StarryThoughts: Facilitating Diverse Opinion Exploration on Social Issues

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Enabling the free and equal exchange of arguments on social issues in a respectful manner is an integral part of establishing the democratic ideal. However, the current manifestation of online spaces tends to facilitate the gathering of like-minded people, leading to the polarization of opinions. Such polarization inhibits the sharing of diverse opinions and deteriorates respect for disagreeing opinions. To tackle this issue, we present StarryThoughts, an online system that supports users to express and explore diverse perspectives on social issues. The system supports three types of exploration of the collected arguments online: navigating opinions based on the demographic identities of the posters, checking the the stereotypes users hold towards demographics in relation to given social issues, and engaging with opinions with semantically different point-of-views. By deploying the system to the public in co-operation with a nationwide broadcasting company, we collected 1,950 opinions with 144 free-form responses from 1,209 visitors as initial data and iterated on the design. Results from a user study with 56 participants showed that the system enables participants to explore a wide range of opinions on social issues, be more informed on the various arguments, and be more confident about their opinions. From our findings, we provide several design considerations for building online systems for supporting users to explore diverse opinions on social issues.

CCS Concepts: • **Human-centered computing → Collaborative and social computing systems and tools**.

Additional Key Words and Phrases: polarization, public sphere, identities, opinion exploration

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1 INTRODUCTION

The deliberative ideal of democracy suggests that the main virtue of democracy is the free and equal exchange of arguments in a respectful manner [14, 19]. Online spaces have shown the possibility of achieving this ideal by facilitating information and opinion exchanges between people [1, 17, 60]. However, at the same time, the current designs of online spaces are responsible for aggravating the problem of political polarization by providing places where like-minded people

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can come together to form networks. As these networks come together, individuals begin to form group identities. Ingroup-outgroup relationships are formed and, as people form stereotypes and biases towards the outgroups, interaction between groups becomes limited and results in a further polarized online space [21]. Online spaces also provide methods to filter content depending on users' preferences, which is known to be a cause of the Filter Bubble [47], where personalized and algorithmic filtering limits access to diverse information, thereby creating an invisible barrier that presents a biased worldview for the user. In this way, polarization also hinders democratic communication by prohibiting each person from being exposed to various alternative ideas [8, 55]. These barriers hinder communication and, in turn, prevent the achievement of an ideal deliberative and democratic space.

Previous work on mitigating polarization has mainly focused on increasing people's awareness of diverse opinions on an issue. Common approaches include explicitly presenting the bias of the user [22, 32, 42] or showing the diversity of opinions [16, 52]. However, simply knowing the existence of diverse opinions might not be enough. Prior research suggests that the mere exposure of diverse opinions might not immediately mitigate polarization [5]. Deliberation literature suggests that listening to other opinions with respect is essential for understanding different points of view [13, 19], but designs for fostering respect towards diverse opinions have been relatively less explored. One of the few examples is Reflect [33], which introduced interaction designs based on active paraphrasing to promote listening in online discussions.

In this work, we aim to explore the possibility of using demographic identities to foster respect towards people with different opinions in the online space. We believe that the identities of individuals could provide context for each opinion to support the user's role-taking process [13] and judgment of opinion credibility. We also use the identity information as a method to bring attention to stereotypes that a user might have, as well as to increase their perceived variability of outgroups, ultimately mitigating outgroup stereotypes and facilitating democratic conversation [9].

We propose StarryThoughts, an online system that supports users to explore diverse perspectives on social issues. The system primarily aims to present the diversity of opinions as well as the context behind the opinions by introducing a visualization of opinions on a 2-D space, following the metaphor of "starry nights" (Figure 3). On top of that, the system provides several different support mechanisms to help the users explore the opinion space. First, the system enables the users to perceive the diversity of backgrounds and experiences behind the opinions by presenting the demographic information of the author of each opinion. The system supports the users in understanding the perspectives of a specific social group by filtering the opinions by demographics of the authors. Second, using the demographic information of the authors, the system explicitly enables the user to state and test their expectations on the demographic identities of the supporters and the dissenters of the issue. Finally, the system engages users to explore the broader range of opinions in the 2-D space by visually recommending opinions with the least semantic similarities to guide them to engage with opinions that contain different perspectives.

We conducted a lab study to investigate how participants would use the features of the system to explore a large number of opinions and how exploring diverse opinions might affect participants' opinions on social issues and their attitudes toward disagreeing opinions. Study results with a total of 56 participants showed that with StarryThoughts participants explored a diverse range of opinions with 2-D visualization of opinions and presentation of demographic identities of the opinion authors. The difference in participants' opinions, level of confidence in their opinions, and argument repertoire before and after using the system showed that StarryThoughts helped the participants to express more concrete opinions and recall more arguments around the issues.

The contributions of the paper are as follows:

- Design implications for systems facilitating the diverse exploration of opinions and fostering a respectful attitude toward different opinions;
- StarryThoughts, an online platform for sharing and exploring a diverse range of opinions on social issues;
- Findings from a user study showing that with StarryThoughts participants explored a diverse range of opinions with respectful attitudes towards them.

2 BACKGROUND

In this section, we review previous work on polarization in online space and solutions for mitigating this issue. After that, we introduce how identity information could support the exploration of diverse opinions and increase respect of these opinions.

2.1 Polarization in the online space

Online polarization refers to the behavior of individuals congregating into like-minded groups online, often showing intolerance towards individuals or groups with opposing views. Polarization can cause a negative impact on society by eroding overall social cohesion as well as the possibility for productive civil discourse [34]. Individual users may not even be aware of the existence of different points of view due to a lack of contact with opposing opinions [8].

Personalized information filtering, as well as the increasing number of information sources, facilitates polarization by causing users to be further separated from unwanted information. This accelerates the process of forming homogeneous groups [55]. As the group develops a collective stance, individual group members become more reluctant to contradict the group's consensus, leading to the solidification of the group attitude [57]. Groups also tend to gravitate towards more extreme views than the aggregation or average of the individual viewpoints. This behavior is further exacerbated by computer-mediated communication [26, 53, 54].

Social media, as a medium of communication, is influential to polarization at hand. Social media can help its users be exposed to diverse information that may not agree with their own opinion [20, 41]. For example, Lee et al. [35] demonstrated that the general usage levels of social media have a positive correlation with an individual's network heterogeneity, meaning that the more active one is on social media, it is more likely that they will encounter people with differing or opposing opinions. However, social media also can either cause or interfere with polarizing behavior. As an example of polarization, bipolar and distinct political clusters could be found in online spaces such as Twitter [12]. Barberá et al. [6] showed that Twitter users primarily exchanged information with people with similar ideological stances.

Bozdag et al. [8] recognize the filter bubble as a threat to the democratic ideal and identify differing approaches to the problem based on each democratic model. For example, from the liberal model of democracy, the filter bubble threatens democracy because it inhibits individuals' freedom of choice among different opinions. To advocate for the liberal model of democracy, the system must be designed to grant users full control and autonomy over their choice and availability of options. From the perspective of deliberative democracy, the filter bubble is harmful because it reduces the chance of discovering a wide range of viewpoints, leading to lower quality arguments and less respect toward people with different viewpoints. Therefore, the system should aim to expose users to diverse points of view.

