to be returned the "return point." Bets also incurred costs. We called these the "cost point," which marked the summation of all the integers from 0 to the points used in a bet on each group. The first bet made on Group 1 cost 1 point. The cost of each additional bet on Group 1 was 1 point more than that of the previous bet on Group 1. For example, if a participant bet 2 points for Group 1, it cost an additional 2 points; hence, the cost point was 3 points. As the third bet cost an additional 3 points, the overall cost point was $1+2+3=6$ points. The $n$th bet cost $n$ points. Similarly, the first bet made on Group 2 in this round cost 1 point and the $n$th bet cost $n$ points. Table 1 shows the cost in each case. When a participant bet on both groups, they had to add the cost points of Groups 1 and 2. For example, if a participant bet 9 points in both groups, their cost point would have been 45+45=90, not 45.

[Table 1 Here]

The participants' "earning point" in each round was the return point minus the cost point. $b_1$ and $b_2$ denote the points bet on Groups 1 and 2, respectively. $p_1$ and $p_2$ denote the probability that Groups 1 and 2 contained the urn selected in this set, respectively. Then, the expected earning point is as follows:

$$10(p_1 b_1 + p_2 b_2) - \sum_{j=0}^{b_1} j - \sum_{k=0}^{b_2} k$$

Payments for the participants were determined by their earning points, which could be positive or negative because the cost point may have been higher than the return point. The bet for each round was independent of the other bets. The participants could choose any point to bet on (between 0 and 9), regardless of the points they bet on in the previous rounds. If we consider the points bet as a continuous variable, the above expected earning point is: $10(p_1 b_1 + p_2 b_2) - \int_{j=0}^{b_1} j dj - \int_{k=0}^{b_2} k dk = 10(p_1 b_1 + p_2 b_2) - \frac{b_1^2}{2} - \frac{b_2^2}{2}$. The value of $b_t$ that maximizes its expected earning point is $b_t = 10p_t$ where $t = 1$ or $2$. Therefore, if individuals are risk-neutral Bayesian payoff maximizers, their bets should reveal their beliefs around the probabilities. For instance, a participant who thinks that the likelihood of

Group 1 being the true state is 40% should place 4 bets on Group 1 and 6 bets on Group 2.

## 3.2 Sessions

A total of 220 undergraduate and graduate students from various majors at Waseda University participated in this study. They were recruited through the sona system used exclusively by the students of Waseda University.[3] Upon their arrival, the participants were randomly allocated to a computer. Each participant had a cubicle, meaning that they were unable to see the others' computer screens. They received a set of instructions (Appendix A), and the computer read them out at the beginning of the experiment. To ensure that the participants clearly understood the experiment, we prepared a practice set, which had one private draw from the red/green compartment and four public draws from the white/black compartment. As the participants understood the experiment well after the practice set, we used the results from all the sets for our analysis. In each round, the participants decided the points bet on each group. They kept track of the draws and their bets in each round using the computer interface. After all the team members completed one round, the selected urn and group as well as the participant's points in each round appeared on the screen.

All the experiments lasted 80 to 90 minutes. The participants were informed that they would receive a participation fee of JPY 1,000 in addition to any earnings they received based on their earning points (conversion rate: 1 point = JPY 3).[4] At the end of each set, two bets were selected at random to determine the earnings of the participants in that set. We called this the "earning round." The payments to the participants were decided by both these earning rounds per set. There were three sets and thus six earning rounds in one session. To guarantee that earnings were non-negative, we provided 45 points per earning round to all the participants at the end of the set because the minimum possible earning point was $-45$ (i.e., when a participant bet 9 points exclusively on the group that did not contain the selected urn). As there were two earning rounds per set, the participants received 90 points per set. Their final earning points were the sum of the earning points of

[3] This is a system for the participant management. See https://www.sona-systems.com/ for more details.
[4] If a participant earned less than JPY 1,500, we increased the participation fee for all the participants such that each received at least JPY 1,500.

the two earning rounds and 90 points. At the end of the experiment, we provided the participants with their earnings in cash. Their profit ranged from JPY 1,500 to JPY 2,800, including the participation fee.

## 3.3 Treatments

### 3.3.1 Providing Information on Others' Actions

If participants can observe both their own and others' private draws, polarization should not occur, theoretically.[5] Although a private draw was observed only once in the first round, the participants could infer others' private draws by observing the other participants' actions. For example, if they observed a red ball in the private draw and more black balls in the public draws, then they could infer that the selected urn was more likely to be B (Group 1). However, if they observed that the other members bet on Group 2 more, they could guess that the other members had observed a green ball in the first round and that Urn C was more likely to have been selected. Then, their optimal choice should have been to place more bets on Group 2. Following Andreoni and Mylovanov (2012), we informed the participants about the total cumulative numbers of bets on each group in the final round in baseline sessions called "**Baseline**." As our primary interest was in examining whether observing others' actions can reduce polarization, we had to reveal others' actions in an earlier round to check this. Thus, the following two treatments were introduced:

1. Offering information on others' actions in earlier rounds
   We revealed the total cumulative number of bets on each group between the second and third rounds and called this treatment "**Round 2.5**." Theoretically, belief polarization occurs after players observe both private and public signals. Therefore, the first time polarization arises is right after the bet on the second round. Thus, we chose the earliest timing to offer information on the other members' actions. After the bet in the first public draw in Round 2, the total points until Round 2 were announced in Round 2.5. This was a summation of all the points to be placed for a bet in Rounds 1 and 2, and the participants placed a bet after they observed it. Then, we had 13 public

[5] Andoreoni and Mylovanov (2012) also run a different treatment in which the participants receive both public and private signals repetitively. They confirm that polarization disappears when both signals are provided several times.

draws, and the summation of all the points up to the bet from Rounds 1 to 15 including Round 2.5 was announced in Round 16.

2. Offering information on others' actions in all the rounds

   The total cumulative number of bets on each group was announced at the end of each round. We called this treatment "**All Rounds**." The total cumulative number of bets was the summation of all the points bet on each group by all the team members in the previous rounds. Therefore, there were 15 points in time at which to reveal the other members' actions. There was no extra bet after the total points bet on each group had been revealed. However, after the total points had been announced in Round 15, the participants had another chance to place a bet without observing a public draw. Thus, there were 16 rounds of bets for each set.

In addition, we ran another treatment in which the private signals observed by the other team members were informed between Rounds 2 and 3. This treatment was called "**2.5 Signal**." In this treatment, the participants did not need to consider whether the other members were rational. This was equivalent to the case in which the participants could observe private draws five times.

### 3.3.2 Uninformed Participant

We employed an additional treatment in which one team member was not informed about the private draw. We announced to all the participants that some of them were not informed about the private draw, but the number of such participants was not announced. We called this treatment "**Uninformed**." Theoretically, even if some participants do not observe a private draw, they can infer the private draws observed by others through other participants' actions for the following reasons. If a participant observes only public draws and no private ones (and no others' actions), they must believe that the probabilities that the urns in Groups 1 and 2 are selected are the same. Thus, they should place 50/50 bets on Groups 1 and 2. Given this optimal choice, the existence of participants who do not observe the private draw should not affect the difference in the total cumulative number of bets on each group. Therefore, if Group 1 has a higher total cumulative number of bets, it means that more participants observed the private draw, which induced them to believe that Group 1 was more likely to be selected. However, the participants may consider the other members' actions to be unreliable, as some may have insufficient information. If this is the case, they should rely only on their own signals, meaning that polarization cannot be reduced by announcing others' actions. This treatment was combined with **Baseline** and **All Rounds**. Table 2 presents the treatments used in each experimental session.

[Table 2 Here]

## 3.4 Measurement of Polarization

### 3.4.1 Frequency of Disagreement

We measured the frequency of polarization following Andreoni and Mylovanov (2012). Theoretically, this frequency is equivalent to the probability of disagreement introduced in Section 2. In the experiments, the frequency of disagreement was defined as follows. Denote $b_1^i$ and $b_2^i$ as the points bet on Groups 1 and 2 by participant $i$, respectively. First, for each participant, the absolute difference between the bets on Groups 1 and 2 is calculated, that is, $|b_1^i - b_2^i|$. If the difference between these bets is the same as or higher than 1, that is, $\left|b_1^i - b_2^i\right| \geq 1$, we suppose that this participant prefers the group on which they placed more bets. Otherwise (i.e., $|b_1^i - b_2^i| = 0$), we suppose that the participant was indifferent. Second, the team members were divided into two groups (termed "parties") based on the color of a ball observed in the private draw, say the red and green parties. Indifferent participants were excluded. Then, the group, namely 1 or 2, that was preferred by most of the remaining participants in each party was determined. If an equal number of the participants strictly preferred different groups or all the participants in the party were indifferent, we concluded that this party was indifferent to both groups. Otherwise, we found the group that was strictly preferred by this party. For example, suppose that two participants observed red and the remaining three observed green. In the red party, if both the members bet on Group 1 more ($b_1^i - b_2^i \geq 1$), the red party would prefer Group 1. If one member was indifferent ($b_1^i - b_2^i = 0$), the other preferred Group 1 ($b_1^i - b_2^i \geq 1$), and the remaining one preferred Group 2 ($b_2^i - b_1^i \geq 1$) in the green party, the green party would be indifferent. The frequency of disagreement was the frequency at which two parties had different preferences (i.e., one party prefers one group, while the other prefers or is indifferent toward the other group they want to bet on). In the above example, there is disagreement.

### 3.4.2 Value of Disagreement

The other measurement is the value of disagreement, namely, the magnitude of polarization. Theoretically, this is equivalent to the difference between the beliefs conditional on different private signals, namely, $|\Pr(\theta = g|t = c', \delta) - \Pr(\theta = g|t = d', \delta)|$. In the experiments, the value of disagreement was defined as follows. First, similar to the frequency of disagreement, the team members were divided into red and green parties based on the color observed in the private draw. Then, we calculated the absolute value of the difference between the average bets on a specific group made by each party. The value of disagreement could next be calculated. In the following example, we use the bets on Group 1. Suppose that the numbers of participants in the red and green parties are $n_r$ and $n_g$ in this team and that the sets of members in the red and green parties are $I_r$ and $I_g$, respectively. Then, the value of disagreement is

$$\left|\frac{\sum_{i\in I_r} b_1^i}{n_r} - \frac{\sum_{j\in I_g} b_1^j}{n_g}\right|.$$

Theoretically, this value should be the same as the one that uses the bets on Group 2, that is, $\left|\frac{\sum_{i\in I_r} b_2^i}{n_r} - \frac{\sum_{j\in I_g} b_2^j}{n_g}\right|$. Although the observed value between them differs, the implications remain relatively unchanged if we use the bets on Group 2 instead of those on Group 1.

### 3.4.3 Theoretical Value and Frequency of Disagreement

We calculated the Bayesian beliefs about whether the urn belongs to Group 1 given the participant's observations (i.e., the posterior probabilities after the participants observe the colors of a few drawn balls). Table 3 presents these results. For example, when a participant observed five white and two black balls from public draws, white balls exceeded black balls by three. Thus, if a participant observed red, the Bayesian belief about whether the urn belongs to Group 1 is 15/56. If a participant observed green, it is 41/56. When the participants observed the same number of white and black balls or had not yet observed a public draw, the Bayesian belief was 1/2 regardless of whether the ball was red or green. Given these settings, the Bayesian belief is less than 3/4 and more than 1/4, and it converges to 3/4 or 1/4 as the participants observe the same color more.

[Table 3 Here]

The theoretical value and frequency of disagreement can be derived using the calculated Bayesian beliefs.[6] They represent the value and frequency when all participants are risk-neutral and Bayesian. The theoretical value of disagreement should be multiplied by 10 to compare it with the observed value of disagreement in the experiments.

