ChamberBreaker: Mitigating Echo Chamber Effects and Supporting Information Hygiene through a Gamified Inoculation System

YOUNGSEUNG JEON, Ajou University, Republic of Korea
BOGOAN KIM, Hanyang University, Republic of Korea
AIPING XIONG, The Pennsylvania State University, United States
DONGWON LEE, The Pennsylvania State University, United States
KYUNGSIK HAN*, Hanyang University, Republic of Korea

Because of the increasingly negative impacts of the echo chamber effect, such as the dissemination of fake news and political polarization occurring in social networking services (SNSs), considerable efforts are being made to mitigate this effect. Prior HCI studies have presented the development of user interfaces to display information that reflects various standpoints, with the aim of nudging people to consume information in a more objective fashion. However, these efforts still lack the ability to highlight the characteristics, generation processes, and negative effects of echo chambers, so they may not be effective in helping people become sufficiently aware of the echo chamber effect and those who are already in an echo chamber. In this paper, we present ChamberBreaker (CB), which has been designed to help increase a player's awareness of and preemptively respond to an echo chamber effect based on psychological concepts: *inoculation*, *heuristics for judging*, and *gamification*. Through a user study with 882 participants (control group: 446, experimental group: 436), we demonstrated the feasibility of our game-based methodology to support the awareness of the echo chamber effect and the importance of maintaining diverse perspectives when consuming information. Our findings highlight the externalization of psychological standpoints in mitigating an echo chamber effect and suggest design implications for system development—the consideration of demographics, playing time, and the connection to fake news recognition—for digital literacy education. You can play CB at http://tiny.cc/chamberbreaker[1]

CCS Concepts: • **Human-centered computing**; • **Applied computing** → **Sociology**;

Additional Key Words and Phrases: echo chamber; inoculation; heuristics; gamification; user experiment

ACM Reference Format:
Youngseung Jeon, Bogoan Kim, Aiping Xiong, Dongwon Lee, and Kyungsik Han. 2021. ChamberBreaker: Mitigating Echo Chamber Effects and Supporting Information Hygiene through a Gamified Inoculation System. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW2, Article 472 (October 2021), 26 pages. https://doi.org/10.1145/3479859

*Corresponding author
[1]The game only works with Chrome.

Authors' addresses: Youngseung Jeon, jeonyoungs@ajou.ac.kr, Ajou University, Republic of Korea; Bogoan Kim, bogoankim@hanyang.ac.kr, Hanyang University, Republic of Korea; Aiping Xiong, axx29@psu.edu, The Pennsylvania State University, United States; Dongwon Lee, dongwon@psu.edu, The Pennsylvania State University, United States; Kyungsik Han, kyungsikhan@hanyang.ac.kr, Hanyang University, Republic of Korea.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
© 2021 Association for Computing Machinery.
2573-0142/2021/10-ART472 $15.00
https://doi.org/10.1145/3479859

1 INTRODUCTION

When individuals feel comfortable sharing their opinions, respecting others' views, and interacting with each other, they tend to believe they are in a "safe space" regarding information they receive [50, 73, 81]. Such beliefs and environments collectively help people cultivate an informed and tolerant citizenry [54, 56], allowing them to make better decisions when facing controversies that require difficult decision-making [37]. In particular, social networking services (SNS) present the opportunity to create a safe place because users can access diverse standpoints of others.

However, contrary to expectations, with the availability of specialized functionalities on SNS, this notion of safe spaces becomes weakened. When a recommendation/personalization service on SNS provides users with hyper-personalized information matching users' specific interests and preferences, while such a service may improve user experience, it may also limit users to only like-minded information and make them only interact with peers with similar thoughts. This phenomenon is known as *selective exposure*, which is defined as individuals' tendency to favor consonant and hence avoid dissonant information [25]. For example, Facebook users tend to consume news that promotes their favored existing perspectives [4, 65].

In addition, people often rely on incomplete judgments or a rule of thumb caused by *heuristics* rather than logical reasoning. This can cause people to unconsciously perceive a source as credible if others think the same [60] and to naturally favor the information they often hear [80, 82]. As a result, people tend to be surrounded by like-minded peers and polarize their opinions through heuristics. This is known to be one of the conditions that can generate an *echo chamber effect*, resulting in creating or sharing biased information [71]. It can further accelerate the dissemination of fake news or cause political polarization [14, 45].

With these negative impacts of echo chambers on fake news generation and dissemination, researchers have tried to understand the characteristics of echo chambers and their effects [51], identify the degree to which an echo chamber exists in a particular community [7], and find differences in the echo chamber phenomenon based on a political stance [13, 26]. In particular, HCI researchers and practitioners have focused on the development and design of social information systems for mitigating the echo chamber effect [22, 28, 47, 48, 55]. They have proposed the design of new interfaces that increase information diversity, nudging individuals to be exposed to challenging information or giving feedback on the polarization degree of the posts that they view.

However, most existing works in HCI have presented related information from different sources or through unique visualizations that are integrated with computational techniques (e.g., machine learning). Unfortunately, such an approach may not be sufficiently effective because it does not explain the characteristics, development procedures, or negative consequences of echo chambers to individuals or communities. When people face corrective evidence that rebuts their views, they tend to strengthen their initial beliefs [46]. Thus, the design of an interface to support information consumption through diverse perspectives may not be sufficient to help people become fully aware of the negative effects of an echo chamber. In addition, this approach may not be helpful for those who are already in one.

In this work, we present ChamberBreaker (CB), a game-based system designed to help increase one's awareness of and respond to the echo chamber effect. In CB, a player becomes an anonymous SNS user and is asked to continuously share biased tweets that are expected to form an echo chamber in an online community to which the player belongs. While playing the game, the player experiences different social problem scenarios caused by the echo chamber. Further, after game play, it is expected that the player can learn about the characteristics of echo chambers and negative consequences of being in one.

In principle, CB is based on three psychological concepts. First, given the practical challenges of fact-checking and the difficulty of correcting misinformation after it has already spread, proactively identifying and taking actions to curtail the spread of misinformation are critical. Thus, the notion of *inoculation* [11] was first employed in the design of CB. In the information science discipline, inoculation emphasizes that the natural antidote for misinformation is a psychological vaccine against the various types of such information because it spreads through networks much like a real virus, rapidly transmitting falsehoods from one mind to another. Second, the story of CB was designed based on the notion of *heuristics decision-making* [27], reflecting the process of creating the echo chamber phenomenon, where people in the game scenarios support the polarized opinions posted by the player. Finally, CB has *gamification* components related to task-based rewards to promote users' willingness to complete a task. CB provides score-winning, score-balancing, and badge-winning functions.

With CB, we strive to answer the following research questions (RQs):

- RQ1: How can we incorporate theoretical insights into the design of CB?
- RQ2-1: Are CB players more likely to increase information diversity during their news consumption than non-CB players?
- RQ2-2: Are CB players more likely to increase their awareness of an echo chamber effect than non-CB players?

To answer these questions, we conducted an online user study with 882 participants (experiment group: 436, control group: 446) on Amazon Mechanical Turk (MTurk) between September and December 2020. The study results demonstrated that participants' perceptions of the importance of diverse perspectives (measured by the echo chamber (EC) breaking score) and their awareness of the echo chamber phenomenon (measured by the reliability score) were significantly elevated after playing the game. Compared with the control group, the experimental group showed significant changes in the two aforementioned scores, highlighting the effectiveness of our design approach regarding CB. We also identified demographic differences such that participants over the age of 50 and those with a pro-liberal political stance exhibited significant changes in their EC breaking and reliability scores, compared to other groups.

In summary, our work makes the following contributions:

- We suggest a theory-driven methodology for system design that can help increase one's awareness of and preemptively respond to an echo chamber effect.
- We demonstrate the feasibility of our methodology based on the results of a user study.

2 RELATED WORK

2.1 Information system for mitigating the echo chamber effect

HCI communities have actively studied the development and design of social information systems for mitigating the echo chamber effect. Researchers have suggested an application that can nudge people toward more diverse perspectives [25, 48, 75]. Here, nudging refers to inducing behavioral change without infringing individuals' freedom of choice and has been considered as one of the critical design features that can expose people to challenging information without incurring a negative user experience with regard to the system or the denial of the information itself.

There are two types of digital nudging for influencing decision-making in relation to consuming information online [76]. The first type is nudging *by presentation*—presenting a user with alternative information that encourages his or her judgment by giving diverse perspectives. For example, Gao et al. [22] developed an interface to allow for the interactive visualization and categorization of original posts about a controversial topic regarding crowd workers' reactions and emotions from different standpoints. The authors evaluated the interface using Reddit posts about the US

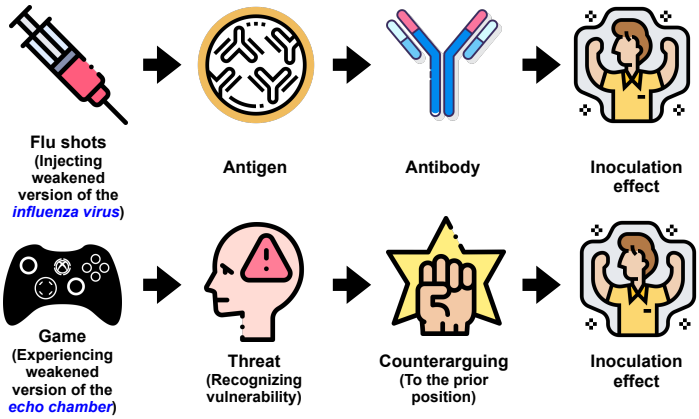


Fig. 1. Inoculation process for biology (top) and information (bottom).

presidential candidates. The results showed that the interface could mitigate selective exposure and help users adopt a broader spectrum of opinions than the traditional Reddit interface.

The other type is nudging *by information*—providing information to raise awareness, such as including a label or signal about the reputability of a source or its political bias. For example, Liao and Fu [47] proved that the source position indicators showing the valence (pro/con) and magnitude (moderate/extreme) of positions on controversial topics have an impact in terms of supporting high accuracy motivation and encouraging the search for diverse information and common ground seeking. Munson et al. [55] created a browser widget that measures and displays the bias of users based on the news articles they read, motivating users to read articles with opposing views. They conducted a field human-subject study (N = 743) to evaluate the effectiveness of such feedback in promoting users to consume more diverse political news. Compared to a control condition without feedback, participants in the feedback condition revealed more visits to ideological opposing and centrist sites. Gillani et al. [28] developed a visualization tool for Twitter networks called Social Mirror to present social media users with a bird's eye view of an ideologically fragmented social network. They found that Social Mirror helped users realize the importance of diverse information.

Prior studies mainly focused on helping participants recognize their biased statuses. Through our work, in addition to this, participants can learn about the features and negative implications of an echo chamber after playing ChamberBreaker (CB). Therefore, CB eventually helps the participants become aware of the gravity of the echo chamber effect.