Building upon this body of work, we aim to tackle online polarization by enabling users to explore the diversity of viewpoints on social issues.

2.2 Designs for mitigating polarization

To mitigate polarization on online spaces, there has been a series of work on designing and building systems to promote exposure to more diverse opinions, with differing levels of intervention. Some of these approaches focus on helping users discover their own bias while consuming political opinions. Balancer [42] starts from a low level of intervention by visualizing how politically skewed the user's browsing history is. The awareness provided by the visualization nudges the user to explore more diverse news outlets toward a better balance. Similarly, ConsiderIt [32] presents the idea of constructing a pros/cons list on a social issue by utilizing other people's opinions. By providing list construction as the main task for the users, the system induces them to explore opinions from the opposite perspective as the users try to balance out their lists. Findings from the deployment showed that the system promoted the users to consider opinions in a balanced manner.

Other studies focused on building an online space for discovering diverse viewpoints around an issue. For example, Opinion Space [16] visualizes opinions in 2-D space based on the similarities of stances on social issues. Their results showed that, although the visualization did not improve the diversity of opinions read by the users, users did perceive the opinions as more diverse after using the visualization and were more respectful of different perspectives. Poli [52] aims to present diverse opinions from users by aggregating information from multiple social media outlets. PolicyScape [27] explicitly used users' identities as stakeholders of issues to present multiple aspects of policy-related issues.

Other researchers have focused on actively recommending opposing viewpoints to the user. For example, Gao et al. [22] proposed an intelligent system for mitigating selective exposure by determining the stance of user opinions with sentiment analysis and explicitly recommending opinions of opposite stances. Their system evaluation showed that the system could help users understand their stances and explore opinions inconsistent with their viewpoints. Nelimarkka et al. [45] investigated designs for recommending opposite viewpoints on social media based on the Habermasian ideal of democracy. Their findings showed that the recommendation contributed to promoting more informed discourse, and recommendations on social media encouraged understanding others' perspectives. At the same time, the authors found that the recommendations could cause self-censorship or stigmatization while users were stating their opinions, and the recommendation of content could manipulate the users' own opinions.

However, literature also suggests that the mere exposure of diverse opinions might not immediately mitigate opinion polarization [5, 44]. The literature on deliberation suggests that the interlocutors may find common ground when they listen to each other with respect [13]. Still, little research has focused on designs for encouraging listening to diverse opinions with respect. One of the few examples is r/changemyview [25], which shows how gamification elements and community rules could create a community norm that encourages listening. Another example is Reflect [33], which introduced rephrasing as a UI element for encouraging listening in online discussions.

In this work, we design a system for discovering diverse viewpoints by building upon literature on mitigating polarization. On top of that, we aim to provide systematic aids that promote users' respect towards differing opinions.

2.3 Role of identity in communication

From the perspective of deliberative democracy, arguments and information exchanged in the public sphere should be considered only by their values and not by the individual properties of the speaker [19]. Based on such an ideal, previous approaches refrained from exposing individual identities that could affect the users' judgment on an issue. For example, ConsiderIt [32] explicitly excluded the information on individual profiles except for the name to prevent stereotyping.

At the same time, deliberative democracy points out the importance of ideal role-taking and inclusiveness [14]. Ideal role-taking means that the participants of the deliberation should try to understand arguments from others' perspectives [14]. By doing so, the participants of deliberation would be able to respect disagreeing perspectives [43]. Inclusiveness means that every relevant individual should be included in the decision-making process so that all relevant arguments could be considered in deliberation [14]. From this thread of research, we expect that the demographic identities could support ideal role-taking by providing initial information on the others' personal interests, circumstances, and experiences. We also expect that presenting these identity cues would help participants reflect on their inclusiveness in terms of the range of opinions being read and considered.

Identity information could also function as a cue for individuals to be more receptive towards an opinion. Social translucence [15] suggests that identity-related to the information could help people gauge the credibility of the opinions. Liao and Fu showed that clear indicators on the opinion source, such as the expertise [38] and the messenger's stance on the issue [37], could convince people to accept information that is inconsistent with their opinions. Willemsen et al. [58] showed that perceived expertise and trustworthiness of online product reviewers could affect the readers' attitudes towards the reviews. Such prior work suggests that the information on the identities could serve as metadata for gauging opinion credibility.

Social identity theory suggests that group memberships take an essential part in forming an individual's identity and that the individuals try to seek a positive understanding of their own identity by comparing their ingroup to other outgroups [23]. This leads to a tendency of individuals to conform to the normative behaviors of the ingroup members [31], even when such groups are formed arbitrarily [2]. Therefore, messages from ingroup members could have a more powerful persuasive effect compared to those from outgroup members when the group distinction is relevant to the issue itself [18, 24, 31, 39, 40, 59]. However, such social identification can negatively affect exposure to diverse opinions if they are perceived as originating from the outgroup.

One way to avoid this type of negative perception is to facilitate the understanding of outgroups in terms of meaningful subgroups [9, 48]. By promoting the concept that outgroups consist of some level of internal diversity and not, in fact, a single cohesive entity, individuals' level of prejudice towards outgroups is reduced, improving their ability to communicate with one another. We aim to leverage the identity information to facilitate the user's association with ingroup opinions, while avoiding emphasizing outgroup relationships so as to control for the pitfall of outgroup hostility.

Regarding previous work supporting the role of identity in communication, we propose using identity as a tool to help users explore diverse opinions on social issues.

3 DESIGN ITERATION

We designed an initial version of the system with the primary goal of exposing the diversity of opinions. (Figure 1). The system aimed to provide a visual platform that users could freely navigate among various opinions, stances, and identities. This version was designed to help users understand the variability and diversity of opinions (through the navigation of space), as well as to emphasize the multifaceted relationship between identity factors and opinions. Table 6 shows the design elements of the system compared to existing approaches. Below, we elaborate on the specific design elements we used to implement these goals on an interactive system.

When the user enters the system, the user is presented with a 2-D spatial visualization of opinions that resembles a "starry night sky of opinions". We used a 2-D spatial visualization to present a visual impression of opinion diversity and the relationship of opinions and demographic identities. Compared to commonly used lists of opinions, the spatial visualization also removed the hierarchy of elements in organizing the opinions so that each element was as equally accessible as any other.