# 4. Experimental Results

## 4.1 Baseline

Andreoni and Mylovanov (2012) was replicated in **Baseline** (sessions 1 and 7). Figure 2(a) presents the value of disagreement, both theoretical and observed, in the first 15 rounds, averaged for each set. In the following, we exclude from the data those sets in which all the (informed) members observed the same color in the private draw regardless of the treatment. The value of disagreement increased over the rounds, reaching 3 to 3.5 in the latter half of the session. Figure 2(b) presents the theoretical and observed frequencies of the first 15 rounds. The observed frequency of disagreement also increased over the rounds, reaching 80–90%. The observed value and frequency of disagreement in the first round were higher than the theoretical value and frequency (zero). In the other rounds, the observed value and frequency had similar values to the theoretical value and frequency, which means that it can elicit their beliefs from participants.[7]

[Figure 2 Here]

Figure 3 compares the frequency and value of disagreement of **Baseline** with those of **Uninformed** (session 3). The participants who did not observe private draws were excluded from data. The observed frequencies and values of disagreement do not differ between them, suggesting that the existence of uninformed participants does not affect the size and frequency of polarization in **Baseline**.

[Figure 3 Here]

[6] We confirm that the theoretical frequencies and values of disagreement differ little among the different treatments.

[7] The value and frequency of disagreement in **Baseline** are slightly lower than those in Andoreoni and Mylovanov (2012), with the value and frequency of disagreement increasing to 3.5–4 and 100%, respectively. The main reason is the difference in the theoretical value and frequency of disagreement. In Andoreoni and Mylovanov (2012), the theoretical value of disagreement and frequency converged to 5 and 1, respectively—even in odd rounds.

## 4.2 Others' Actions

### 4.2.1. Providing Information in Round 16

Andreoni and Mylovanov (2012) inform their participants about the total cumulative number of bets on each group in the final round (i.e., Round 16). They show that despite providing such information, a sizable number of participants maintained their opposing views; hence, polarization persisted. Hence, we also check whether our participants changed their actions after observing the others' actions. To understand the factors that affected their actions in the final round, we regress the difference between one's own bets on Groups 1 and 2 in Round 16 on the cumulative differential in one's own and others' bets in the preceding 15 rounds, with standard errors clustered for each subject. Only individual data from **Baseline** (with and without **Uninformed**) are included (i.e., we use sessions 1, 3, and 7 from Table 2).

Table 4 shows the estimation results. In Table 4, "own differential" is the summation of the differences in the participant's own bets on Groups 1 and 2 from Rounds 1 to 15. "Others' differential" is the summation of the differences between the other members' bets on Groups 1 and 2 from Rounds 1 to 15, divided by 4 (the number of the other members). Model 2 includes the dummies of **Uninformed** and their interactions with one's own and others' differentials. "Uninformed subject" is a dummy variable coded one if the subject did not observe a private draw. "Uninformed session" is a dummy variable coded one if it is Session 7 (the session in which a subject does not observe a private draw). Model 3 includes the dummy of "irrational" bets in the first round and their interactions with one's own and others' differentials. In the first round, as the participants observed only the private draw, red or green, the posterior probability that the selected group was Group 1 was 50%. Therefore, Bayesian participants should prefer to bet the same points on each group. Among symmetrical bets, the best choice for the participants was to place 4 or 5 bets on both groups, as they would be guaranteed to obtain 20 earning points. For the other symmetrical bets, the participants' earning points were always lower than 20. However, several participants made such unreasonable choices in the first round.

"Incorrect" is a dummy variable coded one if the subject did not place 4 or 5 bets on both groups.[8]

[Table 4 Here]

As long as all participants are assumed to be rational, information about both one's own and other's bets in Rounds 1 to 15 is equally important for the decision in Round 16. Thus, the coefficients of one's own and others' differentials should be almost equal in Table 4. While one's own differential receives more than the weight placed on others' differentials in Model 1, both weights are similar in Model 2, while others' differential receives more weight in Model 3. This differs from the estimations of Andreoni and Mylovanov (2012), who show that the weight on one's own differential is about twice that on the others' differential. This means that our participants react to others' actions more than the participants in Andreoni and Mylovanov (2012).

Another two important implications arise. First, in Model 3, while those participants who placed 4 or 5 bets on both groups in the first round ("correct" bet) placed more weight on others' actions, those who chose "incorrect" bets in the first round placed much less weight on others' actions. In other words, many "rational" participants who understand the rules of this experiment care about others' actions, while "irrational" participants who do not understand the rules tend to ignore them.

Second, theoretically, participants who do not observe a private signal should respond heavily to others' actions since they do not have a private signal. However, according to the estimations in Models 2 and 3, they actually react to others' differential to a lesser degree. On the contrary, the participants in the session with **Uninformed** place less weight on others' actions. That is, those participants who observe a private signal and think that others may not be informed tend to ignore others' actions. One possible interpretation is that they mix up "uninformed" and "irrational," believing that others' actions are unreliable when some members are uninformed. This issue is discussed further in Section 4.2.3.

[8] Andreoni and Mylovanov (2012) also include the dummies of sets 2 and 3 and show that the coefficient of the set-2 dummy is significantly negative. When these two dummies are included in our estimation, our main implications are unchanged and these two dummies are not statistically significant.

### 4.2.2. Offering Information Earlier

In our experiments, the participants, at least those who chose the optimal action in the first round, were concerned about others' actions and made decisions based on them in Round 16. Is this evidence sufficient to show that others' actions in an earlier round can reduce polarization? The answer is not simple.

Figure 4 shows the value and frequency of disagreement under **Round 2.5** in which the total cumulative number of bets on each group are shown between the second and third rounds. As Figure 4 shows, just after Round 2.5, both the value and the frequency of disagreement decrease before increasing again a few rounds later and returning to the same level as in **Baseline**. Therefore, offering information on the other members' actions sufficiently early is effective in the short run; however, there is almost no effect in the long run.

[Figure 4 Here]

Since the total cumulative number of bets is shown only in Round 2.5, the participants may have forgotten it in the later rounds. To check this possibility, we show the private draws observed by all the team members instead of others' actions in **2.5 Signal**. Figure 5 illustrates the value and frequency of disagreement in **2.5 Signal**, showing that they are both much lower than in **Baseline**. It suggests that the participants did not forget the information shown in the early round until Round 15 and that polarization disappeared when they shared private signals.

[Figure 5 Here]

One possible interpretation of these results is that our participants do not ignore others' actions, but also do not rely heavily on them. While they can make decisions based on others' actions for only a few rounds, they hesitate to rely on others' actions in many rounds. On the contrary, the participants rely on the private signals observed by others and have an incentive to make decisions based on the signals in all the remaining rounds.

### 4.2.3. Offering Information in All the Rounds

Figure 6 shows the value and frequency of disagreement in **All Rounds** in which the total cumulative number of bets on each group is informed in all the rounds. Both the value and the frequency of disagreement are much lower than in **Baseline**. Therefore, we conclude that information on others' actions must be provided repeatedly to reduce polarization. Although our participants do not rely on others' actions that much, others' actions can affect their decisions when information is provided frequently.

[Figure 6 Here]

Figure 7 compares **All Rounds** with **2.5 Signal**, showing that both have a similar frequency and value of disagreement. Thus, when others' actions are shown frequently, polarization is reduced to the same extent as in the case in which all information is publicly available.

[Figure 7 Here]

However, if a participant who cannot observe private draws (i.e. the **Uninformed** treatment) is included in **All Rounds**, polarization reoccurs and its value reaches a similar level to in **Baseline** (see Figure 8). The frequency of disagreement is between **Baseline** and **All Rounds**. Here, recall that the participants who did not observe the private draw were excluded from the data. This finding implies that if people believe that others have insufficient information, they tend to maintain their own opposing views. In other words, to increase polarization, people should be induced into believing that others lack important information.

[Figure 8 Here]

Theoretically, the existence of uninformed participants should not decrease the reliability of others' actions, as Section 3.3.2 discusses. However, many participants ignore others' actions when uninformed participants exist, perhaps because they confuse "uninformed" and "irrational." That is, they misunderstand that uninformed participants should make irrational choices and thus they may feel that others' actions are unreliable when "uninformed" participants exist. The estimation results in Table 4 are related to this issue. Even in **Baseline**, the participants who believe that an uninformed member exists are less likely to rely on others' actions, which means that they trust others little.

This implication can explain an important characteristic of political polarization. In reality, others' actions are clearly visible in some cases such as vaccination rates and face mask use in the recent COVID-19 pandemic. Such frequent observations can reduce the size and frequency of polarization if people believe that others have sufficient information. However, if people believe that others have insufficient information, they will not rely on others' actions and maintain their own opposing views. This issue is discussed more in depth in Section 5.2.

## 4.3 Welfare Improvement by Reducing Polarization

When information on others' actions is provided in all the rounds, both the size and the frequency of polarization are reduced. But can such a reduction in polarization improve welfare? Figure 9 shows the total earning points from Rounds 1 to 15, highlighting that no significant difference among the treatments exists. Therefore, we cannot conclude that a reduction in polarization by observing others' actions induces our participants to obtain higher earning points.

[Figure 9 Here]

In **All Rounds**, the participants can observe others' actions, allowing them to infer the private draw observed by others and make more accurate predictions of the urn selected. To check whether the participants' expectations were accurate, Table 5 shows the rate of incorrect bets, defined as the rate at which participants placed more bets on an incorrect group in Round 15. Betting the same points on both groups does not amount to an incorrect bet. We see that **2.5 Signal** has a lower rate than the others (not in sets 2 and 3), but no significant difference among the treatments exists. Clearly, **All Rounds** does not have a lower rate of incorrect bets.

[Table 5 Here]

One reason for the rate of incorrect bets not decreasing in **All Rounds** is that some of the participants continued to ignore others' actions. A more important reason is that all the team members converged to the unselected group in some cases. Among the 33 cases (three sets times 11 teams), all the members placed more bets on the same group (with no indifferent member) in Round 15 in **All Rounds** in six cases. In **Baseline**, on the contrary, this is only one case among the 33. Hence, polarization disappeared to a greater extent in **All Rounds** than in **Baseline**. Among the six cases in **All Rounds**, all the members placed bets on the unselected group in two cases for the following reasons:

1. The team observed a wrong public signal. They observed more black balls even though the urn selected was D, which contains more white balls.

2. The team members were affected by the bets of one member who observed a wrong private signal. The urn selected was B (Group 1), and the majority of the members more often received a correct private signal (red). However, one member who observed a green ball (a wrong private signal) bet 9 points on Group 2 from Rounds 5 to 15. As a result, Group 2 had the higher cumulative number of bets and the other members also bet more on Group 2 by observing it.

Therefore, although frequently providing information on others' actions can reduce polarization, it can also induce people to make the wrong decisions. People may obtain the wrong information accidentally (the first case above) or be affected by extremists (the second case).

# 5. Discussion

## 5.1 Interpretations of a "Team"

There are three main implications from our experiments:

1. Showing others' actions only once cannot reduce polarization.
2. Showing others' actions multiple times can reduce polarization.
3. If people believe that others may have insufficient information, polarization does not reduce—even if others' actions are revealed multiple times.

To apply these implications to real-world political issues, it is important to consider how to interpret a "team" with five members, as it was designed in our experiments. The first interpretation is that a team represents a whole society and that other members are the public. The second interpretation is that a team represents a group to which an individual belongs. In this case, the other members are their friends, coworkers, and family members. According to the first interpretation, reducing polarization in a team always means reducing polarization in the society. Therefore, polarization in a society does not occur when others' actions are frequently observed and people believe that the public has sufficient information. According to the second interpretation, reducing polarization in a team does not necessarily mean reducing polarization in a society because different groups (teams) may go in different directions. That is, one group converges to choose Group 1, while the other group converges to choose Group 2. In the real world, when a conservative group and a liberal group go in different directions, polarization increases, as people frequently observe the actions chosen by their fellow group members and tend to trust such members. Therefore, opinions tend to converge among in-group members in the same group, suggesting that informing others' actions in the same group can cause a rise in polarization in a society. Our experimental findings imply that to reduce polarization in a society, it is important to inform the actions of not only in-group members but also out-group members.