2.2 Application of inoculation concepts to awareness tools

The psychological concept of inoculation [11, 52] is based on a biological metaphor. Inoculation is a promising approach to proactively mitigating the echo chamber phenomenon. According to this concept, injecting a weakened dose of a virus into the body creates an antigen. The antigen produces antibodies that create an immune response and resist future infections. If this mechanism is applied to the echo chamber, the inoculation of information can be achieved by creating mental antibodies against the echo chamber effect, as illustrated in Figure 1.

Research has found that inoculation can still be effective even when applied to those individuals who have already been exposed to bad situations, such as misinformation and fake news [39, 41]. This approach is based on the concept of "therapeutic vaccines," which are administered to those who already have the disease. Therapeutic vaccines can strengthen host defenses and still induce

antiviral immunity [3]. Similarly, those who already possess an informational bias can still benefit from inoculation treatments and become less susceptible to future biased information and the environments this information is found in. Recent advances in inoculation theory have called for both prophylactic and therapeutic tests for inoculation principles [12], which is especially relevant in the context of the echo chamber effect.

Research in social science has applied the inoculation theory to many controversial issues, such as climate change [77], medical [39], and political issues [14], demonstrating its effectiveness on one's perception of these issues in a positive way. More recently, Roosenbeek and Linden [66] developed the Bad News Game, which allows players to experience the serious and potentially harmful outcomes of fake news, helping them improve their ability to spot such information. However, to the best of our knowledge, our research is the first to identify the possibility and effectiveness of using inoculation against the echo chamber effect through the design of an awareness tool.

2.3 Occurrence of an echo chamber

The online environment allows people to communicate with others anytime, anywhere. Yet, people still tend to communicate more with those who share similar views, for example, on politics and cultures [30]. This phenomenon has intensified as the consumption of news through SNS has become more active. A filter bubble refers to a state of intellectual or ideological isolation that may result from algorithms feeding people information they agree with, here based on their past behaviors and search histories. Because many SNS platforms provide personalized recommendation services, their users are likely to receive information based on their behaviors and preferences. This could lead to people mainly consuming selective and narrow-minded information [5].

Heuristics are general decision-making strategies people use and are based on limited information; heuristics can be seen as mental shortcuts that reduce the cognitive burden associated with decision-making [69]. Although heuristics are often correct, there are many cases that lead to incomplete or wrong judgments. Researchers have warned that heuristic-based decision-making could cause people to become gradually trapped in an intellectual isolation state. The uncertainty of online information leads people to rely on a rule-of-thumb rather than logical considerations [40, 74] and to carry out irrational information processing [72]. Pennycook and Rand [61] unveiled that the reason behind people believing false information is that they inherently have cognitive laziness when identifying the factuality of the information. Similarly, Wang et al. [79] conducted a study on the clicks on shared links on SNS and confirmed that 59% of the links shared or mentioned on SNS have never been clicked on and that the majority of people consume news based on the title alone. Likewise, people tend to judge the authenticity of information based on peripheral cues (e.g., sounds, colors, speakers) rather than the logical flow of the content [59].

This indicates that heuristic decision-making could lead to motivated reasoning [44] that prioritizes an individual's thoughts and beliefs and drives him or her into an echo chamber that can accelerate the dissemination of fake news or cause political polarization [14, 45]. Such characteristics of negative aspects of heuristics could also make people susceptible to fake news. For example, malicious users or groups can exploit patterns of information consumption (e.g., relying on the title rather than the content) to disseminate fake news [34]. Fake news websites spread the news to the public by providing negative emotional cues through peripheral routes while hiding information that looks suspicious and that can be identified by the public [59].

In this paper, we investigate the process of one's falling into an echo chamber because of heuristics, develop a game scenario that reflects the characteristics of such an echo chamber, and evaluate whether the game helps users become aware of the characteristics of echo chambers and their effects.

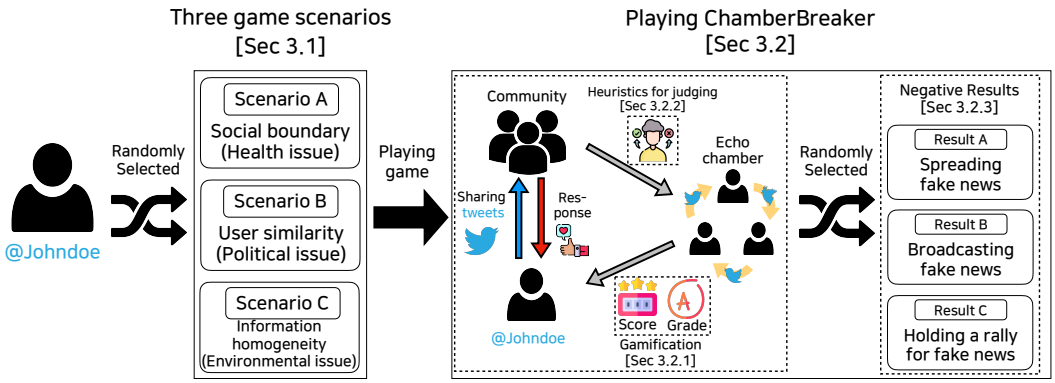
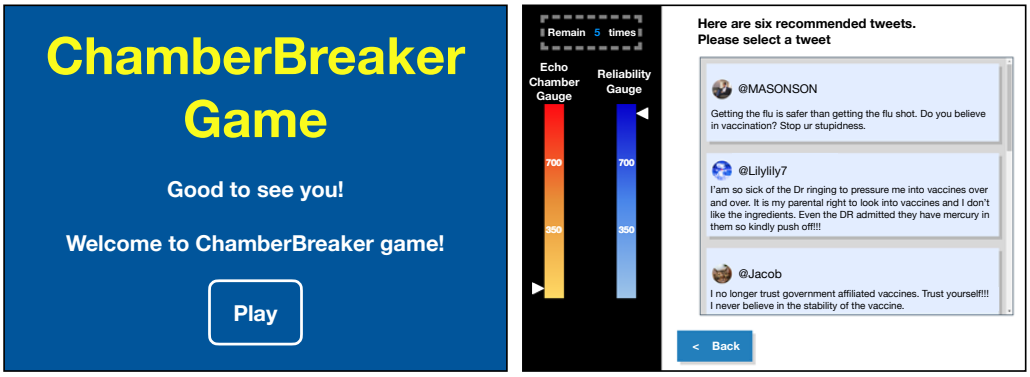


Fig. 2. The process of ChamberBreaker



(a) (b)

Fig. 3. Screenshots of CB. (a) is the onboarding page. (b) is the playing page. On the left in (b), both the echo chamber gauge and reliability gauge are shown. On the right in (b), six tweets are presented (by using the scroll bar, the player can check all six tweets). The player is asked to place the community members in the echo chamber by choosing the tweets that reflect the characteristics of this echo chamber, which will be shared with the community members. Through the echo chamber gauge, the player can check to what extent the community members falling into the echo chamber. Through the reliability gauge, the player can check how much the members trust the player. The player needs to meet the requirement for each gauge (keeping them both above the given thresholds) to successfully complete the game.

2.4 Application of gamification to awareness tools

Gamification is a strategy that can enhance intrinsic motivation by employing game-like elements, such as problem-solving, engaging storylines, and game mechanics (e.g., scores, tokens, achievement badges) [15]. Many studies have experimentally demonstrated that gamification exerts a positive influence on changes in psychological and physical behavior [31]. A gamified system can effectively promote self-awareness [53], user engagement, and feelings of excitement, fun, and desire, while inducing improvements in targeted behaviors [38].

Research has employed gamification factors as a tool to promote users' self-awareness, improve their learning environments and increase participation, or help them easily recognize overlooked problem behaviors [58]. Ibanez et al. [36] conducted a case study to investigate the effectiveness of a gamified curriculum (e.g., points, leaderboard) to increase students' participation in a class. There

has been a growing body of research on developing gamified systems designed to enlighten cybersecurity awareness and prevent future cyber attacks. For example, Canova et al. [10] presented NoPhish, a gamified mobile app that aims to enhance users' self-awareness in terms of identifying phishing links. This anti-phishing education app consists of an awareness part that teaches the user about the phishing process of spoofing messages and a gaming part that directly identifies phishing links through games, with 79% of the study participants reporting significant improvements through the app. Scholefield et al. [67] developed a role-playing quiz app for password security education. Users (golden knights) are able to score points and eventually defeat enemies (dark knights) by selecting the most commonly used password, which is susceptible to a security vulnerability. Over half of the study participants (59%) said the app's gamification elements helped acquire knowledge about password security.

In summary, gamification has been pervasively used as a system design element to enhance users' awareness in diverse domains. Hence, we applied gamification elements to the overall process of system design to expose users to the process of the formation of an echo chamber and its negative consequences for individuals and communities.

3 THE ECHO CHAMBER GAME: CHAMBERBREAKER (CB)

Figure 2 shows the process of CB, and Figure 3-a shows the onboarding page of CB. A player becomes an anonymous SNS user, @Johndoe, who is a member of an SNS community that shares ideas about various societal issues with other members. As @Johndoe, the player has the responsibility to help solidify the echo chamber phenomenon in the community. The player proceeds with three scenarios in a randomized order. Each scenario describes characteristics of the echo chamber effect (see Section 3.1). The player is first asked to choose tweets that have echo chamber characteristics, which are then shared with community members. After the player shares a tweet, he or she can see the responses from other community members. Those responses come from the community members' heuristics (see Section 3.2.2). Here, CB employs two indicators—an echo chamber gauge and a reliability gauge (Figure 3-b). The player should raise the echo chamber gauge above its threshold (700 points) while ensuring that the reliability gauge does not drop below its threshold (350 points). When these two conditions are met, the community members will fall into the echo chamber. If the player succeeds, the player will see the negative consequences of the echo chamber effect on the community (see Section 3.2.3). Then, the player will receive grades, depending on the game scores (see Section 3.2.1). We present more details of CB in the following sections.

3.1 Three game scenarios

Each of the three scenarios focuses on one specific characteristic of an echo chamber effect [51]. The first scenario deals with "social boundaries," which refers to the fact that people primarily interact with their acquaintances within small and tight networks [70]. These relatively isolated networks mean that people prefer not only polarized opinions but also extreme expressions. For example, it has been reported that a group exhibiting significant echo chamber characteristics tends to use more aggressive expressions or hate speech [1, 19, 49] or use "them" more frequently than "we" [19]. The first scenario describes anti-vaccine ideology (a health issue).

The second scenario considers the characteristic of "user similarity," which means that the people who are in an echo chamber are like-minded or share similar political views [16]. Based on the particular political stance, special phrases tend to be used more often by particular sides [26] (e.g., conservatives, liberals). The player will learn the expressions used to support a conservative or liberal political position in this scenario [13, 26]. The second scenario describes tax cuts (a political issue).