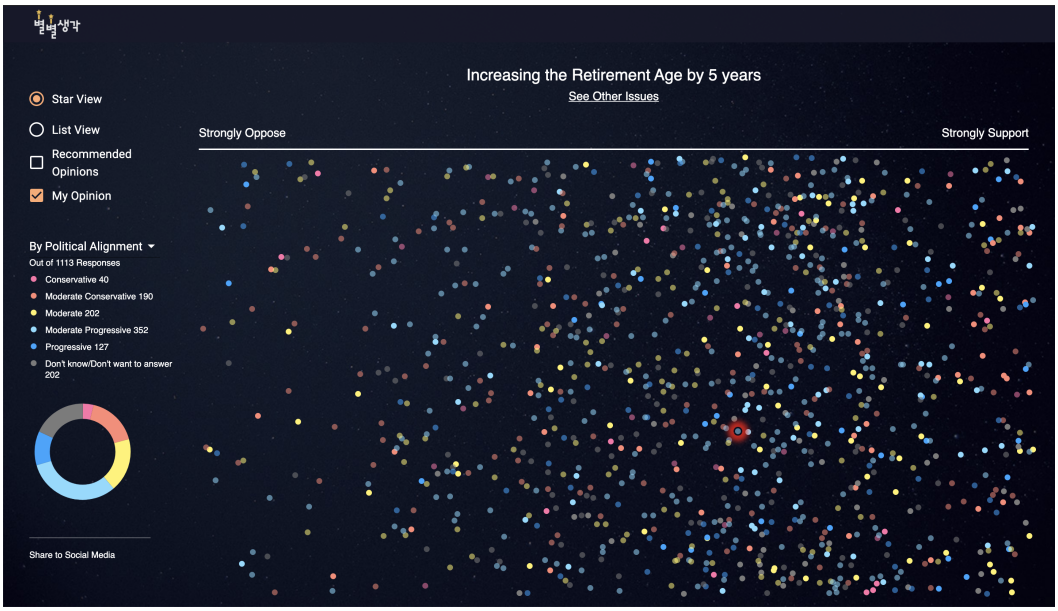

Fig. 1. The initial version of the system. The initial version of the system presents the variability and diversity of opinions by showing the opinions as dots on a 2-D space.

Each opinion is visualized as a dot on the screen. Unlike previous research that placed the opinions by the similarity of opinion profile [16], the horizontal position of each dot was determined by the author's stance on the issue. By doing so, we expected the users to see the opinion distribution easily. While each opinion has information on the author's identity, we intentionally did not encode any information in the vertical axis to not give an impression that each social group is segregated. Instead, we placed each opinion randomly on the vertical axis so that each opinion could be equally noticed. The data points are color-coded in regards to which demographic group the author is in. Users can choose between three modes of color-coding: age group, gender, and political alignment, to see how the distribution of each demographic characteristic matched up within the opinion distribution.

One of the significant design considerations was deciding which and how many identity factors to disclose. If the factors were too few or too general, they might not have enough informational value. Fine-grained identity factors would provide the readers with a more detailed context to the opinions. However, it also can lead to various problems, such as an increased level of stereotyping of or prejudice on the authors or the possibility of disclosing personal information. With such considerations, we chose a combination of four general categories for the users to classify themselves in: age group, gender, occupation, and political stance. These were criteria that were already being used widely for public opinion polls, so they are easy to understand and general enough not to pose a threat to the users' privacy while still providing meaningful context.

The user can filter the opinions by selecting a demographic to focus on, so that they are able to choose and focus on the opinion distribution of a particular demographic group. By doing so, the user could investigate the opinion distribution of specific groups. For example, the user can check whether their peers share the same view on an issue or verify the validity of their preconceptions on specific groups. The user can hover or click on the dots to see the arguments of others. The user could also use the recommendation feature of the system to discover new perspectives. In the

initial version, the user could see the opinions of the 'most distant' authors, who are the people with different stances and different demographic characteristics from the user.

We deployed the initial version of the system in collaboration with a nationwide broadcasting company in South Korea. The system was open from October 9th, 2019, to October 31st, 2019. During the deployment, 1,209 people visited the website, and 335 people signed up. A total of 1950 opinions and 144 open-ended arguments were shared on the platform, spanning over six controversial social issues.

From the experience from deployment and several pilots for design iterations, we came up with several design lessons to better help users explore diverse opinion landscapes. In the following subsections, we introduce some of the lessons (denoted as L1-L3) that led us to the second version of the system.

3.1 L1: Inspecting fine-grained demographic groups

In the initial version, the system supported filtering opinions with only one demographic characteristic at a time. For example, a user would select the 'Male' filter from the 'Gender' category to see all the opinions that male-identifying authors provided. However, pilot study participants mentioned that using only one demographic characteristic was too coarse-grained. We revised the system to support multiple filtering options simultaneously after receiving feedback on the lack of specificity on the group selection during pilot studies. Users can select multiple filters across the three categories to control the level of granularity and also the amount of information provided at a given moment.

3.2 L2: Leveraging users' prior knowledge for engagement

From the pilot studies, we learned that one of the most common usage scenarios of the system was to discover the trend of opinions according to the demographic factors. Specifically, the participants had prior expectations on the strongest supporters or dissenters of an issue in terms of demographics. They used the system to check whether such expectations were aligned with the opinion distribution in the system. The participants mentioned that discovering an unexpected trend of opinion to a specific demographic group or discovering opinions that are out of trends made exploration more intriguing and made them explore the opinions to understand the reasoning for such instances. Inspired by Kim et al. [30], we aim to support the users of the system to externalize their prior expectations and verify them.

3.3 L3: Active guidance for exploring diverse opinions

The users of the initial version of the system were only able to see the dispersed opinions, with support from a simple recommendation feature focusing on presenting opinions from different social groups. So, the initial algorithm suggested opinions that are the most distant from the user regarding the authors' demographic profiles and the stance on the issue. However, from a series of pilot studies, we learned that the users heavily relied on the recommendation feature when they started exploring the opinions as they tended to be overwhelmed from seeing a large number of data points all at once. The participants were also concerned that randomly selecting opinions would often return opinions too similar to what they have read before. Therefore, we decided to improve the recommendation focusing on fostering exploration of more diverse arguments with more transparent criteria.

4 SYSTEM

In this section, we introduce StarryThoughts, an online platform to support the exploration of a diverse range of opinions. Upon entering the system and adding their own opinion and demographic

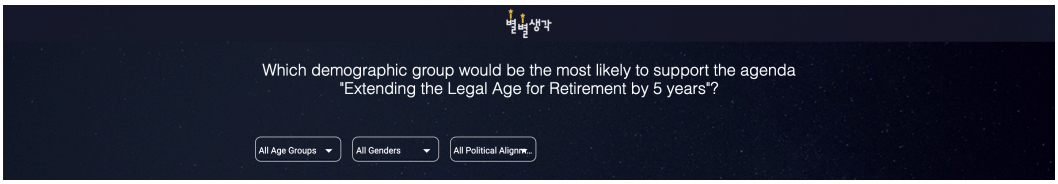

Fig. 2. Prediction screen for the user. Before seeing the visualization of the opinions, the user is first asked to share their prediction on the groups who would likely support or object to the issue. The user can quickly verify their prediction by seeing actual opinions in the next step.