## 5.2 COVID-19 Vaccination Rate

If we interpret a "team" as a whole society, polarization should not occur when people frequently observe the actions of all its members. However, we can seldom observe the actions of *all* citizens. For example, even when others' actions are revealed by a public opinion poll, that poll is not conducted frequently and few people change their actions based on the results of a poll, as in **Round 2.5**.

One example of when the actions of all citizens are frequently announced is the COVID-19 vaccination rate. According to our implications, frequent announcements of the increasing vaccination rate should raise the incentive for more people to become vaccinated. For example, after the vaccination program started in 2021,[9] the Japanese government and media outlets announced the number of vaccinated and vaccination rate almost everyday. These aggregate data are akin to the total cumulative number of bets on each group in our experiments. According to one poll by NHK, a Japanese public broadcaster, 61% of adult respondents answered that they wanted to be vaccinated, while 28% said that they did not.[10]

Figure 10 shows the number of vaccinated in Japan. This number gradually increased and reached around 80% of the population by the end of 2021. Note that the children under the age 11 (around 10% of population) was not able to be vaccinated at that time. This suggests that around 20-30% of Japanese adult citizens changed their opinion and

[9] In Japan, COVID-19 vaccinations started in February 2021, originally only for medical staff. The program was expanded to people aged 65 and older from April and all adult citizens from June.
[10] https://www.nhk.or.jp/senkyo/shijiritsu/archive/2021_02.html.

decided to be vaccinated from February to December. While there could be many reasons for their behavioral change, one possible reason is the frequent announcement of the vaccination rate. On the contrary, around 10-20% of Japanese adult citizens decided to remain unvaccinated. Anti-vaccination citizens tend to believe that most other citizens have insufficient information. Hence, according to our experimental results, it is reasonable that they do not rely on others' actions, but rather maintain their own opposing view.

[Figure 10 here]

## 5.3 Cross-cutting Views on Social Media and Polarization

A growing proportion of people rely on social media such as Twitter and Facebook to digest political news and discuss it in their personal networks. The rise of social media has led to concerns that people are becoming more isolated from diverse perspectives through "filter bubbles" and "echo chambers." That is, social media creates communities of like-minded individuals primarily exposed to only like-minded views (e.g., Sustain, 2001; Prior, 2007; Hindman, 2008). This is related to our second interpretation of a team. If social media induces users to communicate only with like-minded groups (a team in our experiments), opinions converge among in-group members, whose actions are frequently observed by users and they may believe that in-group members have sufficient information. However, this can cause greater polarization with out-group members. Indeed, empirical studies show that persistent ideological sorting exists in online communication networks, which may exacerbate political polarization (Adamic and Glance, 2005; Conover et al., 2012; Colleoni, Rozza, and Arvidsson, 2014; Lelkes et al., 2017; Boxell, Gentzkow, and Shapiro, 2017).

One way to reduce such polarization is to induce individuals to observe the actions of not only in-group members but also out-group members. Some social media platforms facilitate exposure to messages from individuals who do not have like-minded views. Through such cross-cutting views on social media, individuals can infer information to which they would not be exposed through offline interactions. This should reduce polarization if they check social media frequently. Indeed, empirical studies show that exposure to political diversity on social media improves political moderation (e.g., Barberá, 2015; Heatherly, Lu, and Lee, 2017; Beam, Hutchens, and Hmielowski, 2018; Ngyuen and Vu, 2019; Melnikov, 2021).[11]

Since our study assumes the ideological polarization of an issue in which common interests exist, cross-cutting views on social media should moderate users' views and reduce polarization. On the contrary, if we suppose affective polarization under which people have biased information processing in a non-Bayesian manner, cross-cutting views on social media may exacerbate users' perceived social distance to the partisan outgroup, thereby raising polarization (Settle, 2018). Indeed, empirical studies of how cross-cutting views on social media affect polarization offer mixed results and some show that exposure to political diversity on social media can increase polarization (e.g., Bail et al., 2018).[12]

Our laboratory experiments confirmed the first effect of cross-cutting views on social media (i.e., a reduction in polarization) when common interests exist without cognitive effects. However, this implication may change by adding conflicts of interest or inducing participants to have cognitive effects in our setting, and this should be considered in future research.

## 6. Conclusion

This study used laboratory experiments to investigate whether revealing others' actions reduces belief polarization. We found that observing others' actions only once does not change the frequency or size of polarization in the long run, whereas polarization can reduce when people observe others' actions repeatedly. However, this does not occur when they believe that others have insufficient information.

While ideological polarization has been studied extensively in recent years, it has been difficult to tease out the contexts that political issues are embedded in and the mechanisms in which belief polarization occurs. In this study, we focused on the latter "belief polarization" by drawing seminal theoretical and experimental work in the past. We believe that the mechanisms elucidated through our novel experiments shed light on an important

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[11] Boxell, Gentzkow, and Shapiro (2017) show that even if social media increases polarization, this increase is the smallest among the youngest cohort, who should be the most active on social media.

[12] Moreover, if they do not trust others with weak ties, polarization cannot reduce that much, and the situation should be similar to the case of **Uninformed** in our experiments. However, if a sufficient number of individuals trusts others, polarization can reduce.

but neglected aspect of how polarization persists or can be reduced. Given that the contexts vary extensively across countries and over time, it is pertinent to examine the essence of belief polarization in decontextualized laboratory settings. The findings from our experiments have multiple implications to real-world examples ranging from the COVID-19 vaccination to cross-cutting views on social media as discussed in the discussion section.

These implications must be investigated in more detail in future work. One of the further inquiries can be pursued on why observing others' actions in all rounds reduces polarization. If, as it seemed, people did not rely on others' actions that heavily in our experiments, people should not be affected by others' actions—even if they are announced in all rounds. In particular, observing others' actions in later rounds should not be as reliable since members often change their actions based on others' actions in earlier rounds. Thus, it is unsuitable to infer others' private signals through their actions in later rounds. In other words, observing others' actions in Round 2.5 is more informative than doing so in later rounds. Therefore, it is puzzling that participants ignore others' actions announced only in Round 2.5, but react to others' actions announced in all rounds. Further investigations are thus needed to understand this conundrum. Second, our experiments intended to build a situation in which common interests exist through decontextualized settings. Yet, many studies show the importance of contexts for considering polarization. Introducing such context into our experiments should thus be important future research agenda. The third question is normative, and related to the second question that we set out at the beginning of this paper. While we found that reducing polarization cannot improve participants' payoffs, future investigations are needed to better understand this.

## References


Abalakina-Paap, M., W. Stephan, T. Craig, and W. Gregory, 1999, "Beliefs in conspiracies," *Political Psychology* 20(3), pp. 637–647.

Abramowitz, A., 2018, *Great Alignment: Race, Party Transformation, and the Rise of Donald Trump*, Yale University Press.

Acemoglu D., V. Chernozhukov, and M. Yildiz, 2016, "Fragility of Asymptotic Agreement under Bayesian Learning," *Theoretical Economics* 11, pp. 187-225.

Adamic, L., and N. Glance, 2005, "The political blogosphere and the 2004 US election: divided they blog," in *Proceedings of the 3rd international workshop on Link discovery*, pp. 36–43.

Anderson, L., and C. Holt, 1997, "Information Cascades in the Laboratory," *American Economic Review* 87(5), pp. 847-862.

Andreoni, J., and T. Mylovanov, 2012, "Diverging Opinions," *American Economic Journal: Microeconomics* 4(1), pp. 209-232.

Aragones E., M. Castanheira, and M. Giani, 2015, "Electoral Competition through Issue Selection," *American Journal of Political Science* 59(1), pp. 71-90.

Bail, C., L. Argyle, T. Brown, J. Bumpus, H. Chen, F. Hunzaker, J. Lee, M. Mann, F. Merhout, and A. Volfovsky, 2018, "Exposure to opposing views on social media can increase political polarization," *PNAS* 115(37), pp. 9216-9221.

Baliga, S., E. Hanany, and P. Klibanoff, 2013, "Polarization and Ambiguity," *American Economic Review* 103(7), pp. 3071-3083.

Barberá, P., 2015, "How Social Media Reduces Mass Political Polarization. Evidence from Germany, Spain, and the U.S.," mimeo.

Baysan, C., 2021, "Persistent Polarizing Effects of Persuasion; Experimental Evidence from Turkey," mimeo.

Beam, M. M. Hutchens, and J. Hmielowski, 2018, "Facebook news and (de)polarization: reinforcing spirals in the 2016 US election," *Information, Communication & Society* 21(7), pp. 940-958.

Bell, A. C. Eccleston, L. Bradberry, L. Bradberry, W. Kidd, C. Mesick, and A. Rutchick, 2022, "Ingroup Projection in American Politics: An Obstacle to Bipartisanship Show less," *Social Psychological and Personality Science* 13(5), pp. 906-915.

Benoît, J., and J. Dubra, 2018, "When do Populations Polarize? An Explanation," mimeo.

Bogart, L., and S. Bird, 2003, "Exploring the relationship of conspiracy beliefs about HIV/AIDS to sexual behaviors and attitudes among African-American adults," *Journal of the National Medical Association* 95(11), pp. 1057–1065.

Boxell, L., M. Gentzkow, and J. Shapiro, 2017, "Greater Internet use is not associated with faster growth in political polarization among US demographic groups," *PNAS* 114(40), pp. 10612-10617.

Bruder, M., P. Haffke, N. Neave, N. Nouripanah, and R. Imhoff, 2013, "Measuring individual differences in generic beliefs in conspiracy theories across cultures: Conspiracy mentality questionnaire," *Frontiers in Psychology* 4, Article 225.

Bullock, J., 2009, "Partisan Bias and the Bayesian Ideal in the Study of Public Opinion," *The Journal of Politics* 71(3), pp. 1109-1124.

Cichocka, A., M. Marchlewska, and A. Golec de Zavala, 2016, "Does self-love or self-hate predict conspiracy beliefs? Narcissism, self-esteem, and the endorsement of conspiracy theories," *Social Psychological and Personality Science* 7(2), pp. 157–166.

Colleoni, E., A. Rozza and A. Arvidsson, 2014, "Echo Chamber or Public Sphere? Predicting Political Orientation and Measuring Political Homophily in Twitter Using Big Data," *Journal of Communication* 64(2), pp. 317–332.

Conover, M., B. Gonçalves, A. Flammini. and F. Menczer, 2012, "Partisan Asymmetries in Online Political Activity," *EPJ Data Science* 1(1), pp. 1–19.

Crocker, J., R. Luhtanen, S. Broadnax, and B. Blaine, 1999, "Belief in US government conspiracies against blacks among black and white college students: Powerlessness or system blame?" *Personality and Social Psychology Bulletin* 25(8), pp. 941–953.

Dagnall, N., A. Denovan, K. Drinkwater, A. Parker, and P. Clough, 2017, "Urban legends and paranormal beliefs: The role of reality testing and Schizotypy," *Frontiers in Psychology* 8, Article 942.

Dixit A., and J. Weibull, 2007, "Political Polarization," *Proceedings of the National Academy of Science of the United States of America* 104(18), pp. 7351-7356.

Douglas, K., J. Uscinski, R. Sutton, A. Cichocka, T. Nefes, C. Ang, and F. Deravi, 2019, "Understanding Conspiracy Theories," *Advanced in Political Psychology* 40(1), p.3-35.

Drague T., and X. Fan, 2016, "An Agenda-setting Theory of Electoral Competition," *The Journal of Politics* 78(4), pp. 1170-1183.

Egorov G., 2015, "Single-issue Campaign and Multidimensional Politics," NBER working paper, No. 21265.