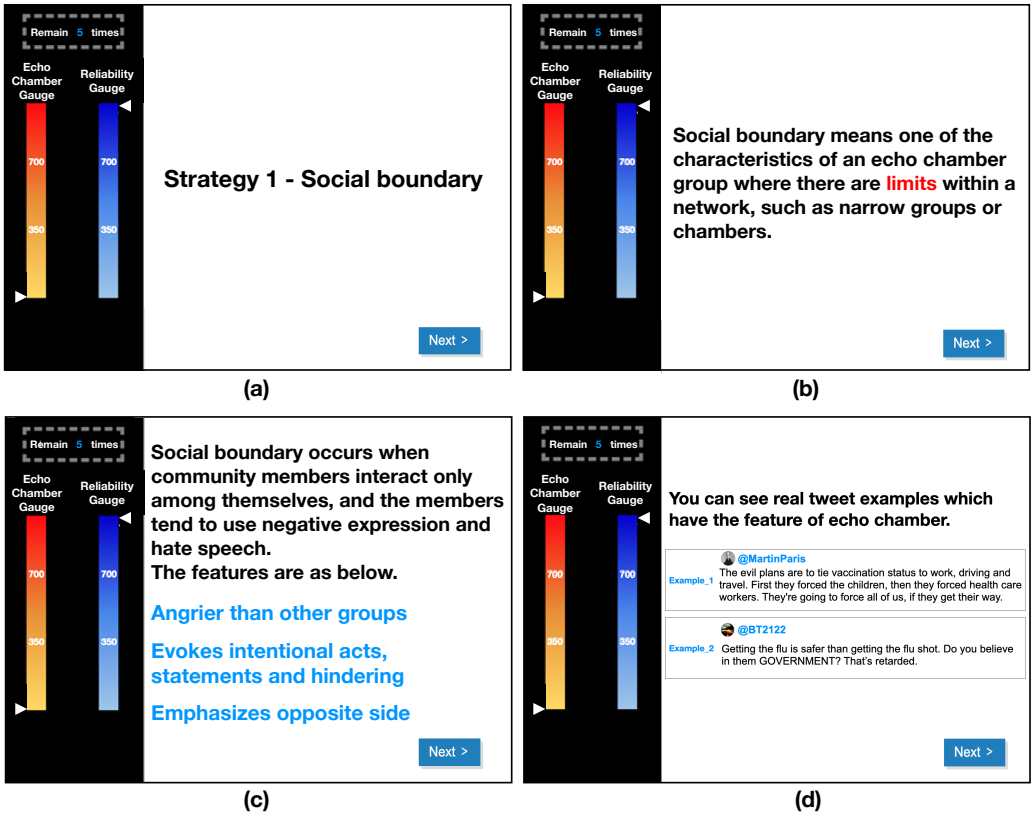


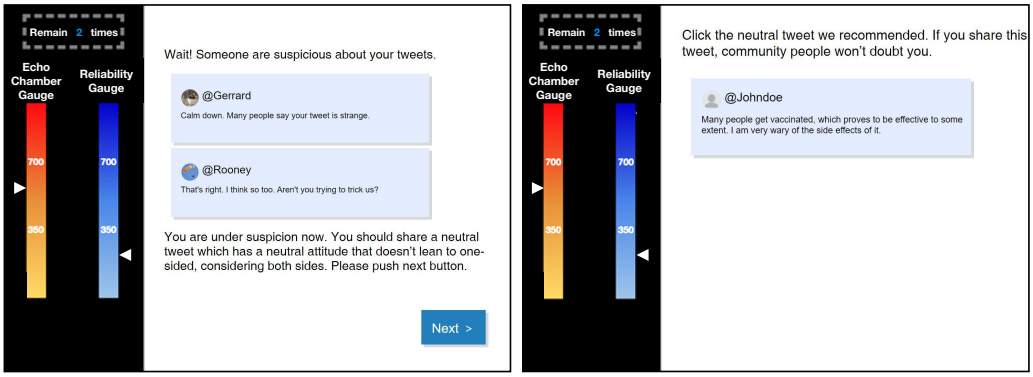
Fig. 4. The explanation and examples of the first "social boundary" scenario. Before each scenario starts, the player will see (b-c) the explanation of each characteristic of the echo chamber and (d) the related tweets.

The third scenario presents the characteristic of "information homogeneity," which describes how an individual only consumes information that conforms to his or her beliefs and previously held opinions [70] and then expresses the same points of view [23, 24]. Community members sometimes provide evidence or additional information to strengthen their opinions and make them more persuasive. The player will learn to use scientific evidence to support his or her opinion in the information homogeneity scenario. The third scenario concerns global warming (an environmental issue).

Before each scenario starts, the player will see the explanation of each characteristic of an echo chamber and the related tweets (taken and modified from real examples of tweets, ensuring privacy therein) and learn about each characteristic (Figure 4).

3.2 Playing ChamberBreaker (CB)

In each scenario, a total of six tweets are separated into two groups based on the strength of their content: (1) three "strong" tweets (strongly presenting an echo chamber phenomenon and supporting a particular side) and (2) three "weak" tweets (no echo chamber effect but supporting a particular side). We collected 1,000 tweets per scenario, posted between June 2019 and June 2020, using hashtags—#antivaccine, #taxcut, #globalwarming—that corresponded to the topic of each scenario. The criteria of the tweet strength were determined based on sentiment scores



(a) (b)

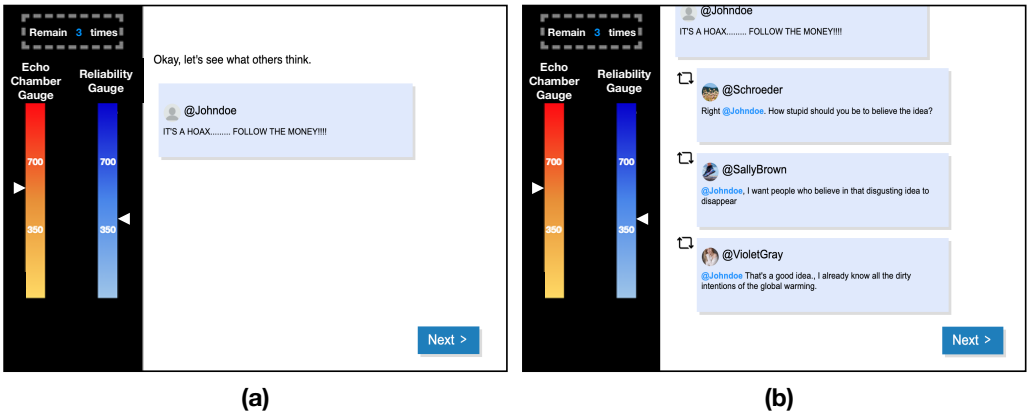
Fig. 5. The responses from the community members to the tweet about the player's suspicious activities. (a) The player can see the response where the community members doubt the identity of @Johndoe. (b) The player is offered an alternative where he or she can gain the trust of community members by sharing a tweet that has a neutral stance.

from Microsoft Azure's sentiment analysis [2]. We used this service, rather than building our own sentiment model or using open source software, because it has been used as a valid and robust tool for sentiment analysis in other related studies [32, 78]. Strong tweets had either 100% negative or 100% positive sentiment polarization scores, and weak tweets had scores between 60% and 80%. We selected 20 tweets (10 strong tweets and 10 weak tweets) per scenario. Then, two authors of this paper independently studied the tweets and chose the final three strong tweets and three weak tweets for each scenario, which were later used in CB.

3.2.1 Gamification. The scoring mechanism of CB is designed based on appointment dynamics. Here, appointment dynamics [68] refer to a game mechanic in which a player performs a task that must be done at a specific time or in a specific situation; otherwise, the player will receive a penalty. This mechanic is used in various domains, such as games and industry, to ensure participants' concentration [42, 43, 64]. We applied this mechanic to motivate participants to concentrate on playing CB. We aimed to motivate participants to complete a task in each scenario using five attempts at most.

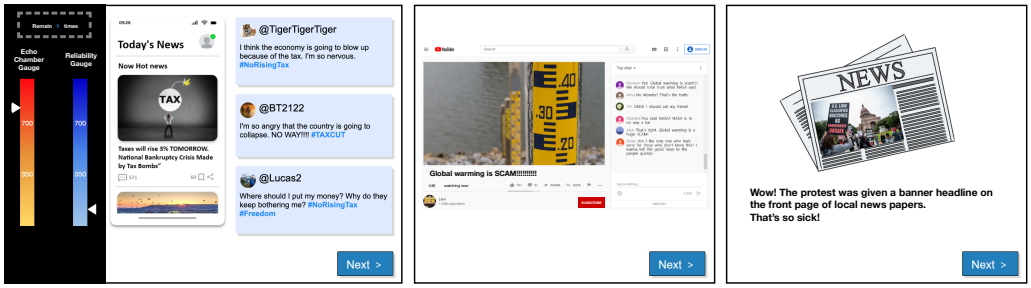
In CB, there are two score gauges—the echo chamber gauge and the reliability gauge—which are opposite concepts. The design rationale for having two scores is that increasing only the echo chamber score would be unrealistic. If someone intentionally shares particular tweets to make an echo chamber, community members are likely to think of such behaviors as suspicious. For this reason, we set up the task of requiring participants to increase the echo chamber score while keeping the reliability score above a certain threshold. This trade-off relationship means that if the echo chamber gauge increases, the reliability gauge decreases or vice-versa. The player should raise the echo chamber gauge to make other community members fall into the echo chamber while trying to reduce the community members' suspicion regarding himself or herself. If the reliability gauge falls below the threshold, the community members start to post tweets about the player's suspicious activities (Figure 5). This means that the player should maintain a balance between the two gauges. The player can increase the echo chamber gauge by strategically choosing a tweet from among six tweets (three strong tweets and three weak tweets). If the player picks a strong tweet, the echo chamber gauge will increase more than if he or she picks a weak tweet. The reliability

[2]https://azure.microsoft.com/services/cognitive-services/text-analytics/



(a) (b)

Fig. 6. The responses to a tweet from community members. (a) The player can confirm the tweet that he or she selected. (b) The player can see the responses, through which the community members strongly support the tweet the player shared.



(a) (b) (c)

Fig. 7. Three negative effects of an echo chamber. The player will see the results after completing each scenario, such as (a) spreading fake news, (b) broadcasting fake news through media outlets, and (c) holding a rally in support of fake news.

gauge will decrease regardless of whether a strong or weak tweet is chosen. Therefore, finding strong tweets first is the quickest way to complete the scenario without worrying too much about the reliability gauge. The player is given five attempts to complete each scenario. Thus, the player should complete the specific task in the given scenario while balancing the two gauges within these five attempts.

When the task in each scenario is complete, the player receives a grade (S, A, or B) based on the echo chamber gauge. If the echo chamber gauge or the reliability gauge is below its threshold, the player is asked to play the scenario again until he or she manages to keep the echo chamber gauge and the reliability gauge above 700 and 0, respectively.

3.2.2 Heuristics for judging. CB gives players the opportunity to experience the process of forming an echo chamber through members' responses based on heuristics for judging. As we explained in Section 2.3, SNS users perceive a tweet as credible if other members perceive the source as credible or if they hear the information in the tweet frequently.