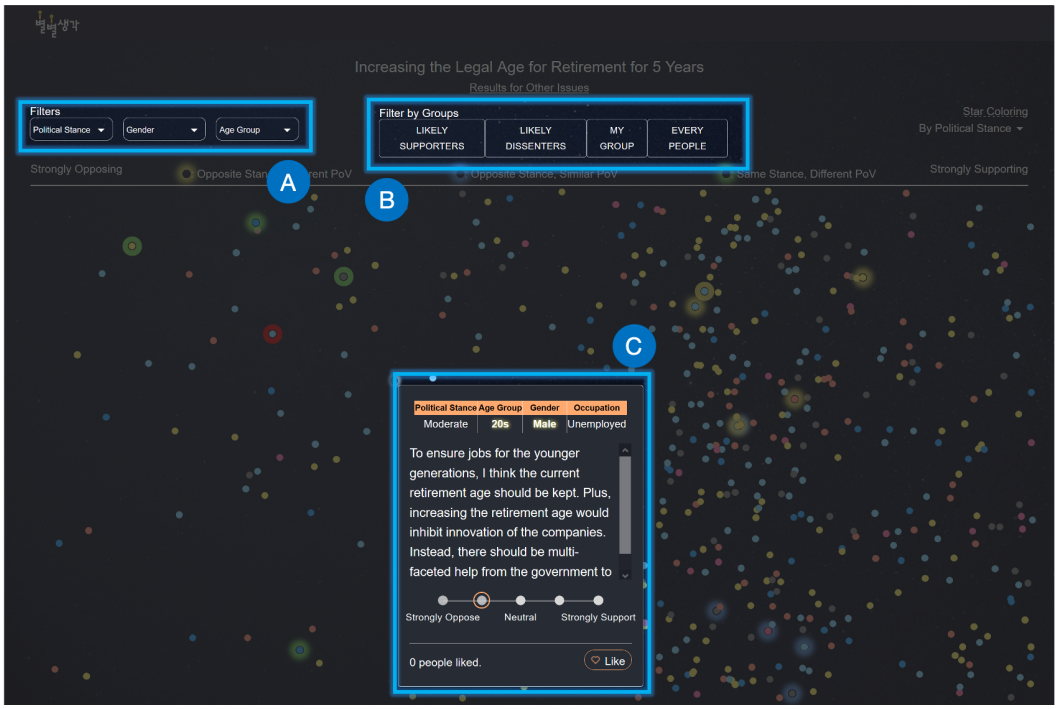

Fig. 3. An overview of StarryThoughts. Each opinion is displayed as a dot in a two-dimensional space. The user's opinion is highlighted in red, and recommended opinions are highlighted in yellow, blue, or green according to the recommendation type. (A) With the filters, the user can specify demographic groups of interest. (B) The user can quickly test their predictions on who would support or oppose the issue with the quick filters. (C) By clicking or hovering on one of the dots, the user can read the opinion along with the demographic profile of the author.

information, the user can see a 2-D visualization of opinions, arranged by the stance on the issue. Then, the user can freely explore the space and read individual opinions using various system features.

4.1 System usage scenario

To present how the user would explore diverse opinions on social issues with StarryThoughts, we introduce a representative scenario of using the system, constructed from the activity logs of the users.

Fig. 4. Demographic filter of StarryThoughts. Each available option is presented as a dropdown menu at the upper left corner of the page. The user can select multiple options of interest. When option is changed, the only the opinions that matches the criteria are presented in the visualization.

Mina is a college senior, recently having been on the search for future jobs after graduation. She recently heard about a suggestion for a new policy that aims to increase the legal age for retirement. In her opinion, the new policy would worsen youth unemployment as the firms would be less likely to hire people. She also thinks that a turnover in the workforce is necessary to promote innovative thinking. Still, she wonders what others would think about the policy and visits StarryThoughts.

4.1.1 Predicting and verifying supporters and dissenters of the issue (L2). Before showing the opinion distribution, the system asks her to predict the demographic groups likely to agree or oppose to the legislation (Figure 2). Mina immediately selects the age group of the 20s as likely to oppose the legislation since she supposes that most people in her age group would be in a similar situation to her own. She considers a little bit about groups that would support the legislation and selects '60s Male', as she thinks they would be the ones whose jobs will be terminated if this comes through.

She sees the 'Star View', where opinions are visualized as dots scattered on a 2-dimensional space (Figure 3). She notices many data points, but she is not sure which dot to choose first. She notices the 'Likely Supporters' and 'Likely Dissenters' filters and decides to take a look at them first (Figure 3B).

She clicks on the 'Likely Supporters' filter to see the responses from male people in their 60s. As she sees how the dots are dispersed, she realizes that the opinions are skewed to supporting the issue as she expected. At the same time, she notices that there are still some dots on the opposing side. She reads one of them, which says that increasing the retirement age causes more social costs than benefits and that the rights of the older citizens would be secured better when provided

through social welfare policies. She is impressed by the opinion as she did not expect that he would support an idea against his benefit. She leaves a Like on the opinion.

4.1.2 Exploring the trend of opinions per demographic group (L1). After reading the opinion related to the issue with social welfare policy, she realizes that the solution of strengthening social welfare policies is not the one she had considered before. She also wonders whether people's attitudes towards welfare policy would affect the opinion on the issue. She uses the demographic filters (Figure 3A) to check how the opinion distribution differs by political alignment (Figure 4). She observes that the opinions do not significantly differ by political alignment and concludes that the social welfare perspective was not a decisive factor.

4.1.3 Exploring diverse opinions with recommendation (L3). She still wants to learn more about diverse arguments around the issue, so she goes back to see all dots. Among the distribution of dots, she discovers that that some dots in the system were glowing in different colors to indicate recommended opinions (Figure 3).

She clicks on her opinion first to get a recommendation based on her opinion, then considers the meaning behind the colors. The yellow dots are the opinions with "Opposite Stance, Different Point of View". They support the policy because 60 is too low of a bar for people to give up their skills and abilities to work, which is an entirely different perspective from her own. The blue dots are the opinions with "Opposite Stance, Similar Point of View". Among them, she finds opinions supporting the policy because it would lead to a better workforce. From the green dots, described as "Same Stance, Different Point of View", she discovers different arguments for opposing the policy, such as that the quality of life for older citizens would be better if they could retire and receive pensions earlier.

Mina wants to know more about the points related to welfare, so she goes back to the opinion that mentioned welfare and starts reading the opinions with blue highlights. One of them emphasizes the importance of enforcing social welfare policies to ensure citizens' rights but claims that keeping citizens in employment for longer is a good way to reduce needless budget losses in the social welfare sector. Mina is intrigued by how similar lines of reasoning are used in different contexts to create completely contrasting opinions. She is also surprised at the fact that this opinion is written by a man in his 20s, but after seeing that he is a graduate student, she justifies the idea that he might think that way because he would probably not be as involved in the job market (Figure 3C).

She reads a few more recommended opinions to find any new perspective on the issue. After exploration, she leaves the system, with her thoughts on the issue moved towards neutral.

4.2 Recommendation algorithm (L3)

From the design lessons, we decided to support users exploring the space by actively providing recommendations from new perspectives. Previous work on fostering exploration of diverse perspectives focused on recommending agreeable opinions. To do so, the metric for recommendation measured the diversity of population the opinion appealed to [16, 32]. Some other research tried recommending attitude-inconsistent opinions using a classifier to predict people's stance on the issue [22]. We aimed to encourage users to consider opinions from new perspectives. We assumed that opinions with similar perspectives would be semantically similar. Therefore, we opted to recommend opinions that were semantically dissimilar to the ones currently being read.