Finkel, E., C. Bail, M. Cikara, P. Ditto, S. Iyengar, S. Klar, L. Mason, M. McGrath, B. Nyhan, D. Rand, L. Skitka, J. Tucker, J. Van Bavel, C. Wang, and J. Druckman, 2020, "Political sectarianism in America: A poisonous cocktail of othering, aversion, and moralization poses a threat to democracy," *Science* 370(6516), pp. 533-536.

Freeman, D., and R. Bentall, 2017, "The concomitants of conspiracy concerns," *Social Psychiatry and Psychiatric Epidemiology* 52(5), pp. 595–604.

Fryer, R., P. Harms, and M. Jackson, 2019, "Updating Beliefs when Evidence is Open to Interpretation: Implications for Bias and Polarization," *Journal of European Economic Association* 17(5), pp. 1470-1501.

Galliford, N., and A. Furnham, 2017, "Individual difference factors and beliefs in medical and political conspiracy theories," *Scandinavian Journal of Psychology* 58, pp. 422–428.

Gerber, A., and D. Green, 1999, "Misperceptions about Perceptual Bias," *Annual Review of Political Science* 1999(2), pp. 189-210.

Goeree, J., T. Palfrey, B. Rogers, and R. McKelvey, 2007, "Self-Correcting Information Cascades," Review of Economic Studies 74(3), pp. 733-762.

Grossmann, M., and D. Hopkins, 2016, *Asymmetric Politics: Ideological Republicans and Group Interest Democrats*, Oxford: Oxford University Press.

Heatherly, K., Y. Lu, and J. Lee, 2017, "Filtering out the other side? Cross-cutting and like-minded discussions on social networking sites," *New Media and Society* 19(8), pp. 1271-1289.

Hindman, M., 2008, *The Myth of Digital Democracy*, Princeton: Princeton University Press.

Houston, D., and R. Fazio, 1989, "Biased Processing as a Function of Attitude Accessibility: Making Objective Judgments Subjectively," *Social Cognition* 7(1), pp51–66.

Iyengar, S., Y. Lelkes, M. Levendusky, N. Malhotra, and S. Westwood, 2019, "The Origins and Consequences of Affective Polarization in the United States," *Annual Review of Political Science* 22, pp. 129-146.

Katz, E., and J. Feldman. 1962. "The Debates in Light of Research: A Survey of Surveys," in *The Great Debates: Background Perspective Effects*, Sidney Kraus eds., pp. 173–223. Bloomington: Indiana University Press.

Kinder, D., and W. Mebane, Jr, 1983, "Politics and Economics in Everyday Life," in *The Political Process and Economic Change*, Kristen R. Monroe eds., pp. 141–80. New York: Algora Publishing.

Kondor P., 2012, "The More We Know about the Fundamental, the Less We Agree on the Price," *Review of Economic Studies* 79, pp. 1175-1207.

Krouwel, A., Y. Kutiyski, J. van Prooijen, J. Martinsson, and E. Markstedt, 2017, "Does extreme political ideology predict conspiracy beliefs, economic evaluations and political trust? Evidence from Sweden," *Journal of Social and Political Psychology* 5(2), pp. 435–462.

Lelkes, Y., G. Sood, S. Iyengar, 2017, "The Hostile Audience: The Effect of Access to Broadband Internet on Partisan Affect," *American Journal of Political Science* 61(1), pp. 5-20.

Levendusky, M., 2018, "Americans, Not Partisans: Can Priming American National Identity Reduce Affective Polarization?" *The Journal of Politics* 80(1), pp. 59-70.

Melnikov, N., 2021, "Mobile Internet and Political Polarization," mimeo.

Nguyen, A., and H. Vu, 2019, "Testing popular news disclosure on the "echo chamber" effect: Does political polarization occur among those relying on social media as their primary political polarization occur among those relying on social media as their primary politics news source?" *First Monday* 24(5).

Nöth, M., and M. Weber, 2003, "Information Aggregation with Random Ordering: Cascades and Overconfidence," *Economic Journal* 113(484), pp. 166-189.

Prior, M., 2007, *Post-broadcast Democracy: How Media Choice Increases Inequality in Political Involvement and Polarizes Election*, Cambridge: Cambridge University Press.

van Prooijen, J., K. Douglas, and C. De Inocencio, 2018, "Connecting the dots: Illusory pattern perception predicts belief in conspiracies and the supernatural," *European Journal of Social Psychology* 48, pp. 320–335.

Rabin, M., and J. Shrag, 1999, "First Impressions Matter: A Model of Confirmatory Bias," *The Quarterly Journal of Economics* 114(1), pp. 37-82.

Radnitz, S., and P. Underwood, 2017, "Is belief in conspiracy theories pathological? A survey experiment on the cognitive roots of extreme suspicion," *British Journal of Political Science* 47(1), pp. 113–129.

Schuette, R., and R. Fazio, 1995, "Attitude Accessibility and Motivation as Determinants of Biased Processing: A Test of the MODE Model," *Personality and Social Psychology Bulletin* 21(7), pp. 704–10.

Settle, J., 2018, *Frenemies: How Social Media Polarizes America*, Cambridge: Cambridge University Press.

Sigelman, L., and C. Sigelman, 1984, "Judgments of the Carter-Reagan Debate: The Eyes of the Beholders," *Public Opinion Quarterly* 48(3): pp. 624–28.

Stieger, S., N. Gumhalter, U. Tran, M. Voracek, and V. Swami, 2013, "Girl in the cellar: A repeated cross-sectional investigation of belief in conspiracy theories about the kidnapping of Natascha Kampusch," *Frontiers in Psychology* 4, Article 297.

Sunstein, C., 2001, *Republic.com*, Princeton: Princeton University Press.

Swami, V., Voracek, M., Stieger, S., Tran, U. S., and Furnham, A., 2014, "Analytic thinking reduces belief in conspiracy theories," *Cognition,* 133(3), pp. 572–585.

Wagner, M., 2021, "Affective polarization in multiparty systems," *Electoral Studies* 69: 102199.

Weizsäcker, G., 2010, “Do We Follow Others when We Should?: A Simple Test of Rational Expectations,” *American Economic Review* 100, pp. 2340-2360.

Wilson, A., 2014, “Bounded Memory and Biased in Information Processing,” *Econometrica* 82(6), pp. 2257-2294.

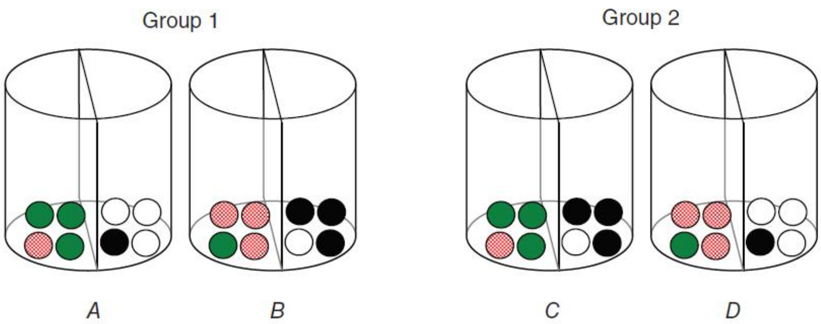
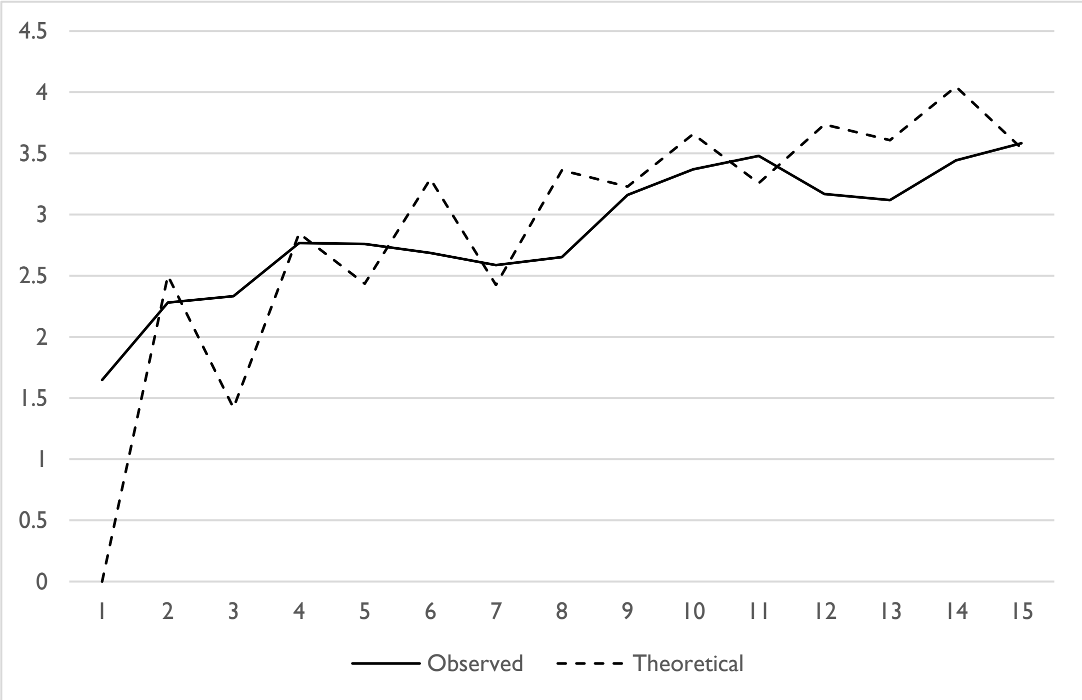
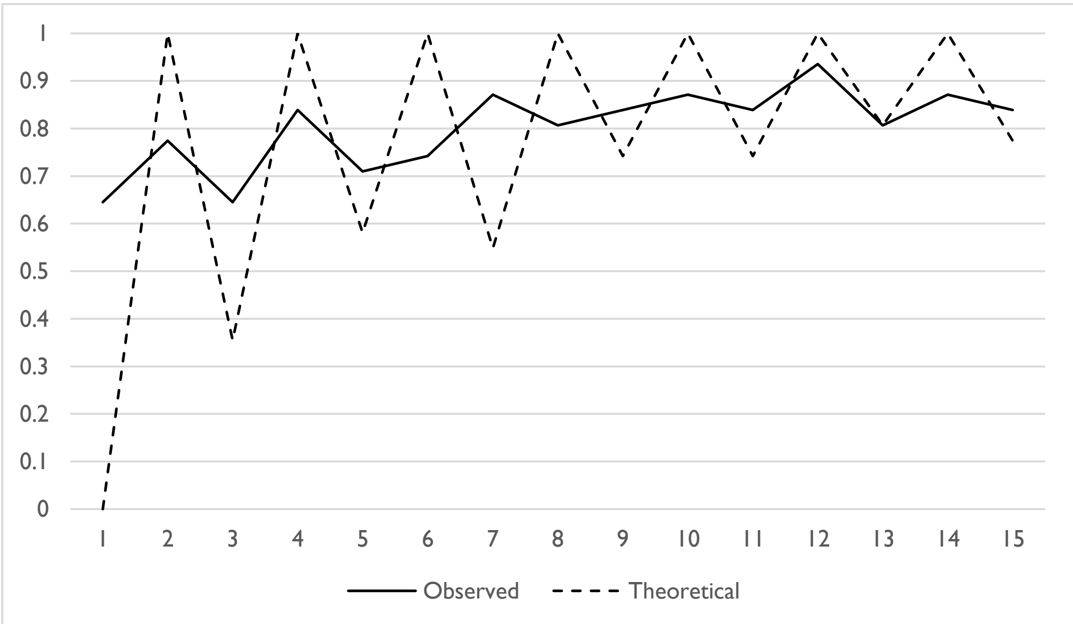



**Figure 1: Four Urns**

Source: Andoreoni and Mylovanov (2012)