In CB, the player can experience heuristics for judging (Figure 6). When the player shares a tweet, he or she can see the responses from other community members who judge and respond to the shared tweet based on heuristics. Figure 6-a shows that the player (@Johndoe) chooses and shares a tweet with the community. In Figure 6-b, a community member judges that the tweet

shared by @Johndoe is credible, and then other members trust and even support the tweet without any further verification. This is a typical example of heuristics for judging. Overall, CB is designed to have the player experience how an echo chamber is gradually formed and developed through game play.

3.2.3 Negative results. After completing each scenario, as illustrated in Figure 7, the player will observe how the propagation of fake news is accelerated by the particular echo chamber, as well as the development of the fake news and how it affects societal issues (e.g., spreading fake news, broadcasting fake news through media outlets, and holding a rally in support of fake news). In summary, through playing the game, we expect that the player will become aware of the characteristics of an echo chamber and its negative consequences, consequently helping him or her become inoculated against echo chambers.

4 AN ONLINE EXPERIMENT

Our experiment had two research purposes. The first purpose was to see whether participants would change their news consumption behaviors (RQ2-1). The second purpose was to examine whether participants' awareness of the echo chamber effect would increase after playing the game (RQ2-2).

4.1 Participants

We recruited 882 participants on Amazon Mechanical Turk (MTurk)[3]. A human intelligence task (HIT) was posted, and the following restrictions were applied to those who took part: they had to (1) be at least 18 years old; (2) have completed more than 100 HITs with a HIT approval rate of at least 95%; and (3) be located in the United States. The study was approved by the institutional review board (IRB) office at the authors' institution. Participants were presented with an informed consent page (explaining the study goal, procedure, duration, compensation, possible benefits/risks, information protection, opt-out option, and contact information) when they first accessed the website, and only the participants who agreed to the study could start the survey.

4.2 Stimuli and procedure

We conducted a between-subjects study. The participants were randomly assigned to either an experimental or control group. The participants in the experimental group were asked to complete the pre-survey, play CB for about 15 minutes, and complete the post-survey. The participants in the control group were asked to complete the pre- and post-surveys, but instead of playing CB, they were asked to read the explanation of an echo chamber and examples of the scenarios and tweets used in CB (Figure 4). In the surveys, we asked the following questions.

4.2.1 Demographic questions. In the pre-survey, we asked about social-demographic information, including gender (male, female, other), age (19-29, 30-39, 40-49, 50+), ethnicity (Caucasian, African American, Asian, Hispanic/Latino, Native American/Pacific/Islander/Native Alaskan, other), political interest (measured on a 5-point scale where 1 is "not at all" and 5 is "very interested"), political stance (measured on a 5-point scale where 1 is "very liberal" and 5 is "very conservative"), the highest level of education completed (high school or less, college, higher degree), and media usage (measured on a 5-point scale where 1 is "never" and 5 is "very often").

4.2.2 EC breaking questions. In both the pre- and post-surveys, we asked the EC breaking questions, which are used for measuring the importance of perspectives in consuming information (RQ2-1). Dubois and Blank [17] suggested the five features of an echo chamber effect that are related to information consumption behaviors, and we used the corresponding survey questions (Table 1) in

[3]https://www.mturk.com/

Question	Pre survey	Post survey
Q1	How often do you read something you **DISAGREE** with?	How often will you read something you **DISAGREE** with?
Q2	Have you ever checked a news source that is **DIFFERENT** from what you normally read?	Will you check a news source that is **DIFFERENT** from what you normally read?
Q3	Do you try to **CONFIRM** information you find by searching online for another source?	Will you try to **CONFIRM** information you find by searching online for another source?
Q4	Do you try to confirm information by checking a major **OFFLINE** news medium?	Will you try to confirm information by checking a major **OFFLINE** news medium?
Q5	Thinking about recent searches you have performed online using a search engine, how often have you discovered something that **CHANGED** your opinion on an issue?	How often will you discover something that **CHANGES** your opinion on an issue?

Table 1. The EC breaking questions [17] based on the features of an echo chamber effect (Disagree, Different, Confirm, Offline, and Changed). In the pre-survey, we asked about the participants' current behaviors. In the post-survey, we asked about their willingness to adopt behaviors that could prevent the echo chamber phenomenon.

Information Veracity	News Title	Echo Chamber Characteristics	Issue
Real 1	NYC's Hart Island and coronavirus: 'A meaningful place in a dark time'	Social boundary	Health
Real 2	California governor lays out deep budget cuts to close $54 billion deficit	User similarity	Political
Real 3	Parts of North America are in a megadrought with their driest years since the 1500s	Information homogeneity	Environmental
Fake 1	Fabric Masks Should Be Sanitized in a Microwave	Social boundary	Health
Fake 2	Kroger Tell Employees They Can Wear BLM Masks, But Not Flag Masks	User similarity	Political
Fake 3	An 'Increase' in Arctic and Greenland Ice Cast Doubt on the Reality of Global Warming	Information homogeneity	Environmental

Table 2. The six news items and corresponding tweets used to measure the reliability score. The news items cover three characteristics of an echo chamber (social boundary, user similarity, and information homogeneity) and three issues (health, politics, and environmental).

the pre- and post-surveys. We used 5-point Likert scales for all the questions (1 is "Almost never" and 5 is "Nearly always"). Here, we name the responses to these questions *EC breaking score*.

4.2.3 Reliability questions. In both the pre- and post-surveys, we asked the reliability questions, which are used for measuring the awareness of an echo chamber effect (RQ2-2). We tried to identify the difference in the reliability of the tweets with the characteristics of an echo chamber effect between the pre- and post-surveys. To collect tweets, we prepared six news items, considering their veracity (Table 2)—three real news items from the CNN site (cnn.com) and three fake news items that were debunked by a fact-checking site (snopes.com). The news topics were the same as those used in the game (themes regarding health, politics, and the environmental), and each topic contained one real news item and one fake news item. Each group of news item tweets had one of the characteristics of an echo chamber used in the game (i.e., social boundary, user similarity, or information homogeneity, as explained in Section 3.1). As in the process of collecting tweets for CB (Section 3.2), we first collected 150 real tweets per news item, filtered out 30 tweets based on their sentiment scores, and then selected the final tweets through reaching a consensus among the authors. The appendix (Section A) shows a total of 30 tweets in detail. Lastly, we studied the tweets and selected the final five tweets per news item. Before and after playing the game, the participants were asked to evaluate the perceived reliability of the tweets based on a 7-point Likert scale (1 is "very unreliable" and 7 is "very reliable"). Here, we name the responses to these questions *Reliability score*. In this work, we consider that a tweet with low reliability is a characteristic of an

Demographic group		E		C	
		N	%	N	%
Gender	Female	206	47%	182	41%
	Male	230	53%	264	59%
Education	High school or less	40	9%	33	8%
	College	227	52%	264	59%
	Higher degree	169	39%	149	33%
Ethnicity	African American	22	5%	10	2%
	Asian	177	40%	294	66%
	Caucasian	214	49%	121	27%
	Hispanic / Latino	12	3%	6	1%
	Native American/Pacific /Islander/Native Alaskan	11	3%	15	4%
Age	19-29	57	13%	136	30%
	30-39	201	46%	225	50%
	40-49	97	22%	55	13%
	50+	81	19%	30	7%
Political stance	Liberal	191	44%	182	41%
	Moderate	84	19%	125	28%
	Conservative	161	37%	139	31%

Table 3. Demographic information. *Note*: the experimental group (**E**, 436 participants), the control group (**C**, 446 participants).

echo chamber. The tweets used in the pre- and post-surveys have this echo chamber characteristic. Our expectation is that the participants will be more aware of the echo chamber phenomenon exhibited in the tweets after playing CB and therefore rate the reliability of the tweets as being lower in the post-survey.

5 RESULTS OF THE EXPERIMENT

Originally, 489 participants were assigned to the experimental group. We excluded 27 participants who failed to complete the survey responses and another 26 participants who reported significantly less playing time. Here, we considered four minutes as the minimum duration for study participation, which is approximately equal to the value of the mean minus the standard deviation (mean: 11 minutes 20 seconds; standard deviation: 6 minutes 21 seconds). As a result, a total of 436 responses were included in the data analysis for the experimental group. On the other hand, 466 participants were originally assigned to the control group. We then excluded 7 participants who failed to complete the survey responses and an additional 13 participants who had repeated their responses to all the questions. As a result, a total of 446 responses were analyzed for the control group. There is no playing time data, because the participants in the control group did not play CB. We also checked the participants' IP addresses and their worker ID to make sure that the same worker did not participate in both groups. The participants in the experimental and control groups were paid $3 in compensation.

Given that the participants were volunteers and did not represent any particular population, the general distribution of the sample was somewhat skewed toward more highly educated (52%), younger (30-39, 46%), and Caucasian (49%) individuals. Nonetheless, the sample size allowed us to collect enough responses from each category (Table 3).

The impacts of CB were examined based on the importance of diverse perspectives in consuming information (RQ2-1) and the awareness of the echo chamber (RQ2-2), which closely pertain to mitigating the echo chamber effect. As previously explained, the reliability scores in the pre- and

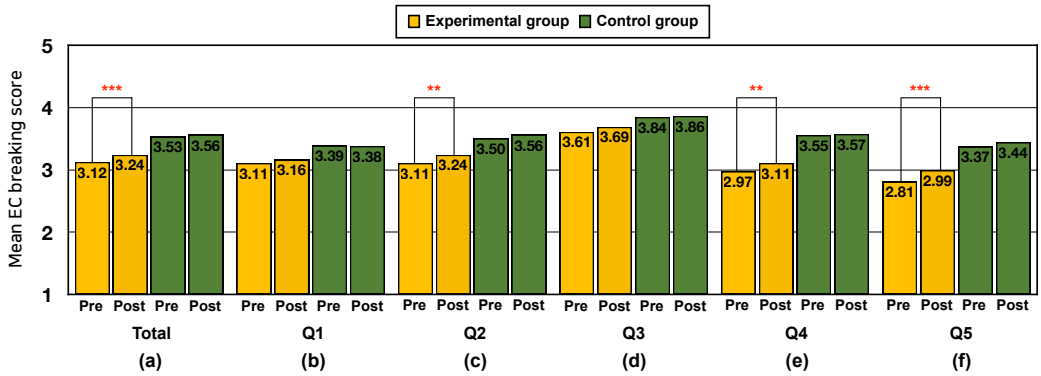


Fig. 8. Bar plots showing the differences in the EC breaking scores between the pre- and post-surveys in the experimental and the control groups (***p<.001, **p<.01, *p<.05). Only the experimental group (Q2, Q4, Q5 and Total) showed significant differences between the pre- and post-surveys. *Note*: Total (panel **a**), Q1 (panel **b**), Q2 (panel **c**), Q3 (panel **d**), Q4 (panel **e**), and Q5 (panel **f**).