The system determines the distance between points of view using the document similarities computed with the method of Arora et al. [3]. In this method, document embedding is constructed by averaging embedding vectors of the words in the document. While averaging, each word vector is weighted by the inverse frequency of the word in the corpus.

As the system was built and deployed in Korean for a Korean audience, the users' opinions were also in Korean. Therefore, it was impossible to apply the technique directly due to the lack of reliable Korean word vectors. However, as the algorithm weights the words by inverse frequency, we expected that the algorithm would work reasonably if we could get the keywords in each opinion correctly. So, we decided to use the pre-computed English word vectors despite sacrificing some meaning of the text. To do so, we translated the collected opinions into English using Naver's Papago API [1] after correcting for spelling and grammar for better machine translation. After translation, we computed each opinion's embedded vector with the algorithm using pre-trained GloVe word embeddings built upon 42B tokens from Common Crawl [49].

4.3 Implementation details

The front-end of StarryThoughts is implemented with React. The back-end is built with Node.js and served on AWS Lambda with a MongoDB database. For the recommendation algorithm, a separate Python server is used to compute the document similarities of the opinions and make recommendations based on them.

5 EVALUATION

To understand whether the features of StarryThoughts effectively support users' exploration of diverse opinions and how users' opinions and attitudes towards the issue would be affected by using StarryThoughts, we conducted an exploratory user study. In evaluating ConsiderIt [32], researchers investigated how users used the system to explore diverse opinions and how such exploration helped their opinion formation. Opinion Space [16] attempted a controlled within-subjects user study to evaluate their system against baseline interfaces in terms of user engagement, helpfulness for finding useful opinions, diversity of opinions read by users, and agreement and respect towards different opinions. Inspired from the previous work, we developed the following research questions to thoroughly understand the experience and the effects of using StarryThoughts.

- RQ1 How would the users of StarryThoughts use demographic identities of the authors and recommendations to explore diverse opinions on social issues?
- RQ2 How would the experience of using StarryThoughts to explore opinions on social issues affect user's opinion strength and quality?
- RQ3 How would the experience of using StarryThoughts affect how the user evaluates diverse opinions around social issues?

5.1 Participants

Our user study consisted of two separate rounds. In the first round, we focused on understanding how using StarryThoughts would affect users' opinions on social issues and attitudes to others' opinions with pre-/post-surveys. The second round of user study was designed to thoroughly understand a) how users used each system component to explore opinions and b) how using demographic identities for exploring opinions affected users' reaction to the opinion of others.

We had 50 participants for the first round. 27 of them were female, and 23 of them were male. Their ages ranged from 18 to 42, and the average age was 24.1. We recruited the participants by posting calls for participation in online communities of two universities in South Korea. The participants were compensated with 10,000 KRW (~8 USD) for participating in the study. In the results, we refer to these participants as P1 through P50. Due to the glitch in the system, the system usage logs of 9 participants were lost, so we excluded them while analyzing the logs.

[1] https://papago.naver.com/

There were six participants for the second round, and all of them were male. Their ages ranged from 20 to 32, with an average age of 26.5. We recruited the participants via posting calls for participation on an online community of a university in South Korea. The participants were compensated with 20,000 KRW (~17 USD) for their participation. In our results, we refer to these participants as Q1 through Q6.

5.2 Conditions

In this evaluation, we focused on understanding the experience of using StarryThoughts and whether the features of the system support exploring diverse opinions rather than quantitatively evaluating the effect of the system against existing approaches. Therefore, we ran the user studies without a specific control condition.

We used two controversial socio-political issues widely known to the public in South Korea at the time of the study (May 2020). We chose the issues for which it is expected for people to have different attitudes depending on their demographic identities. At the same time, we decided to refrain from choosing too controversial and sensitive issues so the users of the system would feel comfortable accepting and respecting the opinions of others.

The first issue is increasing the legal age for retirement (Retirement Age) [28, 36]. Due to population aging in South Korea, the government proposed it as a solution for maintaining a reasonable size of the productive population and supporting the senior citizens to sustain their living. However, the younger generations tend to oppose the issue due to the fear of reduced opportunities for their jobs, as the plan would increase the labor cost for the companies.

The second issue is whether to classify game addiction as a disorder (Game Addiction) [4, 29]. The controversy on the second issue was initiated from the World Health Organization (WHO) decision to include gaming disorder in the Internal Classification of Disease (ICD). However, considering the people's negative perceptions of games and the Korean government's previous attempts to regulate games, game players and the game industry perceived the Game Addiction issue as another example of imposing excessive regulation on games.

For the opinions in the system, we used data from the deployment study, as well as the data from two rounds of surveys on people's opinions on the issues, which were conducted separately. Survey participants were recruited by a commercial online survey agency, with their age and gender equally balanced. The participants' responses during the study were also collected and presented to other participants, yielding a total of 515 responses for the Retirement issue and 461 responses for the Game Addiction issue.

Figure 5 and 6 present how the opinions were distributed in the system. For the Retirement issue, a significant difference of opinion distribution was observed only by age groups (Kruskal-Wallis test, $p = 0.0002$). Post-hoc analysis with Dunn's test with Bonferroni correction showed that the opinion distribution of age group 20-29 significantly differed from that of age group 30-39 ($p = 0.000144$) For the Game Addiction issue, a significant difference of opinion distribution was observed by age groups (Kruskal-Wallis test, $p < 1e\text{-}8$) and gender (Mann-Whitney U test, $p = 0.00002$). Post-hoc analysis with Dunn's test with Bonferroni correction showed that the opinion distribution of age group 20-29 significantly differed from that of age group 40-49 ($p = 0.0002$), 50-59 ($p = 0.0006$), and 60-69 ($p < 1e\text{-}6$), and that of age group 30-39 significantly differed from that of age group 60-69 ($p = 0.0467$).

5.3 Procedure

For the first round of user study, we conducted 12 usability testing sessions. Each session lasted for approximately 75 minutes, including pre-/post-study surveys. For the second round of user study, we conducted six individual sessions with a length of approximately 90 minutes. Every session was