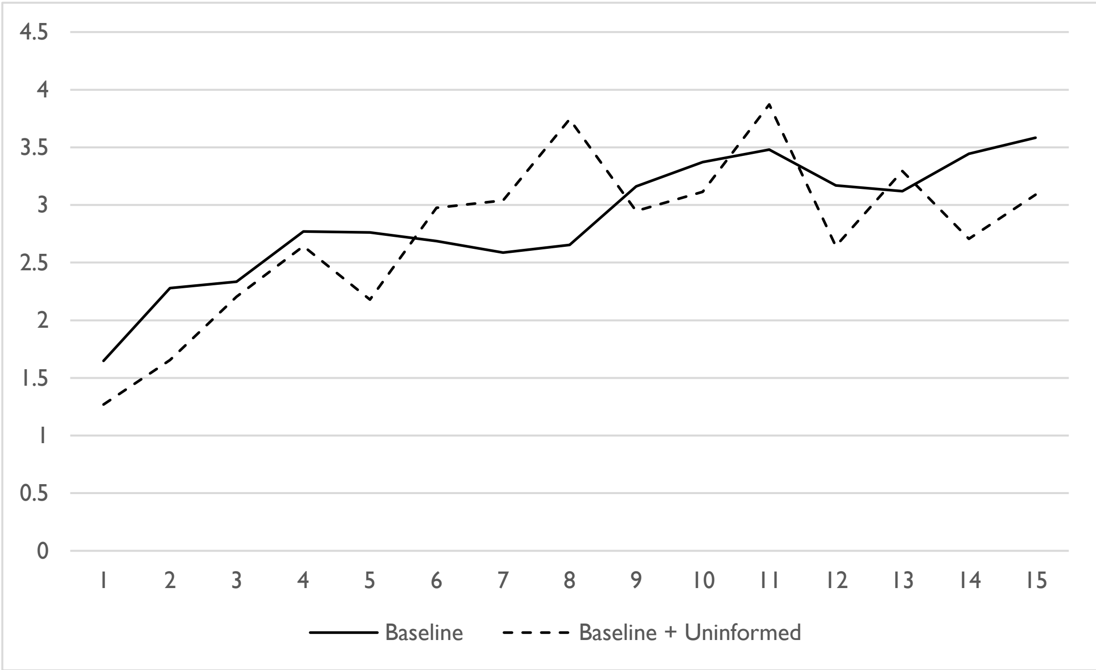



**(a) Value of Disagreement**

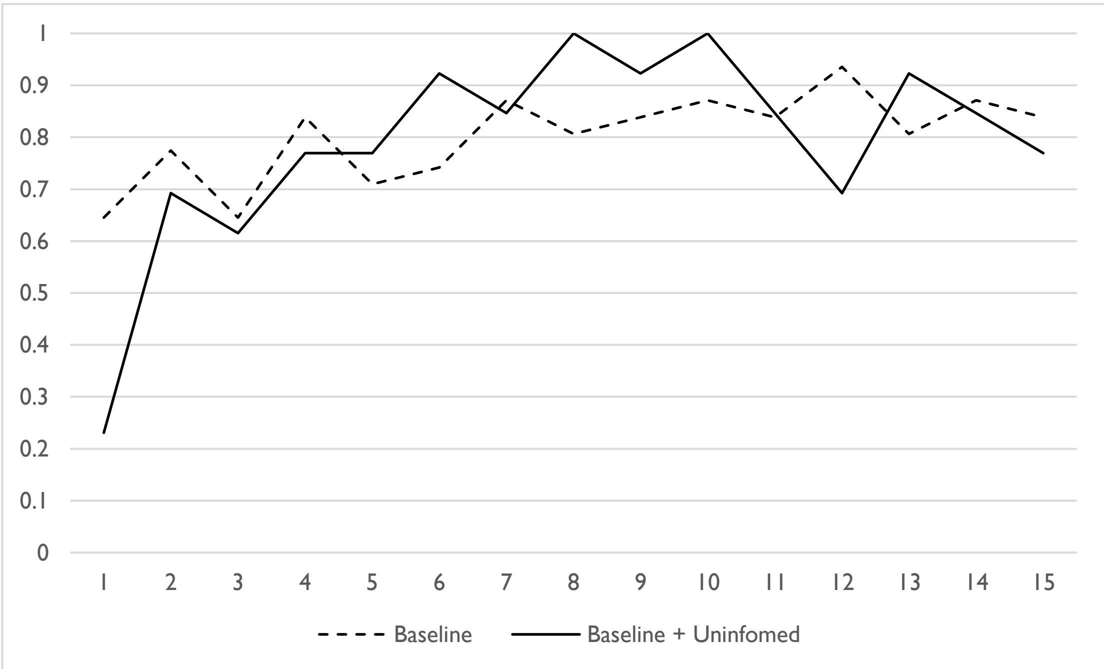



**(b) Frequency of Disagreement**

**Figure 2: Baseline**



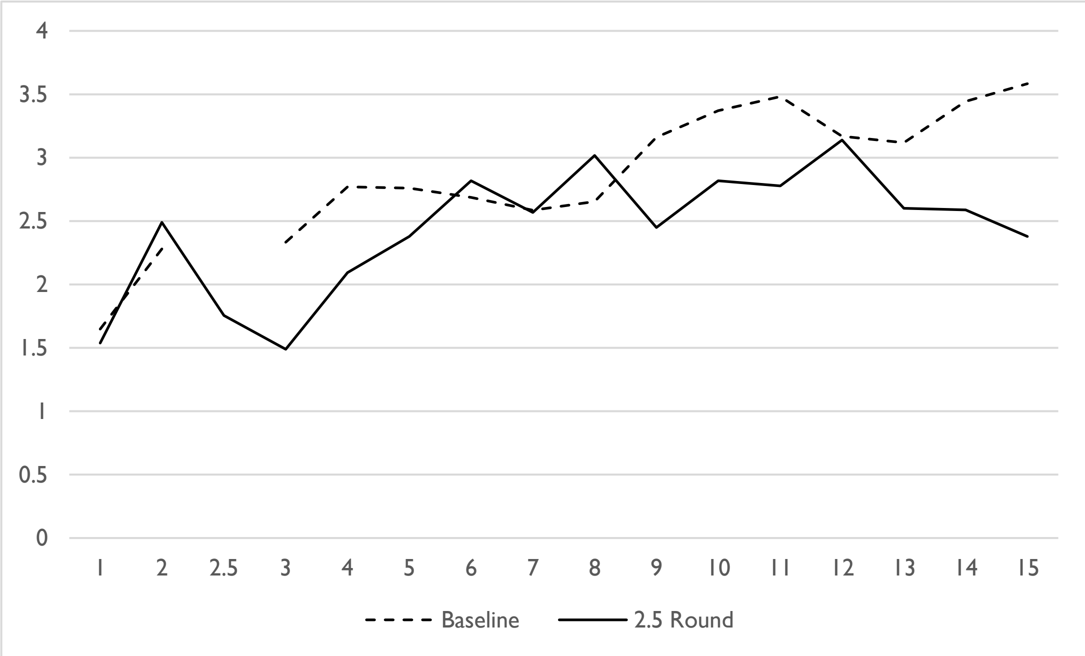

**(a) Value of Disagreement**



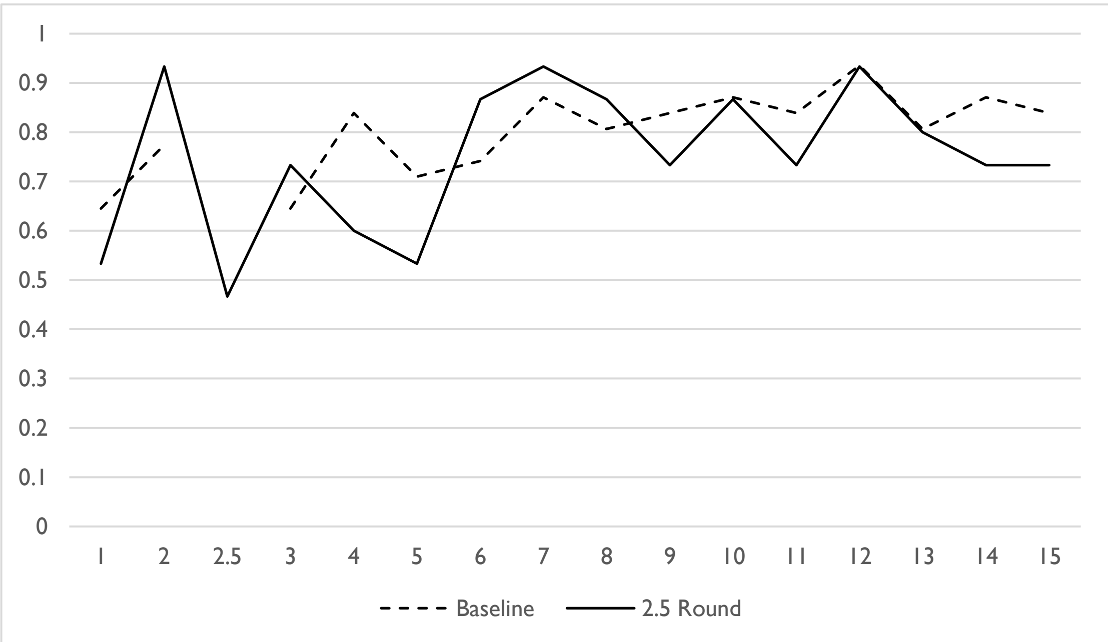

**(b) Frequency of Disagreement**

**Figure 3: Baseline and Informing Payoffs with Uninformed**

Note: Participants who did not observe the private draw were excluded.