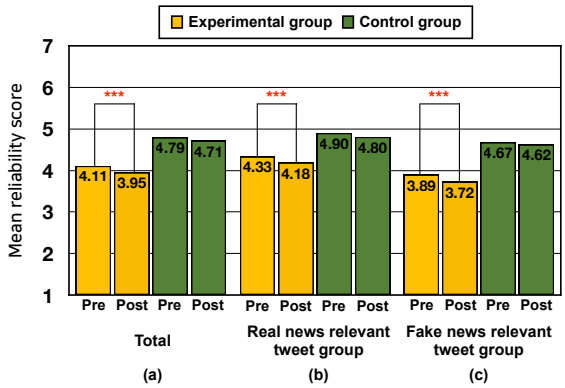


Fig. 9. Bar plots showing the differences in the reliability scores between the pre- and post-surveys in the experimental group and the control group (***p<.001, **p<.01, *p<.05). Only the experimental group showed significant differences between the pre- and post- surveys. *Note*: Total (panel **a**), Real news relevant tweet group (panel **b**), Fake news relevant tweet group (panel **c**).

post-surveys were used to measure the awareness of the echo chamber, and the EC breaking score was used to measure the importance of diverse perspectives (note that these scores are different from the gauges used in CB). To understand the main impact of CB on a participant's perception of echo chambers and the importance of diverse perspectives, we compared the effect of the treatment condition (experimental and control) on the difference in the pre-and-post reliability scores and EC breaking scores (Section 5.1). Furthermore, we did an exploratory analysis on how demographic information plays a role in terms of the scores obtained (Section 5.2) since prior research indicates that demographics, such as age or political stance, can influence people's attitudes toward news consumption [21, 57]. For the statistical analysis, we used the open source tool, jamovi [4].

5.1 Comparison between the experimental and control groups

5.1.1 EC breaking score. A 2 (experimental group vs. control group) × 2 (pre-survey vs. post-survey) mixed ANOVA was conducted to measure whether the CB effect on the importance of diverse perspectives in the experimental condition was more evident than that in the control condition. Post-hoc comparisons were also conducted with Bonferroni correction.

[4]https://www.jamovi.org/

As a result, the EC breaking scores of the pre- and post-surveys showed significantly different patterns between the experimental and control groups ($F(1,880)=8.740$, MSE=.832, $p=.003$, $\eta_p^2=.010$). Figure 8-a shows that the participants in the experimental group increased their EC breaking score after playing CB (experimental: $p<.001$), but this was not the case for those in the control group (control: $p=.189$). Moreover, the effect of CB in the experimental group was evident in Q2 ($p=.004$), Q4 ($p=.004$), and Q5 ($p<.001$), but not in Q1 ($p=1.00$) or Q3 ($p=.236$).

Q1, Q2, Q3, and Q4 are about diverse perspectives. Unlike these four questions, Q5 is related to the change in opinion (Table 1). The results indicate that CB can have an impact on the willingness to recognize the importance of diversity perspectives and to change one's opinion in general.

The significant increase in the EC breaking scores in the experimental group, compared to the control group, indicates that CB could help participants realize the importance of diverse perspectives when consuming information. We discuss this in Section 6.

5.1.2 Reliability score. We conducted a 2 (experimental vs. control) × 2 (real vs. fake) × 2 (pre-survey vs. post-survey) mixed ANOVA to measure whether the impact on the awareness of an echo chamber effect is related to the veracity of tweets (i.e., real or fake). Post-hoc comparisons were also conducted with Bonferroni correction. The result indicated that three-way interactions were not significant ($F(1, 880)=1.261$, MSE=.288, $p=.262$, $\eta_p^2=.001$).

However, we found significant differences in the reliability scores regardless of the veracity of the tweets (Figure 9-a). We observed significant differences between the pre- and post-reliability scores across the experimental and control groups ($F(1, 880)=3.91$, MSE=.783, $p=.048$, $\eta_p^2=.004$). In agreement with the EC breaking score results, only participants in the experimental group saw a reduction in their reliability scores after playing CB ($p<.001$).

In the case of the average reliability of real news-relevant tweet groups, the difference was not significant between the experimental and control groups, $F(1, 880)=.817$, MSE=.255, $p=.366$, $\eta_p^2=.001$. In the post-hoc tests of real news-relevant tweet groups (Figure 9-b), only the experimental group showed a significant difference between the pre- and post-surveys ($p<.001$). In the case of the average reliability of fake news-relevant tweet groups, the difference was significant between the experimental and control groups, $F(1, 880)=5.04$, MSE=1.599, $p=.025$, $\eta_p^2=.006$. In the post-hoc tests of fake news-relevant tweet groups (Figure 9-c), only the experimental group showed a significant difference between the pre- and post-surveys ($p<.001$). These results show the effectiveness of CB in increasing a player's awareness of the echo chamber effect, yet this occurs regardless of the veracity of the news information. Since echo chambers and fake news are closely related, we will discuss the relationship between echo chamber awareness and fake news detection, considering our findings, in Section 6.

5.2 Subgroup analysis

Prior studies [8, 21, 57] mentioned the impacts of demographic variables on changing people's attitudes toward information consumption. We analyzed the differences in the EC breaking scores and reliability scores of the experimental group between the pre- and post-surveys based on the demographic variables (age, political stance, education, and gender). The analysis was similar to the previous one except that the between-subject factor of the group was replaced by each demographic variable.

In addition, playing time is a good indicator of participants' engagement with a game [9]. In our context, playing time also indicated the completion time of several decision-making processes encountered in an echo chamber. In other words, users with longer playing times might follow the game instructions rather than using heuristics to avoid falling into an echo chamber [18]. Thus, we analyzed the differences in the playing times among the demographic variables.

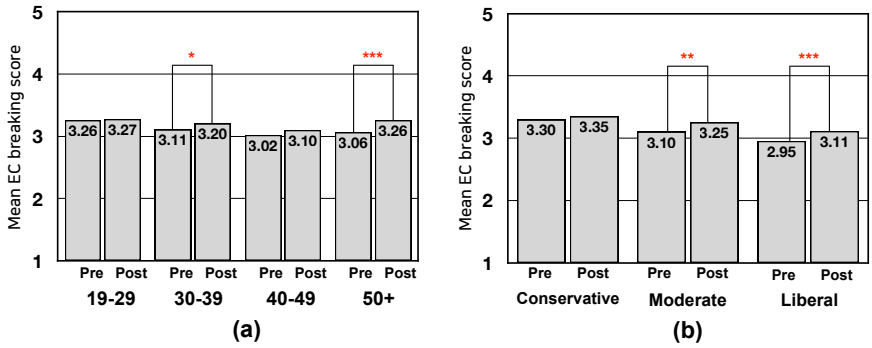


Fig. 10. Bar plots showing the differences in the EC breaking scores between the pre- and post-surveys according to age and political stance (***p<.001, **p<.01, *p<.05). In the case of age, the 30 and over 50 age groups showed significant differences. In the case of political stance, the moderate and liberal groups showed significant differences. *Note*: age group (panel **a**), political stance group (panel **b**).

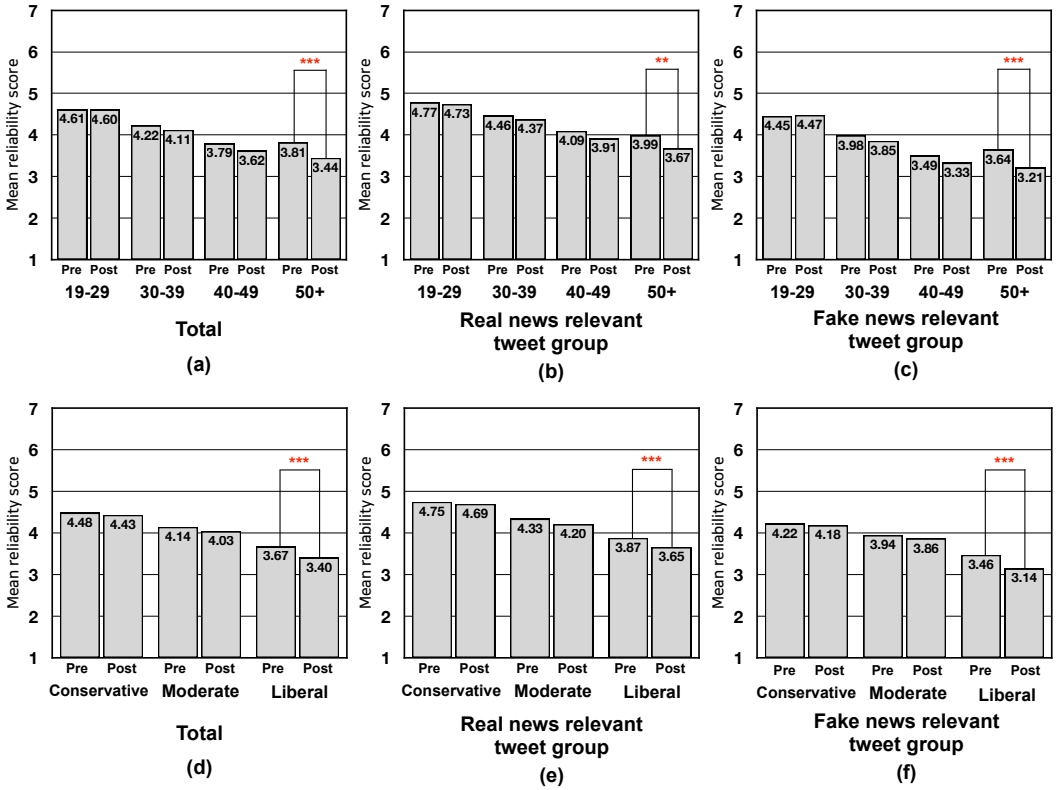


Fig. 11. Bar plots showing the differences in the reliability scores between the pre- and post-surveys according to age and political stance (***p<.001, **p<.01, *p<.05). In the case of age, the over 50 age group showed significant differences. In the case of political stance, the liberal group showed significant differences. *Note*: Age-Total (panel **a**), Age-Real news relevant tweet group (panel **b**), Age-Fake news relevant tweet group (panel **c**), Political stance-Total (panel **d**), Political stance-Real news relevant tweet group (panel **e**), Political stance-Fake news relevant tweet group (panel **f**).

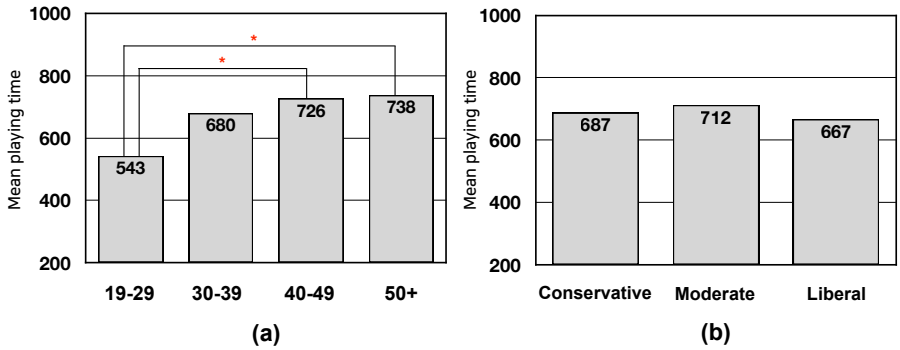


Fig. 12. Bar plots showing the differences in the mean playing times (seconds) according to age and political stance. ($^*p$<.05). Only one age group showed significant differences.