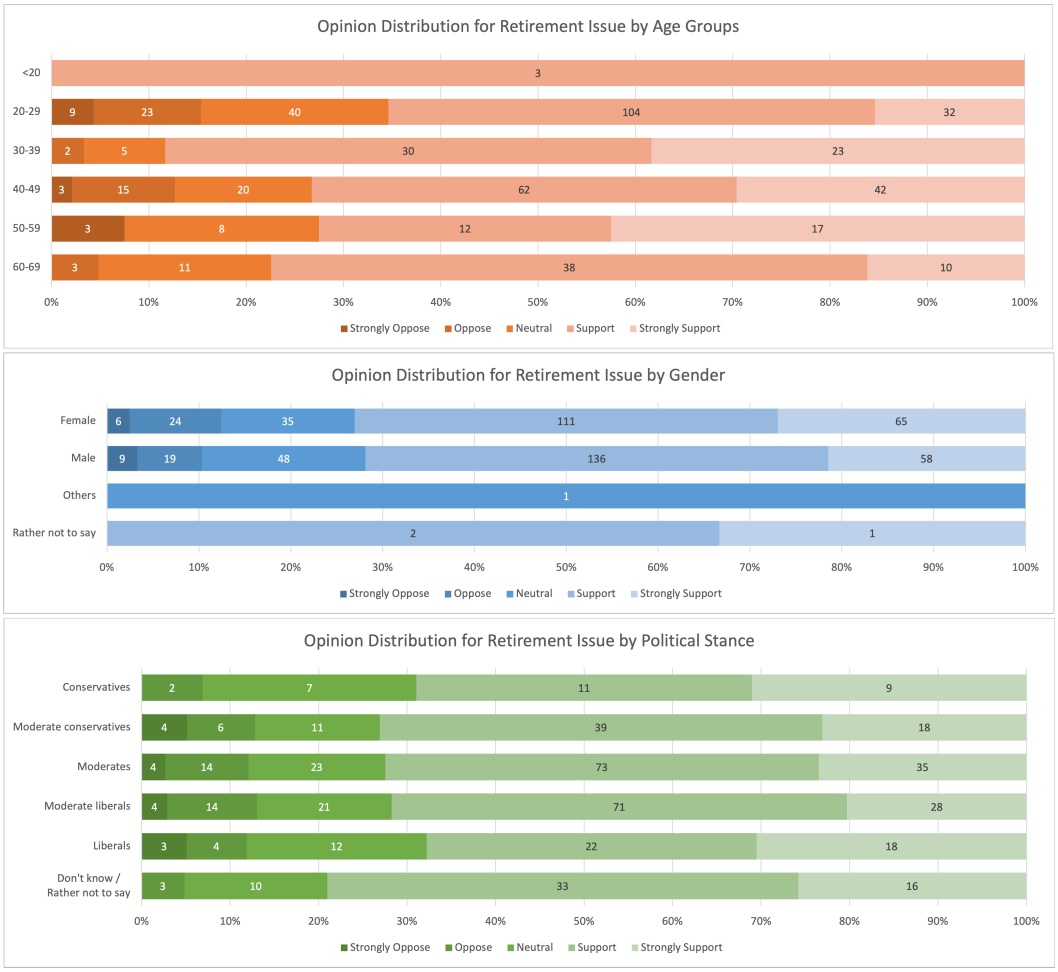

Fig. 5. Distribution of opinions on the Retirement issue used for the study.

conducted remotely over Zoom. During the session, the researcher gave verbal instructions for the tasks, and the participants used the system with their computers.

First, the participants were briefed about the goal of the study and the overview of the task. Then the participants answered a pre-study survey. We asked for their prior knowledge, interests, and opinions on the two issues for the experiment. We also measured their argument repertoire on the issues and surveyed attitudes towards people with incoherent opinions on the two issues.

Next, they were asked to sign up to the system and leave their own opinions on the two issues.

After a brief overview of the system, the participants used the system to understand the overall opinion landscape on each issue. We did not impose any specific restrictions for using the system, other than asking them to use the system for more than five minutes to ensure that they had thorough experiences with the system. All participant activity, such as which dots they clicked or hovered on and which set of filters were active while reading opinions, were logged.

After using the system, the participants answered a post-survey about their experience with the system. We asked them if their opinions on the issues did or did not change after using the

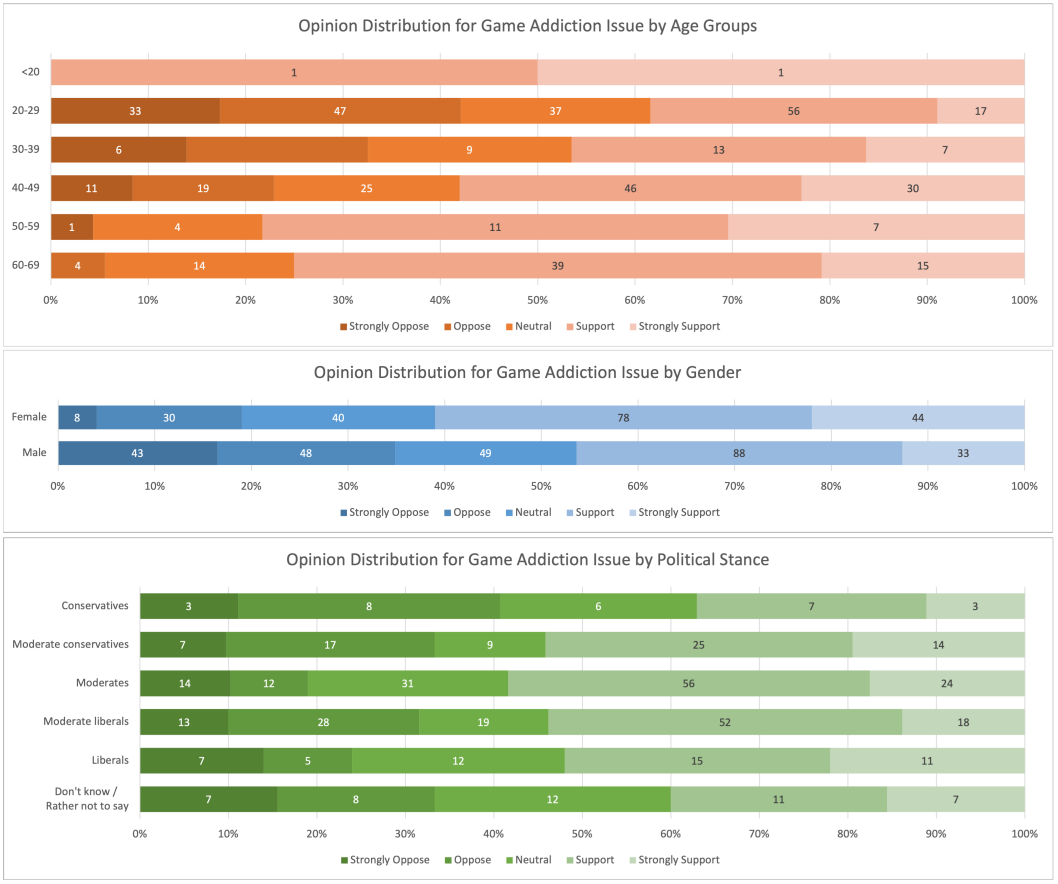

Fig. 6. Distribution of opinions on the Game Addiction issue used for the study.

system, their reason for doing so, and their attitudes towards people of the opposite stance. We also measured the argument repertoire [10] on the issues after using StarryThoughts, as well as comments on the experiences and the overall level of satisfaction they felt from using the system. In the second round, we conducted user interviews instead of the survey, focusing on their experience of using demographic identities for exploring and reading opinions.

5.4 Measures

5.4.1 Experience of using StarryThoughts. To understand how the participants used our system, we analyzed the activity logs of the participants. When logging, we decided that the participant "read" an opinion if the opinion box was visible for more than 0.5 seconds. With such a tight time limit, we tried to capture every opinion the participant paid attention to. We also logged the characteristics of each opinion that the participants read, such as what kinds of filters were applied when reading the opinions and whether the opinion was a recommended opinion at the time of reading.