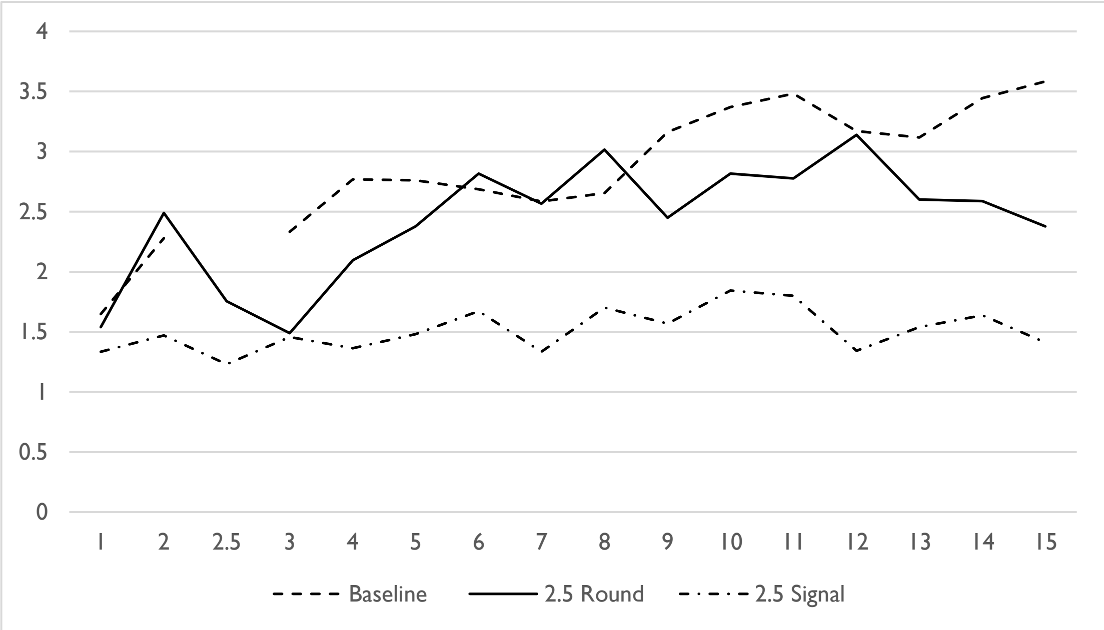



**(a) Value of Disagreement**

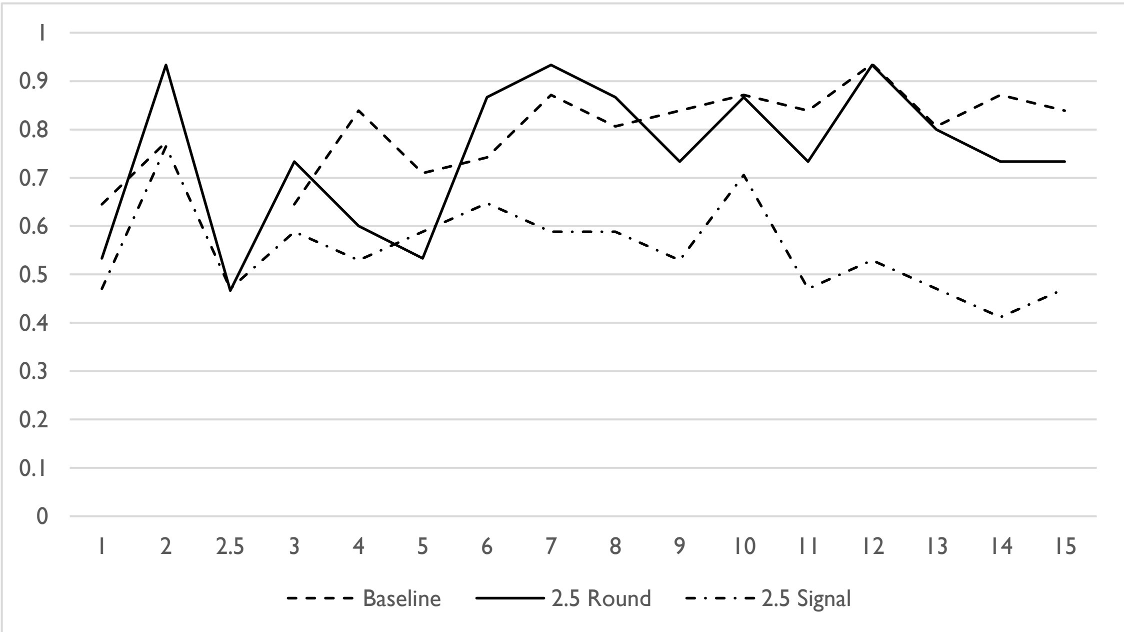



**(b) Frequency of Disagreement**

**Figure 4: 2.5 Round**

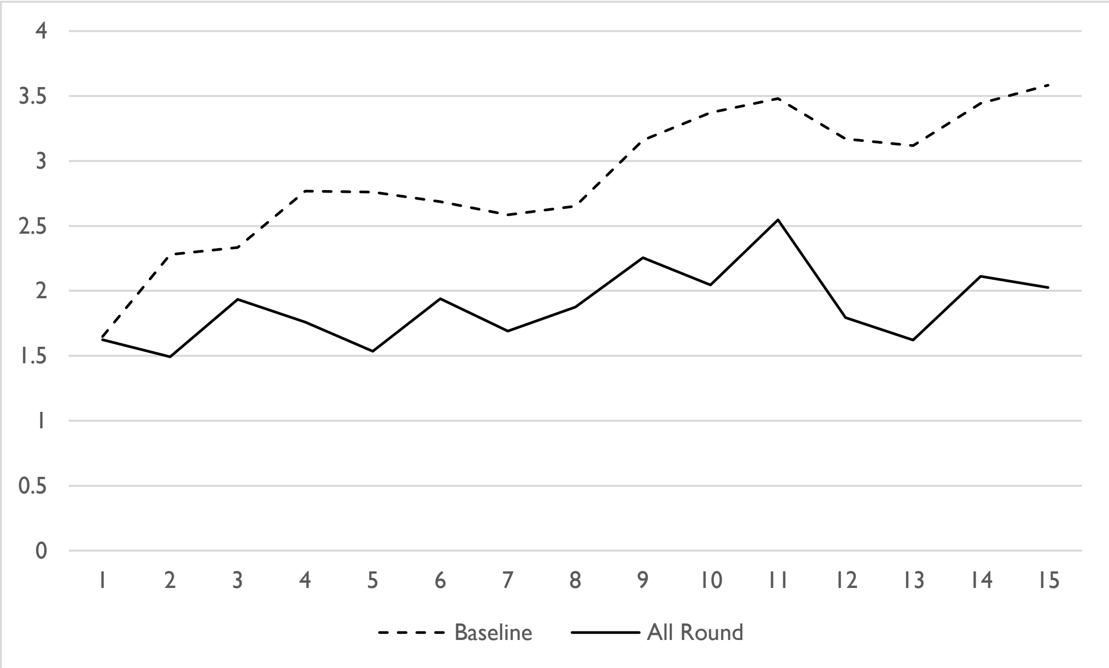



**(c) Value of Disagreement**

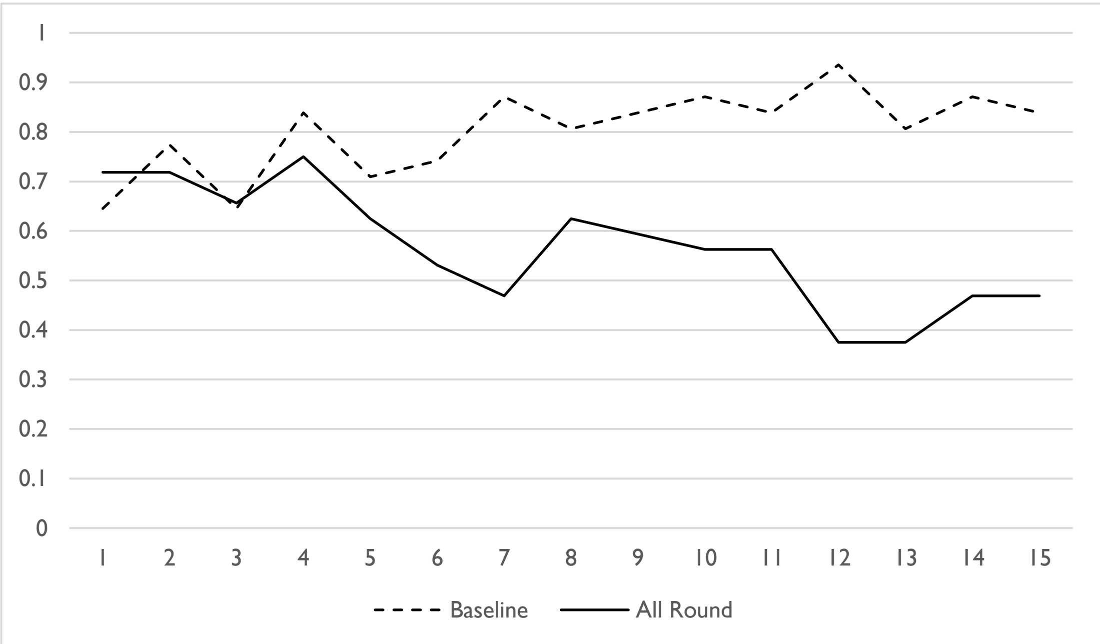



**(d) Frequency of Disagreement**

**Figure 5: 2.5 Round and 2.5 Signal**

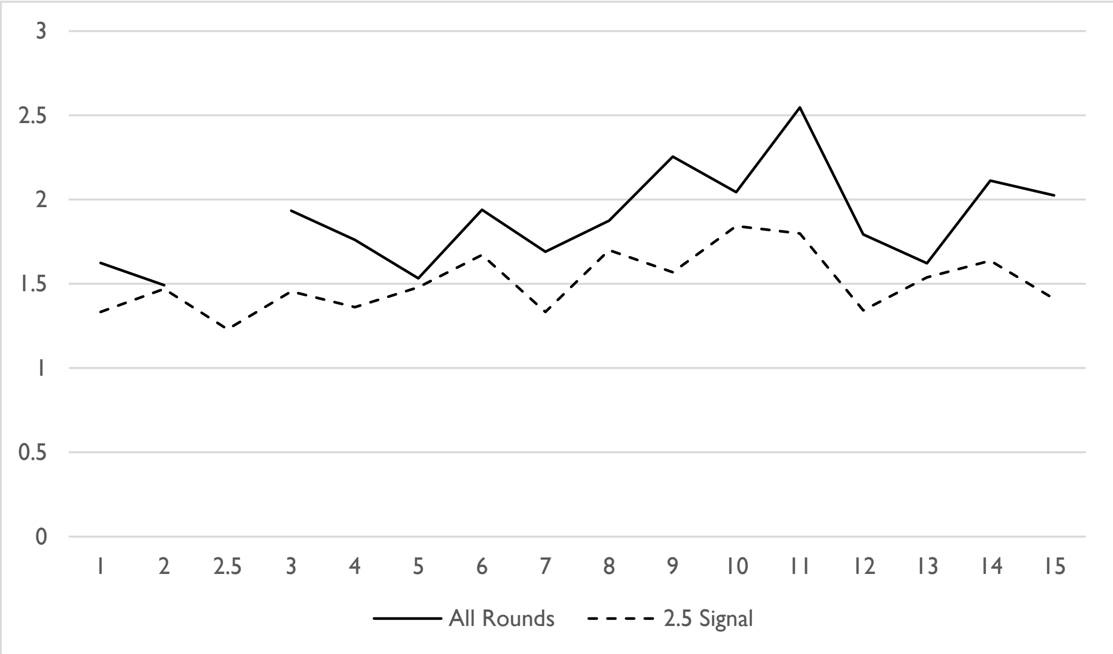



**(a) Value of Disagreement**

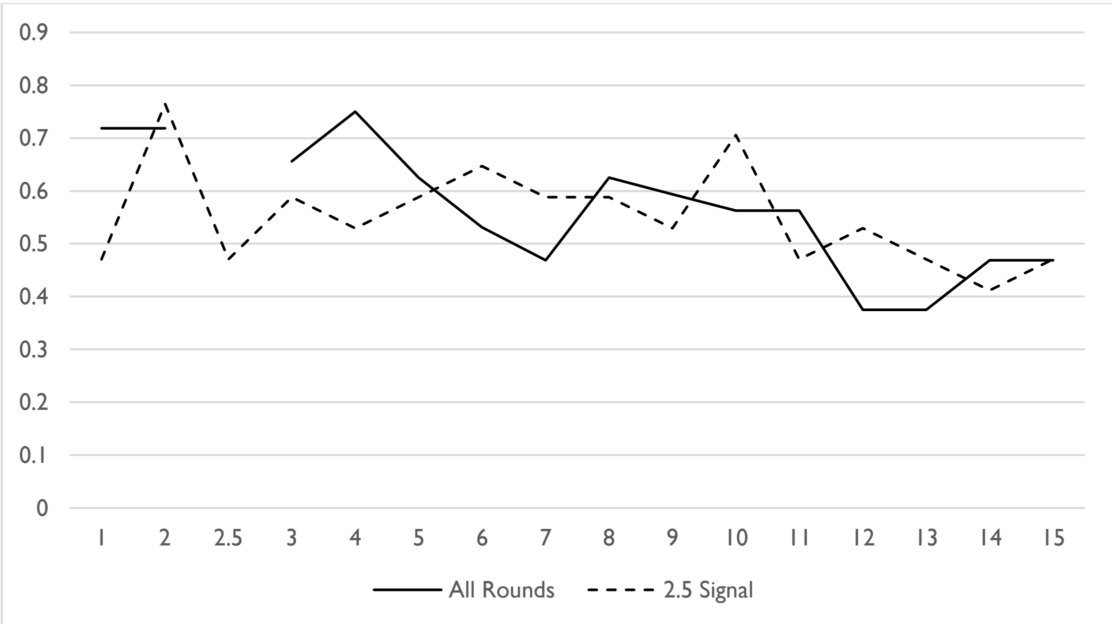



**(b) Frequency of Disagreement**

**Figure 6: All Rounds and Baseline**

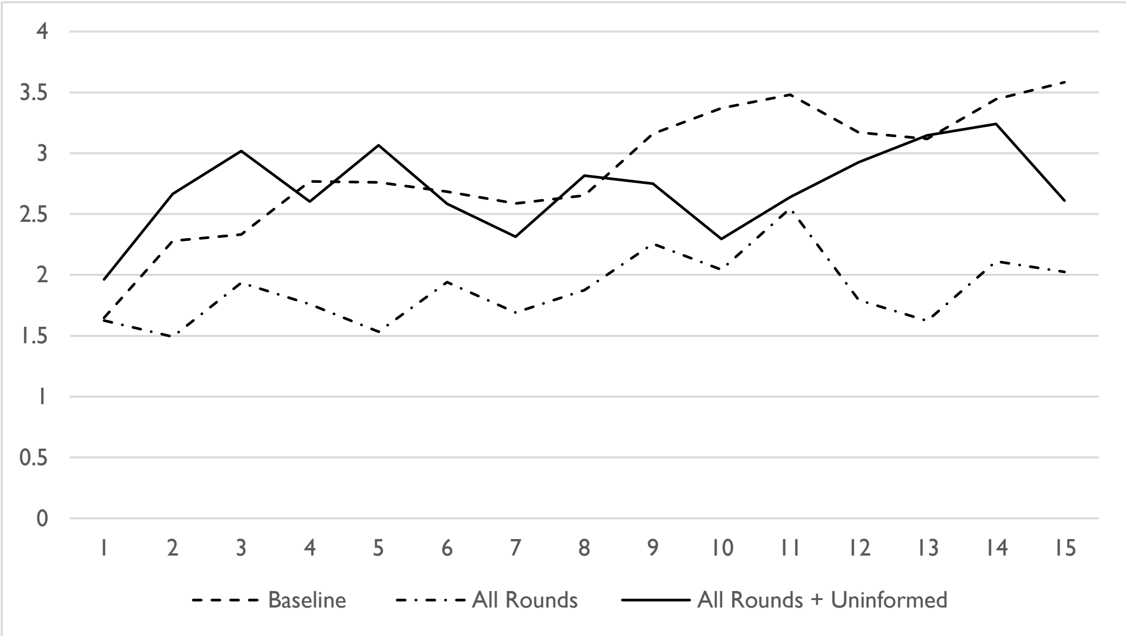



**(a) Value of Disagreement**

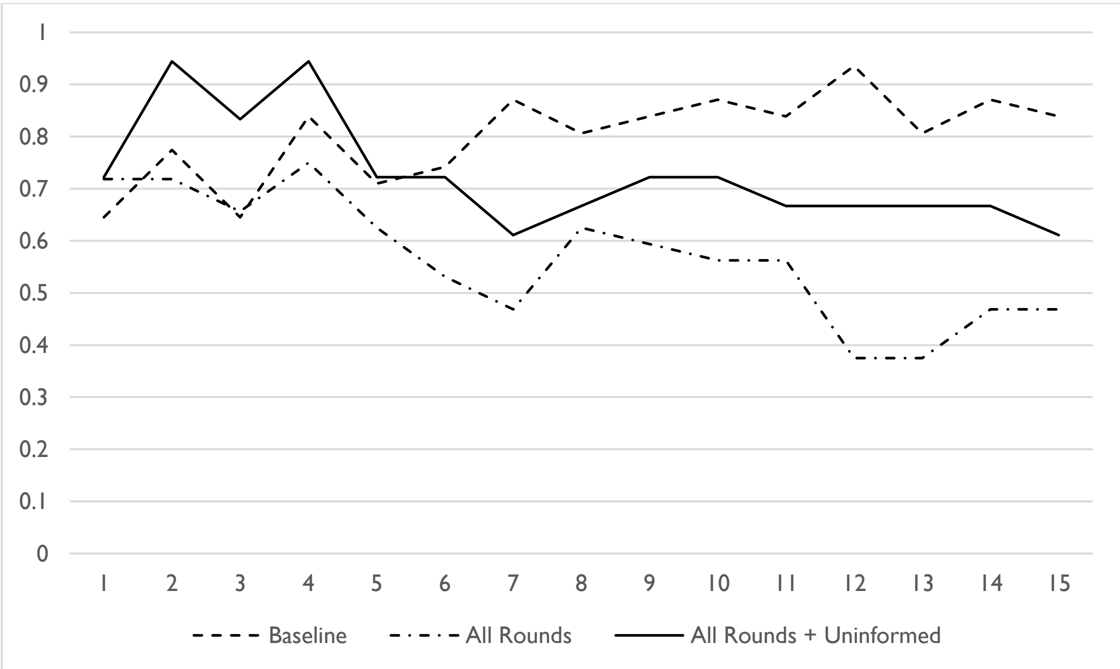



**(b) Frequency of Disagreement**

**Figure 7: All Rounds and 2.5 Signal**




**(a) Value of Disagreement**




**(b) Frequency of Disagreement**

**Figure 8: All Rounds with Uninformed**

Note: Participants who did not observe the private draw were excluded.