5.2.1 EC breaking score. We identified significant differences in the EC breaking scores among the age groups between the pre- and post-surveys (F(3, 432)=2.83, MSE=.22 p=0.038, η_p^2=.019). The post-hoc analysis (Figure 10-a) showed that the difference was evident for the 30 age group (p<.05) and for the over 50 age group (p<.001).

We also identified significant differences in the EC breaking scores among the political stance groups (F(2, 433)=3.28, MSE=.25 p=.039, η_p^2=.015) between the pre- and post-surveys. According to the post-hoc analysis (Figure 10-b), the liberal and the moderate groups showed significant differences between the pre- and post-surveys (liberal: p<.001; moderate: p=.010). For the education and gender variables, there were no significant differences.

5.2.2 Reliability score. We identified that the age variable had a significant impact on the reliability scores between the pre- and post-surveys (F(3, 432)=4.20, MSE=.89 p=.006, η_p^2=.028). The post-hoc comparisons (Figure 11-a) showed that the over 50 age group reported a significant difference between the pre- and post-surveys (p<.001). Moreover, the age variable did not have any significant impact on the real-news-related tweets, (F(3, 432)=1.95, MSE=.66, p=.120, η_p^2=.013), but the post-hoc analysis showed that the difference was mainly due to the lower score of the over 50 age group (see Figure 11-b). While the age variable was not shown to have any significant influence on the real news-related tweets (p=.120), the post-hoc analysis showed a significant difference in the over 50 age group (p=.012). This could have been because post-hoc tests focus on differences between groups and have more power to detect such differences, even though the overall ANOVA result indicates that the differences among the means are not statistically significant [35], and such a case is not uncommon. The effect of age was significant for the fake-news-related tweets (F(3, 432)=1.95, MSE=1.29, p=.016, η_p^2=.023). The post-hoc analysis showed that the difference was mainly due to the lower score of the over 50 age group (see Figure 11-c).

The political stance variable had a significant impact on the reliability scores between the pre- and post-surveys (F(2, 433)=5.31, MSE=1.13 p=.005, η_p^2=.024). In the post-hoc comparisons (Figure 11-d), only the liberal group showed a significant difference between the pre- and post-surveys (p<.001). We did not find a significant impact of differences in ethnicity, education, or gender on the reliability scores between the pre- and post-surveys.

5.2.3 Playing time. Across all the demographic variables, we only identified a significant difference in the playing time among the age groups (F(3, 432)=5.54, p<.001). The post-hoc comparisons (Figure 12-a) indicated that the participants in the 20 age group spent a shorter time (M_{19-29}=533, SD_{19-29}=271) on EC than the participants in the 40-49 age group (M_{40-49}=726, SD_{40-49}=403, p<.05) and those in the over 50 age group ($M_{above50}$=738, $SD_{above50}$=299, p<.05). The significantly longer

playing times for the participants in the over 50 age group could have influenced the gap between pre- and post-surveys.

6 DISCUSSION

6.1 Summary of the contributions

We have demonstrated our methodology and how it can help game players increase their awareness of and preemptively respond to the echo chamber effect (RQ1). The concept of inoculation worked in the context of an echo chamber by allowing players to experience the generation process of an echo chamber and its negative effects. We also demonstrated the feasibility of our methodology in a user study. The results indicated that by playing CB, the participants revealed their intention to observe online information from more diverse perspectives (RQ2-1) and showed an increased awareness of the echo chamber phenomenon, which is formed in tweets about news (RQ2-2).

6.2 Application of psychological concept standpoints

CB was designed to incorporate functions and contents through the externalization of psychological standpoints. We demonstrated that guiding participants to naturally experience the processes of making an echo chamber effect during game play was effective in helping the participants understand what an echo chamber is, how an echo chamber develops, and how much an echo chamber can negatively affect individuals and communities. The significant results from the user study indicate the possible applicability of our methodology to serious social problems. Oltman et al. [33] highlighted the importance of considering psychological concepts when dealing with social problems (e.g., racial discrimination and sexual harassment). They mentioned the limitations of prior intervention efforts, which reflected a poor conceptualization of the problems involved, poor training intervention designs, approaches that engender cynicism, or the misunderstood psychological principles of attitude and behavior change.

Our study showed the expansion of our method to digital literacy education, which refers to helping news consumers correctly interpret news through critical thinking and have good "information hygiene" [20]. According to the News Literacy Project, it is recommended to encourage people to take one step back before making their decisions based on the information they see online[5]. Through this recommendation, people may have an opportunity to glance through comments, do a quick search for relevant information, and ask for the original source of questionable information. In summary, the process of news literacy education needs not only an objective attitude to consuming news for delaying decision-making but also a willingness to find materials expressing from diverse perspectives for good decision-making. Although most prior studies have focused on either preventing people from having information biases or helping people consider diverse perspectives when consuming information, our approach placed greater weight on both focal points. The significant results from the user study highlight that our methodology could be an educational tool, especially for digital literacy.

6.3 Importance of playing time in developing the interface

Prior studies have indicated the importance of demographic information in terms of changing people's attitudes to consuming news [8, 21, 57]. In the case of political stance, the conservative group showed much less flexibility in changing their beliefs or thoughts than the liberal group did. When it comes to age, young people showed greater flexibility in changing their beliefs or thoughts than older people did. In our results, although the results regarding political stance were the same as those in prior work [57], those concerning age were not [21]. We interpret this result through

[5]https://newslit.org/tips-tools/information-hygiene-sanitize-before-you-share/

the lens of playing time (Section 5.2.3). The older age groups (the 40 and over 50 groups) reported significantly longer playing times than the younger age group (the 20 age group). In their echo chamber study, Eidelman et al. [18] mentioned that users with longer playing times may follow logical considerations rather than heuristics to avoid falling into an echo chamber. For a similar reason, we conjecture that the significant difference in the time spent playing CB between age groups could have influenced the effects of our game.

Younger generations are accustomed to creating, consuming, and sharing information in online environments and have a strong tendency to consume information quickly [2, 6]. Given that CB uses tweets and has a similar interface to Twitter, it is somewhat reasonable that the participants in their 20s showed a similar pattern and short playing times in terms of their use of CB, compared with those in their 40s or older. Perhaps there was not enough time for the participants in their 20s to learn about the echo chamber phenomenon through the CB game. This is certainly not the only factor, but a minimum time spent playing CB may be needed for players to figure out what CB is trying to convey. Hence, it seems that additional studies are necessary to fully understand the relationship between playing times and the learning effects of CB. Insights from this investigation may help us understand how to better utilize game-based education systems for different age groups or, more broadly, for different demographics.

6.4 Limitations and future work

Our study has several limitations. First, our study results may not be representative. The participants in our study certainly did not represent all SNS users. Imbalanced samples across age groups could cause a bias in our study results. Also, we considered only six actual tweets corresponding to each news topic. In future studies, we plan to recruit more diverse participants and include more news and tweets on different topics to increase the external validity of our findings. Second, we did not measure the long-term effect of CB. A study related to the effectiveness of a digital media literacy intervention showed that, after three weeks, the effectiveness of the intervention disappeared with regard to 50% of the participants [29]. Similarly, studies on the inoculation effect indicated that the effectiveness disappeared within a week or two [62] or lasted for up to six weeks [63]. The duration of the effectiveness varies between studies, and prior work has emphasized the necessity to consider a long-term effect. We plan to validate the sustainable effectiveness of game-based inoculation effects on an echo chamber phenomenon through varied durations (e.g., one week, two weeks, three weeks, and six weeks). Third, given the average playing time (11 minutes 20 seconds), it is reasonable to assume that most respondents did not find the game particularly difficult. Considering that the difficulty could have an impact on the results, we plan to develop a shortened version of the game and run additional user studies, including questions on the difficulty to quantitatively evaluate the perceived difficulty of CB. We have a plan to quantitatively evaluate the complexity of CB by confirming the number of attempts required to complete the task, as this can determine how many attempts would be considered a reasonable number in order for the participants to experience an echo chamber effect. Then, we will be able to adjust the complexity of CB to a reasonable level. Fourth, there are possible limitations with regard to the self-reports in the pre- and post-surveys, while prior research (Section 2.1) helped participants recognize their biased statuses using self-reports [22, 28, 47, 55]. To overcome the limitations, we should consider ways to collect information on behaviors in a quantitative fashion. For example, we could add a search feature to the game, allowing the participants to search for information (e.g., other tweets, news) related to a news item. Through this, we can measure whether participants search for information, which search keywords or terms they use, and so on. Fifth, there might be an impact of bias after understanding the context of the survey. We used six news items in the pre- and post-surveys because we wanted to have an equal ratio of real and fake news (information veracity) as well as of

the three echo chamber characteristics (Table 2). By doing this, we were able to demonstrate that the decreased reliability score occurred in the post-survey regardless of the information veracity and echo chamber characteristics. While we believe our evaluation method was valid, we also agree that there are possible pitfalls (e.g., participant bias).

As one of the directions for future work, our results could be expanded to examine the relationship between the awareness of an echo chamber effect and discrimination against fake news. Prior work indicated the importance of providing people with enough information that is both diverse and representative of opposite perspectives to help them recognize the value of information diversity [28, 71]. In our work, the development of CB and the user study results showed the possibility of increasing a player's ability to identify the echo chamber phenomenon. When measuring the reliability score, the data used in the survey include the component of information veracity (i.e., fake or real). The results in Figures 9 and 11 showed a decrease for all the cases, meaning that the participants in the control and the experimental groups perceived the echo chamber phenomenon from the list of tweets used in the survey. While it is promising to obtain significant decreases in the experimental group (Figure 9), which highlights the effectiveness of CB on increasing one's ability to identify the echo chamber effect, those decreases occurred regardless of the veracity of the information. This result can be attributed to the limited information conveyed by the news title only. Since we focused on echo chambers in this work, one of our next research objectives will be to examine the relationship between the awareness of an echo chamber and the detection of fake news. Another possible future work could involve finding ways to help people judge the veracity of information when echo chambers appear or are identified through the design of an interface, such as game visualizations.

7 CONCLUSION

In this paper, we designed and developed ChamberBreaker, a game-based system, to help increase one's awareness of and preemptively respond to an echo chamber effect. The design rationales of CB were theoretically grounded, incorporating the notions of inoculation, heuristics for judging, and gamification, and the effectiveness of CB was demonstrated by the user study results. Unlike the participants in the control group, those in the experimental group who experienced CB revealed their intention to see the online information from more diverse perspectives and increased their awareness of the echo chamber phenomenon displayed in the tweets about news articles. Our results have highlighted the applicability of our design methodology to and suggested design implications—demographics, playing time, and the connection with fake news recognition—for digital literacy education.

ACKNOWLEDGMENTS

This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government(MSIT) (No.2020-0-01373, Artificial Intelligence Graduate School Program (Hanyang University)). The works of Aiping Xiong and Dongwon Lee were in part supported by NSF awards #1742702, #1820609, #1909702, #1915801, and #2114824.