5.4.2 Opinion quality. To gauge how the quality of the opinion changed before and after using StarryThoughts, we adopted the argument repertoire [10], a list of supporting or opposing reasons related to an issue. The measure was used in deliberation research to measure the quality of

participants' opinions [10, 56]. To measure the argument repertoire, we asked the participants to list the reasons why supporters of the issue would support it and why dissenters would oppose it in the pre-/post-task survey.

To compare the argument repertoire before and after using the system, we sampled the responses of 30 participants and coded them with the help of two external evaluators. We thought it might not be likely that the participants forgot reasonings after the task, so we evaluated in an additive manner as follows. First, we grouped the pre-task arguments and post-task arguments as a set, yielding four sets of arguments (Retirement / Game Addiction issues X Supporting / Opposing). The evaluators identified all relevant reasons to support or object to the issue from the pre-task responses. Then, they reviewed the post-task responses in comparison with pre-task responses and identified newly added arguments after using the system.

While identifying the arguments, we asked the evaluators to count only the arguments relevant to the issue (i. e. not a mere preference or emotional response to the issue). Also, we did not consider the factual accuracy of the arguments. We followed the practice of the original paper measured the argument repertoire [10], which justified the practice as it would be tough to verify the reasons and evidence supporting the claims.

To build a consensus on the coding criteria, the evaluators worked on the set of supportive arguments for the Retirement issue together. With consensus on the rating process from the collaborative rating, the evaluators individually evaluated the remaining three sets of arguments and resolved the conflicts afterward. Due to the complex nature of the coding process, we could not directly report the inter-rater reliability. Still, the two evaluators' results exactly matched for 63% of the responses that were individually evaluated.

5.4.3 Attitude towards diverse opinions. To gauge participants' attitudes towards different opinions, we first observed whether there were any changes in opinion or stance after using the system. We used 7-point Likert scale to rate the quality of opinions in the system, including whether the opinions were logical, well-supported, agreeable, provided new perspectives, and helpful for deciding their own opinion. With the open-ended responses on the opinion changes and the ratings on the opinion qualities in the system, we aimed to understand how being exposed to diverse opinions could change their opinions.

As a more direct measure, we adopted the Respectfulness Composite survey questions from previous work on openness towards opposing views [50]. The composite consisted of four statements on why dissenters would disagree with the participant: "They come from a different cultural (e.g., racial, political, financial, religious) background than I come from", "They do not understand the issue as well as I understand it", "The issue is complex and warrants different opinions", and "They are not as intelligent as I am". The participants were asked to rate each statement on a 7-point Likert scale (1 = Strongly disagree, 7 = Strongly agree). The ratings were averaged to yield a composite measure, with the ratings for disrespectful statements reversed.

6 RESULTS

In this section, we present how participants used StarryThoughts and how the experience of using StarryThoughts affected the participants' opinions towards social issues.

We first present participants' perceived importance and prior knowledge level of the issues used in the study (Table 1). From the difference, we provide some clues on the different experiences of using the system dependent on the issue characteristics. Overall, participants reported that they considered the Retirement issue more important than the Game Addiction issue. On the other hand, they responded that they knew less about the Retirement issue than the Game Addiction issue.

Table 1. Perceived importance and prior knowledge level of the issues used in the study. Results suggest that the participants considered the Retirement issue as more important but knew less about it. (Wilcoxon signed-rank test, *: $p \leq 0.05$, **: $p \leq 0.01$, ***: $p \leq 0.001$)

		Retirement	Game Addiction
First round	Perceived importance ***	5.30 / 7	3.82 / 7
	Prior knowledge **	3.46 / 7	4.46 / 7
Second round	Perceived importance	5.17 / 7	4.00 / 7
	Prior knowledge	3.67 / 7	4.67 / 7

Table 2. Characteristics of opinions read by the participants from the first round of evaluation. The numbers suggest that people were more interested in the opinions of their own groups.

	Opinion		Age		Gender		Political stance	
	Same	Different	Same	Different	Same	Different	Same	Different
Retirement	45.0	24.1	32.2	36.9	38.3	30.8	36.5	32.6
Game Addiction	30.8	25.6	26.7	29.6	30.1	26.2	28.2	28.1

6.1 Strategies and patterns of exploration

To answer our **RQ1**, we analyzed the participants' system usage logs and their open-ended responses on their experience of using StarryThoughts. In this section, we first present statistics showing the diversity of opinions browsed by the users. Then, we examine the behavioral patterns as well as the survey and interview responses to analyze how the participants valued the system features.

6.1.1 Balanced opinion exploration. To gauge the extent of the diversity of opinions participants explored, we counted the number of opinions that the participants read. We defined that the opinion had the same stance with the participant if both the opinion and the participants supported the issue or opposed the issue. If the participant was neutral on the issue, we defined the neutral opinions or moderately supportive or opposing opinions as opinions with the same stance. Every opinion that did not have the same stance as the participant was counted as different. For age group and gender, we only counted the opinions from the group that the participant belonged to as the same group. We analyzed the opinion diversity with respect to the political alignment as we did in terms of the stance on the issue.

Table 2 shows the characteristics of opinions read by the participants. The results suggest that the participants were interested in the opinions of groups with shared characteristics. For instance, Q4 mentioned that he was interested in his peer groups' opinions because he had to live with such peers, so he wanted to better understand their opinions.

6.1.2 Exploring opinions with visualization. Participants benefited from the 2-D visualization as they could investigate the general trend of opinions. Among 5,143 events of opinions being read, 3,341 (65.0%) events occurred without any filters on demographics factors. Participants mentioned that they tried to explore the opinions in a balanced manner in terms of demographic profiles as well as the stance on the issue. Quotes of Q6, who focused on reading the most extreme opinions first, revealed some underlying intent behind such behavior. He mentioned that he was curious about "how people with extreme opinions think", while he thought "moderate people would have opinions that everyone would know already". In other cases, the participants mentioned that they were selecting the opinions without specific criteria in mind.

6.1.3 Exploring opinions with identity factors. With the visualization of opinion distribution and filtering function, one of the most common usage patterns was to inspect the opinion trends of each demographic group. The participants observed the trend of opinions by trying the filter with every possible identity option and glancing at how the dots were horizontally distributed across the 2-D space. Such exploration helped them quickly understand how the opinions on the social issues differed by demographic factors.

Participants used the filters to focus on opinions from a specific group of interest. Participants were commonly interested in the opinions from the groups they belonged to as well as the expected supporters and dissenters. Participants were also intrigued by the groups that had unexpected trends of opinions.

Patterns of opinion distribution for each demographic group served as a starting point of exploration by separating the majority opinions from the minority ones. Doing so allowed them to read both types of opinions to learn how the selected groups think about the issue. For example, Q5 said, "I read the opinions when I looked into a new group to understand why each group thinks the way they do. (...) I chose 2-3 opinions from the majority opinion and 1-2 opinions from the minority opinions."