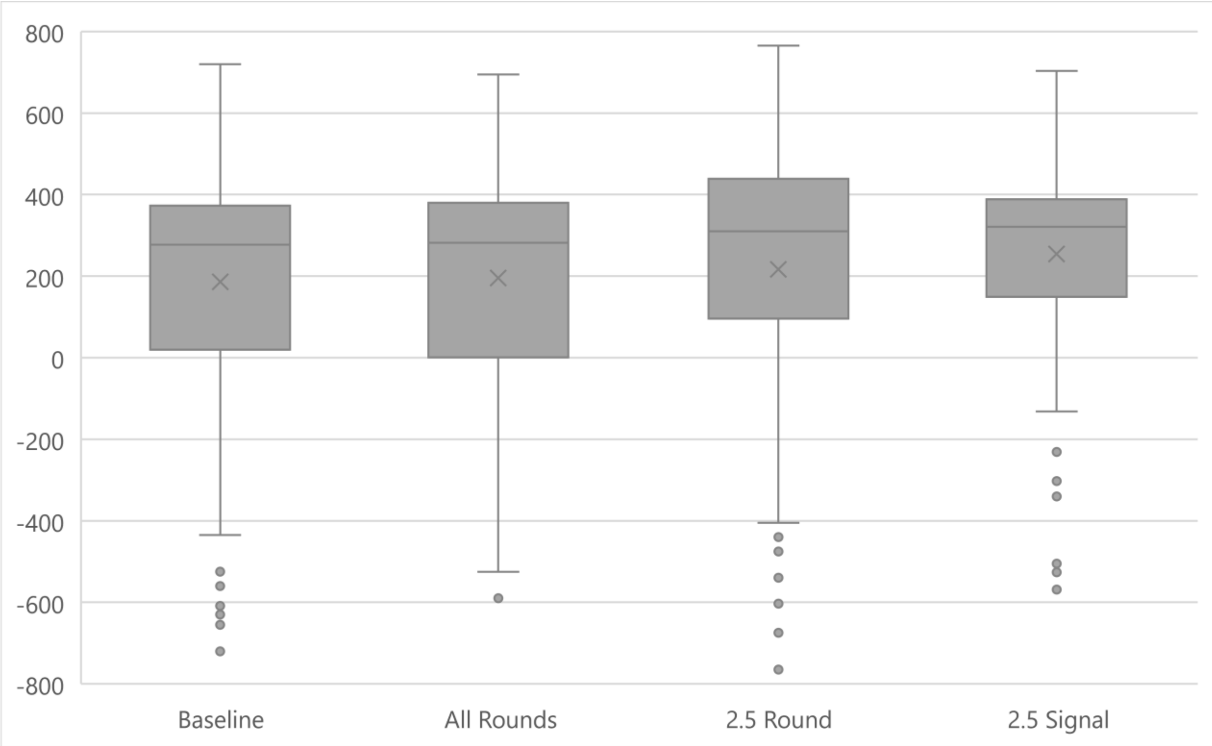



**Figure 9: Total Earning Points**

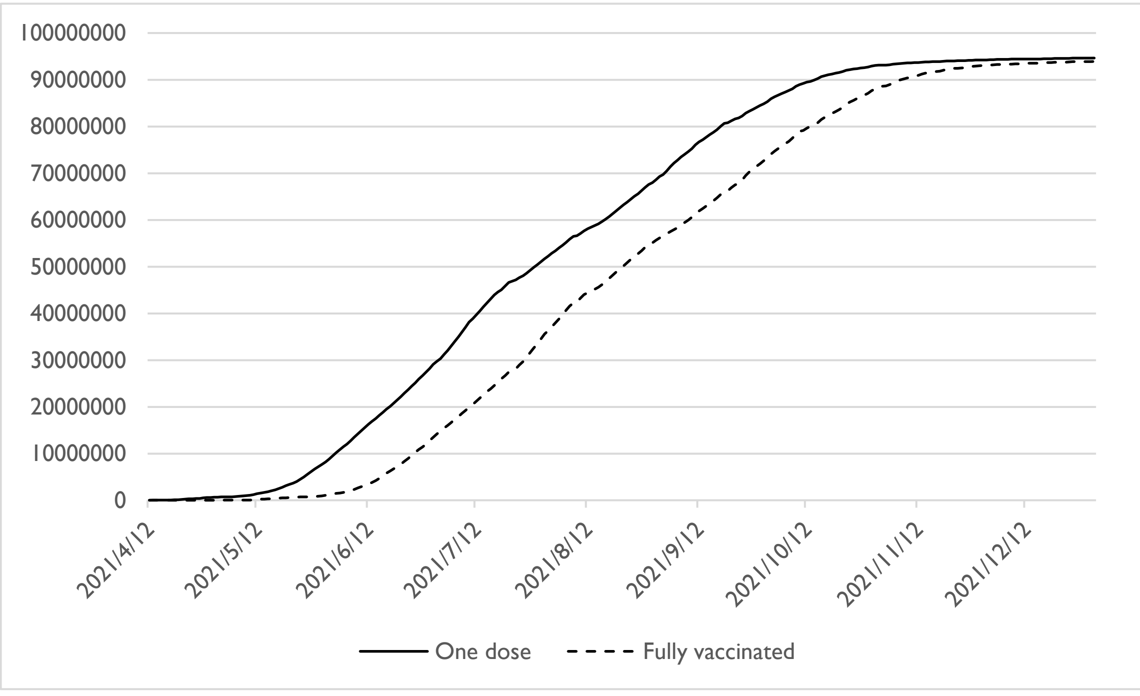



**Figure 10: Vaccinator in Japan**

Source: Vaccination Record System, The Japanese Digital Agency

(https://info.vrs.digital.go.jp/dashboard/)

**Table 1: Points to Bet and Cost Points**

| Points to Bet | Cost Points |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 3 | 6 |
| 4 | 10 |
| 5 | 15 |
| 6 | 21 |
| 7 | 28 |
| 8 | 36 |
| 9 | 45 |

**Table 2: Summary of Experimental Sessions**

| Session | Day | Participants | Baseline | 2.5 Round | All Rounds | Uninformed |
|---|---|---|---|---|---|---|
| 1 | Dec. 22 | 25 | ○ | | | |
| 2 | Jan. 7 | 25 | | ○ | | |
| 3 | Jan. 11 | 25 | ○ | | | ○ |
| 4 | Jan 14 | 25 | | | ○ | |
| 5 | Jan. 17 | 30 | | | ○ | ○ |
| 6 | Apr. 27 | 30 | | ○* | | |
| 7 | Jun. 27 | 30 | ○ | | | |
| 8 | Jul. 12 | 30 | | | ○ | |

* In session 6, the private signals observed by all team members are announced between Rounds 2 and 3.