REFERENCES

[1] Moh Gandhi Amanullah and Syahrur Marta Dwisusilo. 2018. Post-Truth and Echo Chamber Phenomena of Indonesian Social Media: Analysis of Political Contestation of Jokowi and Prabowo's Supporters in Facebook. In *International Conference on Language Phenomena in Multimodal Communication (KLUA 2018)*. Atlantis Press, 96–105.

[2] Dunja Antunovic, Patrick Parsons, and Tanner R Cooke. 2018. 'Checking'and googling: Stages of news consumption among young adults. *Journalism* 19, 5 (2018), 632–648.

[3] Brigitte Autran, Guislaine Carcelain, Béhazine Combadiere, and Patrice Debre. 2004. Therapeutic vaccines for chronic infections. *Science* 305, 5681 (2004), 205–208.

[4] Eytan Bakshy, Solomon Messing, and Lada A Adamic. 2015. Exposure to ideologically diverse news and opinion on Facebook. *Science* 348, 6239 (2015), 1130–1132.

[5] Pablo Barberá, John T Jost, Jonathan Nagler, Joshua A Tucker, and Richard Bonneau. 2015. Tweeting from left to right: Is online political communication more than an echo chamber? *Psychological Science* 26, 10 (2015), 1531–1542.

[6] Pablo Boczkowski, Eugenia Mitchelstein, and Mora Matassi. 2017. Incidental news: how young people consume news on social media. In *Proceedings of the 50th Hawaii international conference on system sciences*.

[7] Francesco Bonchi, Edoardo Galimberti, Aristides Gionis, Bruno Ordozgoiti, and Giancarlo Ruffo. 2019. Discovering polarized communities in signed networks. In *Proceedings of the 28th ACM International Conference on Information and Knowledge Management*. 961–970.

[8] Levi Boxell, Matthew Gentzkow, and Jesse M Shapiro. 2017. *Is the internet causing political polarization? Evidence from demographics*. Technical Report. National Bureau of Economic Research.

[9] Elizabeth A Boyle, Thomas M Connolly, Thomas Hainey, and James M Boyle. 2012. Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior* 28, 3 (2012), 771–780.

[10] Gamze Canova, Melanie Volkamer, Clemens Bergmann, and Benjamin Reinheimer. 2015. NoPhish app evaluation: lab and retention study. In *NDSS Workshop on Usable Security*.

[11] Josh Compton. 2013. Inoculation theory. *The Sage handbook of persuasion: Developments in theory and practice* 2 (2013), 220–237.

[12] Josh Compton. 2020. Prophylactic versus therapeutic inoculation treatments for resistance to influence. *Communication Theory* 30, 3 (2020), 330–343.

[13] Michael Conover, Jacob Ratkiewicz, Matthew Francisco, Bruno Gonçalves, Filippo Menczer, and Alessandro Flammini. 2011. Political polarization on twitter. In *Proceedings of the International AAAI Conference on Web and Social Media*, Vol. 5.

[14] John Cook, Stephan Lewandowsky, and Ullrich KH Ecker. 2017. Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PloS one* 12, 5 (2017), e0175799.

[15] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. From game design elements to gamefulness: defining" gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*. 9–15.

[16] Adrián Domínguez, Joseba Saenz-de Navarrete, Luis De-Marcos, Luis Fernández-Sanz, Carmen Pagés, and José-Javier Martínez-Herráiz. 2013. Gamifying learning experiences: Practical implications and outcomes. *Computers & Education* 63 (2013), 380–392.

[17] Elizabeth Dubois and Grant Blank. 2018. The echo chamber is overstated: the moderating effect of political interest and diverse media. *Information, Communication & Society* 21, 5 (2018), 729–745.

[18] Scott Eidelman, Jennifer Pattershall, and Christian S Crandall. 2010. Longer is better. *Journal of Experimental Social Psychology* 46, 6 (2010), 993–998.

[19] Mai ElSherief, Vivek Kulkarni, Dana Nguyen, William Yang Wang, and Elizabeth Belding. 2018. Hate lingo: A target-based linguistic analysis of hate speech in social media. In *Proceedings of the International AAAI Conference on Web and Social Media*, Vol. 12.

[20] Jennifer Fleming. 2014. Media literacy, news literacy, or news appreciation? A case study of the news literacy program at Stony Brook University. *Journalism & Mass Communication Educator* 69, 2 (2014), 146–165.

[21] Andy Furlong and Fred Cartmel. 2006. *Young people and social change*. McGraw-Hill Education (UK).

[22] Mingkun Gao, Hyo Jin Do, and Wai-Tat Fu. 2017. An intelligent interface for organizing online opinions on controversial topics. In *Proceedings of the 22nd International Conference on Intelligent User Interfaces*. 119–123.

[23] Kiran Garimella, Gianmarco De Francisci Morales, Aristides Gionis, and Michael Mathioudakis. 2018. Quantifying controversy on social media. *ACM Transactions on Social Computing* 1, 1 (2018), 1–27.

[24] R Kelly Garrett. 2009. Politically motivated reinforcement seeking: Reframing the selective exposure debate. *Journal of Communication* 59, 4 (2009), 676–699.

[25] R Kelly Garrett and Paul Resnick. 2011. Resisting political fragmentation on the Internet. *Daedalus* 140, 4 (2011), 108–120.

[26] Matthew Gentzkow and Jesse M Shapiro. 2010. What drives media slant? Evidence from US daily newspapers. *Econometrica* 78, 1 (2010), 35–71.

[27] Gerd Gigerenzer and Wolfgang Gaissmaier. 2011. Heuristic decision making. *Annual Review of Psychology* 62 (2011), 451–482.

[28] Nabeel Gillani, Ann Yuan, Martin Saveski, Soroush Vosoughi, and Deb Roy. 2018. Me, my echo chamber, and I: introspection on social media polarization. In *Proceedings of the 2018 World Wide Web Conference*. 823–831.

[29] Andrew Guess, Jonathan Nagler, and Joshua Tucker. 2019. Less than you think: Prevalence and predictors of fake news dissemination on Facebook. *Science Advances* 5, 1 (2019), eaau4586.
[30] Mario Haim, Andreas Graefe, and Hans-Bernd Brosius. 2018. Burst of the filter bubble? Effects of personalization on the diversity of Google News. *Digital Journalism* 6, 3 (2018), 330–343.
[31] Juho Hamari, Jonna Koivisto, and Harri Sarsa. 2014. Does gamification work?–a literature review of empirical studies on gamification. In *2014 47th Hawaii International Conference on System Sciences*. Ieee, 3025–3034.
[32] Osama Harfoushi, Dana Hasan, and Ruba Obiedat. 2018. Sentiment analysis algorithms through azure machine learning: Analysis and comparison. *Modern Applied Science* 12, 7 (2018), 49.
[33] Theodore L Hayes, Leah E Kaylor, and Kathleen A Oltman. 2020. Coffee and controversy: How applied psychology can revitalize sexual harassment and racial discrimination training. *Industrial and Organizational Psychology* 13, 2 (2020), 117–136.
[34] Benjamin Horne and Sibel Adali. 2017. This just in: Fake news packs a lot in title, uses simpler, repetitive content in text body, more similar to satire than real news. In *Proceedings of the International AAAI Conference on Web and Social Media*, Vol. 11.
[35] Schuyler W Huck. 2008. *Statistical misconceptions*. Routledge.
[36] Maria-Blanca Ibanez, Angela Di-Serio, and Carlos Delgado-Kloos. 2014. Gamification for engaging computer science students in learning activities: A case study. *IEEE Transactions on Learning Technologies* 7, 3 (2014), 291–301.
[37] Irving L Janis and Leon Mann. 1977. *Decision making: A psychological analysis of conflict, choice, and commitment*. Free press.
[38] Daniel Johnson, Sebastian Deterding, Kerri-Ann Kuhn, Aleksandra Staneva, Stoyan Stoyanov, and Leanne Hides. 2016. Gamification for health and wellbeing: A systematic review of the literature. *Internet Interventions* 6 (2016), 89–106.
[39] Daniel Jolley and Karen M Douglas. 2017. Prevention is better than cure: Addressing anti-vaccine conspiracy theories. *Journal of Applied Social Psychology* 47, 8 (2017), 459–469.
[40] Daniel Kahneman. 2003. Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review* 93, 5 (2003), 1449–1475.
[41] L Karthik, Gaurav Kumar, Tarun Keswani, Arindam Bhattacharyya, S Sarath Chandar, and KV Bhaskara Rao. 2014. Protease inhibitors from marine actinobacteria as a potential source for antimalarial compound. *PloS one* 9, 3 (2014), e90972.
[42] B Price Kerfoot, Harley Baker, Louis Pangaro, Kathryn Agarwal, George Taffet, Alex J Mechaber, and Elizabeth G Armstrong. 2012. An online spaced-education game to teach and assess medical students: a multi-institutional prospective trial. *Academic Medicine* 87, 10 (2012), 1443–1449.
[43] Bohyun Kim. 2015. Game mechanics, dynamics, and aesthetics. *Library technology reports* 51, 2 (2015), 17–19.
[44] Ziva Kunda. 1990. The case for motivated reasoning. *Psychological Bulletin* 108, 3 (1990), 480.
[45] David MJ Lazer, Matthew A Baum, Yochai Benkler, Adam J Berinsky, Kelly M Greenhill, Filippo Menczer, Miriam J Metzger, Brendan Nyhan, Gordon Pennycook, David Rothschild, et al. 2018. The science of fake news. *Science* 359, 6380 (2018), 1094–1096.
[46] Stephan Lewandowsky, Ullrich KH Ecker, Colleen M Seifert, Norbert Schwarz, and John Cook. 2012. Misinformation and its correction: Continued influence and successful debiasing. *Psychological Science in the Public Interest* 13, 3 (2012), 106–131.
[47] Q Vera Liao and Wai-Tat Fu. 2014. Can you hear me now? Mitigating the echo chamber effect by source position indicators. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*. 184–196.
[48] Q Vera Liao, Wai-Tat Fu, and Sri Shilpa Mamidi. 2015. It is all about perspective: An exploration of mitigating selective exposure with aspect indicators. In *Proceedings of the 33rd Annual ACM Conference on Human factors in computing systems*. 1439–1448.
[49] Lucas Lima, Julio CS Reis, Philipe Melo, Fabricio Murai, Leandro Araujo, Pantelis Vikatos, and Fabricio Benevenuto. 2018. Inside the right-leaning echo chambers: Characterizing gab, an unmoderated social system. In *2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)*. IEEE, 515–522.
[50] Leanna Lucero. 2017. Safe spaces in online places: Social media and LGBTQ youth. *Multicultural Education Review* 9, 2 (2017), 117–128.
[51] Moritz Markgraf and Manfred Schoch. 2019. Quantification of echo chambers: a methodological framework considering multi-party systems. (2019).
[52] William J McGuire and Demetrios Papageorgis. 1961. The relative efficacy of various types of prior belief-defense in producing immunity against persuasion. *The Journal of Abnormal and Social Psychology* 62, 2 (1961), 327.
[53] Elisa D Mekler, Florian Brühlmann, Alexandre N Tuch, and Klaus Opwis. 2017. Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior* 71 (2017), 525–534.

[54] Tali Mendelberg. 2002. The deliberative citizen: Theory and evidence. *Political Decision Making, Deliberation and Participation* 6, 1 (2002), 151–193.

[55] Sean Munson, Stephanie Lee, and Paul Resnick. 2013. Encouraging reading of diverse political viewpoints with a browser widget. In *Proceedings of The International AAAI Conference on Web and Social Media*, Vol. 7.

[56] Diana C Mutz. 2002. Cross-cutting social networks: Testing democratic theory in practice. *American Political Science Review* (2002), 111–126.

[57] Jaime L Napier and John T Jost. 2008. Why are conservatives happier than liberals? *Psychological Science* 19, 6 (2008), 565–572.

[58] Siobhan O'Donovan, James Gain, and Patrick Marais. 2013. A case study in the gamification of a university-level games development course. In *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference*. 242–251.

[59] Babajide Osatuyi and Jerald Hughes. 2018. A tale of two internet news platforms-real vs. fake: An elaboration likelihood model perspective. In *Proceedings of the 51st Hawaii International Conference on System Sciences*.

[60] Christopher Paul and Miriam Matthews. 2016. The Russian "firehose of falsehood" propaganda model. *Rand Corporation* (2016), 2–7.

[61] Gordon Pennycook and David G Rand. 2019. Lazy, not biased: Susceptibility to partisan fake news is better explained by lack of reasoning than by motivated reasoning. *Cognition* 188 (2019), 39–50.

[62] Michael Pfau, Joshua Compton, Kimberly A Parker, Chasu An, Elaine M Wittenberg, Monica Ferguson, Heather Horton, and Yuri Malyshev. 2006. The conundrum of the timing of counterarguing effects in resistance: Strategies to boost the persistence of counterarguing output. *Communication Quarterly* 54, 2 (2006), 143–156.

[63] Michael Pfau, Joshua Compton, Kimberly A Parker, Elaine M Wittenberg, Chasu An, Monica Ferguson, Heather Horton, and Yuri Malyshev. 2004. The traditional explanation for resistance versus attitude accessibility: Do they trigger distinct or overlapping processes of resistance? *Human Communication Research* 30, 3 (2004), 329–360.

[64] Seth Priebatsch. 2010. Welcome to the Decade of Games. *HBR Blog Network, Harvard Business Review* (2010).

[65] Walter Quattrociocchi, Antonio Scala, and Cass R Sunstein. 2016. Echo chambers on Facebook. *Available at SSRN 2795110* (2016).

[66] Jon Roozenbeek and Sander van der Linden. 2019. Fake news game confers psychological resistance against online misinformation. *Palgrave Communications* 5, 1 (2019), 1–10.

[67] Sam Scholefield and Lynsay A Shepherd. 2019. Gamification techniques for raising cyber security awareness. In *International Conference on Human-Computer Interaction*. Springer, 191–203.

[68] Erick Schonfeld. 2010. SCVNGR's secret game mechanics playdeck. *TechCrunch, August* 25 (2010).

[69] Anuj K Shah and Daniel M Oppenheimer. 2008. Heuristics made easy: an effort-reduction framework. *Psychological Bulletin* 134, 2 (2008), 207.

[70] Jesse Shore, Jiye Baek, and Chrysanthos Dellarocas. 2016. Network structure and patterns of information diversity on Twitter. *arXiv preprint arXiv:1607.06795* (2016).

[71] Kai Shu, Amy Sliva, Suhang Wang, Jiliang Tang, and Huan Liu. 2017. Fake news detection on social media: A data mining perspective. *ACM SIGKDD Explorations Newsletter* 19, 1 (2017), 22–36.

[72] Herbert A Simon. 1990. Bounded rationality. In *Utility and probability*. Springer, 15–18.

[73] Daniel J Singer, Aaron Bramson, Patrick Grim, Bennett Holman, Jiin Jung, Karen Kovaka, Anika Ranginani, and William J Berger. 2019. Rational social and political polarization. *Philosophical Studies* 176, 9 (2019), 2243–2267.

[74] Steven Sloman, Steven A Sloman, and Philip Fernbach. 2018. *The knowledge illusion: Why we never think alone*. Penguin.

[75] Richard H Thaler and Cass R Sunstein. 2009. *Nudge: Improving decisions about health, wealth, and happiness*. Penguin.

[76] Calum Thornhill, Quentin Meeus, Jeroen Peperkamp, and Bettina Berendt. 2019. A digital nudge to counter confirmation bias. *Frontiers in big data* 2 (2019), 11.

[77] Sander Van der Linden, Anthony Leiserowitz, Seth Rosenthal, and Edward Maibach. 2017. Inoculating the public against misinformation about climate change. *Global Challenges* 1, 2 (2017), 1600008.

[78] Michel Visalli, Benjamin Mahieu, Arnaud Thomas, and Pascal Schlich. 2020. Automated sentiment analysis of Free-Comment: An indirect liking measurement? *Food Quality and Preference* 82 (2020), 103888.

[79] Lucy Wang, Arthi Ramachandran, and Augustin Chaintreau. 2016. Measuring click and share dynamics on social media: a reproducible and validated approach. In *Proceedings of the International AAAI Conference on Web and Social Media*, Vol. 10.

[80] Robert B Zajonc. 2001. Mere exposure: A gateway to the subliminal. *Current Directions in Psychological Science* 10, 6 (2001), 224–228.

[81] Qinfeng Zhu and Marko M Skoric. 2021. From Context Collapse to "Safe Spaces": Selective Avoidance through Tie Dissolution on Social Media. *Mass Communication and Society* (2021), 1–26.

[82] Arkaitz Zubiaga, Ahmet Aker, Kalina Bontcheva, Maria Liakata, and Rob Procter. 2018. Detection and resolution of rumours in social media: A survey. *ACM Computing Surveys (CSUR)* 51, 2 (2018), 1–36.

A TWEETS USED IN THE PRE- AND POST-SURVEYS

News Title	Tweets
NYC's Hart Island, Largest natural burial ground in the United States for CoronaVirus	No fewer than 40 caskets were buried in a mass grave on NYC's Hart Island on Thursday.
	That is how New York deals with unclaimed bodies. Maybe homeless or no family. Based on this news, this is one of the most efficient ways. Face the fact.Don't be so daft!
	Street people die all the time from drugs, diabetes and alcohol,etc. As for me, the news tells me the truth about dealing with their unclaimed bodies. Is it fake? Don't be retarded hahaha.
	It's heartbreaking, but it's true. Is there another alternative to deal with the unclaimed bodies that no one is looking for? It is true. How stupid are the people who don't believe in this news? It's SILLY
	Yes, these are unclaimed dead. Hart Island has been a public cemetery for a long time. Just more bodies now. Someone tweets it is false. What makes you say that? Please wake up, FOOLS.
California governor lays out deep budget cuts to close $54 billion deficit	It's a good policy. Cutting budget is a good way to decrease taxes. Don't take away the right to spend money at will. It's individual freedom.
	I wish all the other states would have reduced their budgets. Using taxes should be based on ECONOMIC GROWTH.
	Is there another good policy than reducing taxes? Freedom is the virtue of CAPITALISM.
	Ha,ha! You are screwed without taxpayers. Serves you right! It is the result of abusing taxes.
	Is this supposed to be equal by increasing the public budget? Small government is the best way that takes into account INDIVIDUAL FREEDOM and CAPITALISM. This is personal freedom!
	Meanwhile in the midst of this terrible pandemic Climate Change marches on regardless. Parts of North America Are Currently Heading For a Megadrought. Lots of papers are supporting this news. Link here (https://bit.ly/2slsHL78)
	Parts of North America are currently in a climate change-fueled megadrought that began in 2000. Conserving water has become more important than ever amidst the impacts of global climate change. Added more scientific evidence than many words. Link here (https://bit.ly/2slsHL38)

News Title	Tweets
Parts of North America are in a megadrought with their driest years since the 1500s. It could get worse	This is an important warning from Earth to us. It's not cool not to think about pollution. Refer to this paper (https://bit.ly/2kesHLTL)
	This paper (https://bit.ly/2slsHLYJ) explains that ClimateChange will change Every rain pattern, so we must change. I feel so pathetic for those who ignore scientific and convincing paper materials.
	I often wonder if there will be a day in 20-30 years when Arizona completely runs out of water. I couldn't help believing in this news that shows lots of SCIENTIFIC materials. I will attach a link (https://bit.ly/2slsHLUI) to their representative lectures.
Fabric Masks Should Be Sanitized in a Microwave	Check out this article: Should Fabric Masks Be Sanitized in a Microwave. There are more germs than you think that can't be killed by washing.
	Should Fabric Masks Be Sanitized in a Microwave? YES, You should!! False washing can cause serious problem. I don't understand and hate people who don't disinfect masks.
	I totally agree with the idea. You can microwave fabric masks to kill germs. The virus lives on cardboard for up to 24hrs, I believe the fabric is a little less but 24hrs to be safe. Please wake up, fools.
	This is a good way to re-use fabric masks. It's very economical. I don't understand why you don't do this. NOW, we can identify idiots through this.
	If you want to have trouble with your respiratory system, you can spray a lot of disinfectant on the mask instead of using a microwave. Don't be retarded hahaha.
Kroger Tell Employees They Can Wear BLM Masks, But Not Flag Masks	People have to fight back against racists. We need to create a society of equality without racial discrimination..
	Black lives DO matter. You can't discriminate for any reason, especially if it's because you're different from yourself. Let's stop now. Everyone's in pain. EQUALITY.
	I totally sympathize with this news. This is not okay to discriminate african american people. We need to focus on the virtue of LIBERALISM.
	I support BLM. The racists want the color of your skin to matter, they want to keep this nation divided. It's a disgusting teaching that needs to be removed
	BIack lives matter! really don't know what else to say!! There is so much wrong within the system. Change is needed! Hopefully I can do my part. It's RACIAL EQUALITY.
	Scientists have come forward confirming that man-made climate change is a hoax perpetuated by the elite in order to make money. Lots of articles said like that. It's really CONVINCING. (link: https://bit.ly/2ulgHL22)

News Title	Tweets
An 'Increase' in Arctic and Greenland Ice Cast Doubt on the Reality of Global Warming	Look at this report which said that demon rats are making millions pushing climate change bs they pollute more then 3/4 of normal Americans https://bit.ly/2usdHL22
	The increase of ICE is greater than you think. I will attach a link(https://bit.ly/2ulsHL54) to their representative lecture video.They are very reliable people, so I fully support their argument.
	This paper mentions that the climate has ALWAYS changed. Look up the Ice Age. I definitely support tremendous smart scientist (https://bit.ly/2tlsHL89)
	Excellent Article! All part of the globalist plan to force their farce on us & control our every action in life. I read about this in the morning. https://bit.ly/2olsHLTL

Table 4. The tweet groups used in the pre- and post-survey. Each group of tweets for the news items has one of the characteristics of an echo chamber used in the game.

Received April 2021; accepted July 2021