**Table 3: Bayesian beliefs on whether the urn belongs to Group 1**

| The number of white (black) balls is more than that of the black (white) ones | Private Draw | |
|---|---|---|
| | Red (Green) | Green (Red) |
| 0 | $\frac{1}{2}$ | $\frac{1}{2}$ |
| 1 | $\frac{3}{8}$ | $\frac{5}{8}$ |
| 2 | $\frac{3}{10}$ | $\frac{7}{10}$ |
| 3 | $\frac{15}{56}$ | $\frac{41}{56}$ |
| 4 | $\frac{21}{82}$ | $\frac{61}{82}$ |
| 5 | $\frac{123}{488}$ | $\frac{365}{488}$ |
| 6 | $\frac{183}{730}$ | $\frac{547}{730}$ |
| 7 | $\frac{1095}{4376}$ | $\frac{3281}{4376}$ |
| 8 | $\frac{1641}{6562}$ | $\frac{4921}{6562}$ |
| 9 | $\frac{9843}{39368}$ | $\frac{29525}{39368}$ |
| 10 | $\frac{14763}{59050}$ | $\frac{44287}{59050}$ |
| 11 | $\frac{88575}{354296}$ | $\frac{265721}{354296}$ |
| 12 | $\frac{132861}{531442}$ | $\frac{398581}{531442}$ |
| 13 | $\frac{797163}{3188648}$ | $\frac{2391485}{3188648}$ |
| 14 | $\frac{1195743}{4782970}$ | $\frac{3587227}{4782970}$ |

**Table 4: Regressions of Round 16 Difference in Groups 1 and 2**

| Independent variable | (1) | (2) | (3) |
|---|---|---|---|
| Own differential | 0.078** | 0.077** | 0.073** |
| | (0.004) | (0.006) | (0.011) |
| Others' differential | 0.055** | 0.072** | 0.097** |
| | (0.011) | (0.014) | (0.016) |
| Uninformed session | | 0.700 | 0.664 |
| | | (0.593) | (0.592) |
| Uninformed subjects | | -1.063 | -0.955 |
| | | (1.260) | (1.248) |
| Own differential × | | 0.008 | 0.007 |
| Uninformed session | | (0.009) | (0.008) |
| Others' differential × | | -0.045* | -0.035* |
| Uninformed session | | (0.018) | (0.017) |
| Own differential × | | -0.027 | 0.005 |
| Uninformed subjects | | (0.070) | (0.063) |
| Others' differential × | | -0.011 | -0.038 |
| Uninformed subjects | | (0.036) | (0.034) |
| Incorrect | | | -0.633 |
| | | | (0.502) |
| Own differential × Incorrect | | | 0.004 |
| | | | (0.010) |
| Others' differential × Incorrect | | | -0.065** |
| | | | (0.020) |
| Constant | -0.271 | -0.457 | -0.147 |
| | (0.280) | (0.366) | (0.418) |
| Observations | 255 | 255 | 255 |
| $R^2$ | 0.539 | 0.554 | 0.576 |

Note: ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$. Robust standard errors in parentheses.

**Table 5: Rate of Incorrect Bet**

| | All Sets | Sets 2 and 3 |
|---|---|---|
| **Baseline** | 0.382 | 0.373 |
| **All Rounds** | 0.364 | 0.436 |
| **2.5 Round** | 0.36 | 0.38 |
| **2.5 Signal** | 0.311 | 0.4 |

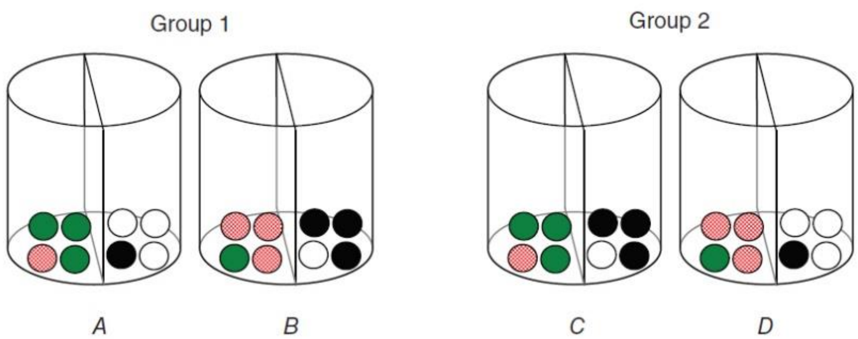
## Appendix A: Instructions

*Note: The paragraphs starting with parentheses [ ] are instructions for a specific session. [Round 2.5] and [All Rounds] refer to sessions where the total points of past bets are announced after the second round and in all rounds, respectively. [Informing Payoffs] means a session where the complete set of payoffs is shown to the participants. All other paragraphs without parentheses are common across all sessions. [Uninformed] refers to a session in which there is a participant who does not observe the first draw.*

Thank you for your participation in this study. You are taking part in an experiment on decision-making. You will not be allowed to talk with other participants or to take notes during the experiment. Please turn off your cellphones. At the end of the experiment, you will be given some money as compensation for your time.

There are 30 (25) participants in this experiment, divided into 6 (5) teams of 5 members each. There are three sets, and, decisions will be made among team members in each set. The details of the decision-making process are outlined below. The members of each team will be randomly matched at the beginning of each set; thus, the composition of the members will change in each set. You will not know who will be playing with you on the same team.

The details of the decision-making process in this experiment are as follows. In each round, a ball is drawn from one of four urns, as shown in the figure below. The urns are labeled A, B, C, and D and divided among the two groups: Group 1 has urns A and B, and Group 2 has urns C and D. Your task during the study will be to try to determine whether the urn we are using is in Group 1 (urn A or B) or Group 2 (urn C or D). To be precise, you are required to place bets on Group 1, Group 2, or on both groups. Each urn will be selected at a probability of 25%.



As you can see, the urns have red, green, white, and black balls. Moreover, the urns have two separate compartments: a red/green compartment and a white/black compartment. To be precise:

- Urns A and C have three green balls and one red ball.
- Urns B and D have one green ball and three red balls.
- Urns A and D have three white balls and one black ball.
- Urns B and C have one white ball and three black balls.

One of the urns will be randomly selected from which to draw balls. Based on these draws, you will have to guess whether the urn is in Group 1 or Group 2.

<u>How the balls will be drawn:</u>
We will make a total of 15 draws from the urn selected at the beginning of each set. Only the first drawing will be performed in front of each participant. The color of the ball drawn in front of you cannot be observed by the other members. In addition, the color of the ball drawn in front of the other members cannot be seen. Since this drawn will be privately witnessed by each participant, we will call it a "private draw." This first draw will be from the red/green compartment only.

A bet will be placed after each draw. The process will be counted until the bet consists of one round. For example, the first round will contain the first private draw and first bet.

**[Uninformed]** However, at least one member will not be able to observe the color of the first draw. You are not informed how many members will not be able to witness a private draw. Even if the first draw cannot be seen, a bet can be made in the first round.

In the following 14 rounds, all members of the team will see the color of the ball. In other words, all members of the team will see the same color. Since this draw will be publicly observed by all members, we will call it a "public draw." Public draws are made only from the white/black compartment.

<u>After each draw, we will return the ball to the urn before making the next draw.</u> Therefore, the probability of obtaining each color will be the same in all the rounds.

**[except All Rounds and Round 2.5]** After your bet on the 15th draw, we will reveal the total points of bets for each group in your team. This is the summation of all points to be bet on for each group from rounds 1 to 15. Then, you will have an additional opportunity to bet. Hence, there will be 16 rounds of bets for each set.

**[Round 2.5]** There are two timings to announce the "total point" which is the summation of all points to bet for each group by all members of your team in the previous rounds. During these two timings, you will have the chance to place a bet after the total point is announced. The first time will be round 3. After the bet of the first public draw in round 2, the total point until round 2 will be announced in the third round. This is the summation of all the points to be placed for a bet in rounds 1 and 2. The second time will be round 17. After the bet in round 16, the total point until round 16 will be announced. It is the summation of all points up until the bet from rounds 1 to 16. The following table summarizes the process.

| | |
|---|---|
| Round 1 | Private draw |
| Round 2 | Public draw |
| Round 3 | Announce the total point until round 2 |
| Rounds 4 to 16 | Public draws |
| Round 17 | Announce the total point until round 17 |

**[All Rounds]** At the end of each round, the "total point" will be announced. The "total point" is the summation of all points to bet for each group by all members of your team in the previous rounds. For example, at the end of round 3, the summation of all points to place a bet for each group by team members from rounds 1 to 3 will be announced. After the total points are announced in round 15, you will have one more chance to place a bet. Thus, there will be 16 rounds of bets for each set.

<u>How to place a bet</u>

After each draw, 0 to 9 bets can be placed for each group of urns. That is, you can bet 0 to 9 points for Group 1 and 0 to 9 points for Group 2. You can place up 18 bets. Only integers can be chosen.

Points that are betted for the correct group will be returned tenfold. Points that are betted for the incorrect group will not be returned. We will call points to be returned the "return point."

However, bets also incur costs. We will call them the "cost point" which is the summation of all integers from 0 to the points used in a bet for each group. The first bet you make for

Group 1 costs one point. If you bet one more point—that is, if you bet two points for Group 1—this will cost an additional two points, so the cost point is three points. The third bet will cost an additional three points, so the cost point in total is 1+2+3=6 points.

The cost points for each case are shown on the table. Please note that when you bet on both groups, you must add the cost points from Group 1 and Group 2. For example, if you bet nine points in both groups, your cost point would be 45+45=90, not 45.

| Points to bet | Cost point |
|---|---|
| 1 | 1 |
| 2 | 3 |
| 3 | 6 |
| 4 | 10 |
| 5 | 15 |
| 6 | 21 |
| 7 | 28 |
| 8 | 36 |
| 9 | 45 |

Your "earning points" in each round will be the return point minus the cost point. Earning points can be both positive and negative because there is a possibility that the cost point is strictly higher than the return point. The bet for each round will be independent of the other bets. You can choose any point to bet on, regardless of the points you bet on in past rounds.

We may ask you to make a decision earlier when it is too slow. Thank you for coordinating a smooth operation.

Earning money

We will select 2 of the 16 rounds (**Round 2.5**: 17 rounds) at random as "earning rounds." We will exchange 3 yen for each point of earning points that you earned in the selected earning rounds. At the same time, we will give 45 points per earning round to all participants at the end of 16 rounds (**Round 2.5**: 17 rounds). Because there are 2 earning rounds, you will obtain 90 points per set. Your final earning points are the sum of the earning points of the 2 earning rounds and 90 points. Then, we will pay you 3 yen for each point at the end of this experiment. For example, if you earned 70 earning points in 2 earning rounds, your final earning points would be 160 after adding 90 points. In this case, you would receive JPY 480.

Note: We use your points from earning rounds to determine payments. The cost and returned points in the other rounds are irrelevant to your payments. The earning round is not announced in advance.

Sets

We have described how a single set, including 16 rounds (**Round 2.5**: 17 rounds), will be run. Today, we will run three sets, where one set contains 16 rounds (**Round 2.5**: 17 rounds). In each set, we will select an urn. First, we will randomly choose one of four urns to draw from with equal probability (25%). For the next set, we will randomly choose one of four urns with equal probability (25%). The same is true for the third set. The selection of the urn in past sets will not affect the selection of the urn in future sets. The sum of payments from each set will be paid to you at the end of the experiment. We will truncate the first place of payment.

In addition, 1,000 yen will be paid as a participation fee for all participants.

Procedure

Everything we have described will be run on a computer. The ball will not be drawn. All the experiments will be performed using a computer screen. The computer will help you keep track of the colors of balls drawn in past rounds. The computer will also tell the true urn and your earning points in all rounds at the end of the set.

Practice set

Before beginning the experiment, we will go through a practice set. The practice set will have one private draw from the red/green compartment, and four public draws from the white/black compartment. This practice set will not include any earning rounds.

**[All Rounds and Round 2.5]** In the practice set, the total points will not be announced.

**[Uninformed]** In the practice set, all participants will be able to observe the color of the private draw.

This practice set will help you to understand this experiment better.

The separate sheet shows the figure for reference during the experiments. Let us begin with the practice set. If you have any questions during the experiments, please raise your hand.

## Separated sheet for others