When exploring a demographic group's opinions, participants mentioned that the absence of a visible trend for each demographic group made the experience less engaging. For example, P37 mentioned that the absence of a clear trend made them feel frustrated, as they could not find a starting point for exploration. Q3, Q4, and Q6 suggested employing more apparent visual elements for visualizing the trend of opinions, such as presenting the histogram or directly showing the proportion. They expected to quickly compare the opinion trends between multiple social groups and recognize the difference with such elements. Q3 mentioned that custom categories more closely related to the issue could make the exploration more intriguing, for example, including their prior experience with games for the Game issue.

6.1.4 Usage of recommendation. Recommending different opinions for fostering diverse exploration of opinions was one of the main features of the system. The activity logs showed that among total 5,143 events of reading opinions, 1,627 (31.6%) opinions were from recommendation. 689 of them were recommended as "Same Stance, Different Point of View", 476 of them were recommended as "Opposite Stance, Different Point of View", and 462 of them were recommended as "Opposite Stance, Similar Point of View".

Out of 50 participants, 43 of them were favorable towards the recommendation of different perspectives. Participants mentioned that the recommendation helped them easily select different opinions to read and compare them against their own in an engaging manner. Participants especially liked the visual design of the recommendation of emphasizing the dots with glows. P11 said that its visual highlights motivated them to click the recommended opinions across the dispersed dots, rather than narrowly exploring a couple of dots near their own.

However, the participants shared some concerns about the recommendation. First, some participants felt the recommendation results did not agree with the description. From the first round of the study, four participants questioned the accuracy of the recommendation algorithm. P37 said, "I did not feel the 'different points of view' were really that different from mine".

Another common concern was about the design of the algorithm itself. After discovering that the recommendation algorithm recommended minority opinions, Q3 and Q4 worried that the algorithm might not accurately show the representative arguments from each group. As an alternative, they suggested focusing on identifying representative opinions for each stance based on user ratings to present the summary of opinions accurately.

Table 3. Argument repertoire of the participants before and after using the system. The participants were divided into three groups according to their prior opinion on the issue: supporters, neutrals, and dissenters. The table shows the number of reasons supporting and disagreeing participants' own stance. For the neutral group, we reported the number of reasons that supported the issue on the column "Reasons for own opinion". The numbers show that the argument repertoire of the participants increased after using the system. (*: $p \leq 0.05$, **: $p \leq 0.01$, ***: $p \leq 0.001$)

		Reasons for own opinion		Reasons for disagreeing opinion	
		Pre	Post	Pre	Post
Retirement	Supporters (N = 20)	1.95	3.2 ***	1.35	2.65 ***
	Neutral (N = 6)	1.33	2.67 *	1.83	2.67
	Dissenters (N = 4)	1.5	2.25	1.5	3.75
Game Addiction	Supporters (N = 14)	1.64	2.79 **	1.43	3.36 ***
	Neutral (N = 4)	1.32	2.51	1.35	3.13
	Dissenters (N = 12)	1.17	2.58 **	0.83	2.08 **

Table 4. Distribution of opinions on Retirement issue from the participants before and after the using the system. While more than half of the participants kept their opinion, it could be observed that the some of the participants with strong prior opinion became moderate after using the system.

Opinion on the Retirement issue		Opinion after using StarryThoughts				
		Strongly Oppose	Oppose	Neutral	Support	Strongly Support
Opinion before using StarryThoughts	Strongly Oppose	1	0	1	0	0
	Oppose	1	3	1	0	0
	Neutral	0	3	4	1	0
	Support	0	2	4	18	3
	Strongly Support	0	1	1	5	1

6.2 Effect of using StarryThoughts for opinion strength and quality

To answer our **RQ2**, we analyzed how the participants changed their opinion after using StarryThoughts and how their confidence in the opinion changed. We included the quotes from the participants that could further explain the effect of StarryThoughts on their opinions.

6.2.1 Argument repertoire. The analysis result of argument repertoire showed that the participants had expanded their argument repertoire for both issues (Table 3). The participants were divided into three groups according to their prior opinion on the issue: supporters, neutrals, and dissenters. We analyzed the number of reasons consistent/inconsistent with their opinion with the Wilcoxon signed-rank test for each group with more than five participants. In all cases except for dissenters and neutrals for the Retirement issues, the participants could come up with at least one more reason for both supporting and objecting to their prior opinion.

6.2.2 Effect of using StarryThoughts on opinion strength. Tables 4 and 5 show how the participants' opinions changed on the issues. The results show that the overall trend of opinions on the issues

Table 5. Distribution of opinions on Game Addiction issue from the participants before and after using StarryThoughts. The results show that the some of the participants with strong prior opinion became moderate after using the system.

Opinion on the Game Addiction issue		Opinion after using StarryThoughts				
		Strongly Oppose	Oppose	Neutral	Support	Strongly Support
Opinion before using StarryThoughts	Strongly Oppose	7	4	0	0	0
	Oppose	1	8	1	0	0
	Neutral	0	5	3	1	0
	Support	0	5	3	10	0
	Strongly Support	0	1	1	0	0

shifted towards less supportive on the issue and the number of people with extreme opinions has decreased.

Exploring diverse opinions with the system helped the participants be more confident in their opinions on the issues. On the Retirement Age issue, the average score for the participants' self-reported level of confidence in their own opinion increased significantly, from 4.18 / 7 to 5.0 / 7 (Wilcoxon signed-rank test, $p = 0.004$). Out of the 50 participants, 29 participants answered that their level of confidence increased for that issue, while 11 participants answered that they became less confident. For the Game Addiction issue, the average score of self-reported level of confidence in participant's opinion also saw a significant increase from 4.38 / 7 to 5.02 / 7 (Wilcoxon signed-rank test, $p = 0.002$). For the Game Addiction issue, 25 out of 50 participants answered that they became more confident, while 7 participants answered that they became less confident.

Open-ended responses from the participants showed some insights on how reading others' opinions could affect participants' opinions.

First, participants could reinforce their opinion by learning that there were others who shared similar opinions. P25 strengthened their opinion on objecting to the Retirement issue, saying, "I thought I was in a minor group, so I expected few people would share my opinion. (After using the system) I felt my opinion was reasonable than I expected."

Second, the participants could discover new supporting arguments for their opinion from reading others' opinions. P31 said they strengthened their opinion on objecting to the Game Addiction issue after using the system. They said, "Among the opinions I read from the system, I found one questioning the specific criteria to define game addiction. I agreed to that opinion a lot, and I became more confident in my opinion."

Third, participants strengthened their own opinion after browsing incoherent opinions and realizing that they were not persuasive enough. Q4 mentioned that his opinion on dissenting the Game Addiction became stronger after reading the supporting opinions. He said "I was surprised to see that people were supportive of the regulation on gaming with such shallow opinions. (...) I could understand them in the sense of personal experiences, but I could not agree with their opinion on how the social regulations or laws should be made."

On the other hand, some participants learned perspectives they had not considered from incoherent opinions and therefore became more prudent in their opinion.

For example, P32, who was initially supportive of increasing the retirement age, changed their opinion to neutral "after reading an opposing opinion pointing that older employees could be less passionate and cause a loss of efficiency in the workforce." P27 said they changed their opinion

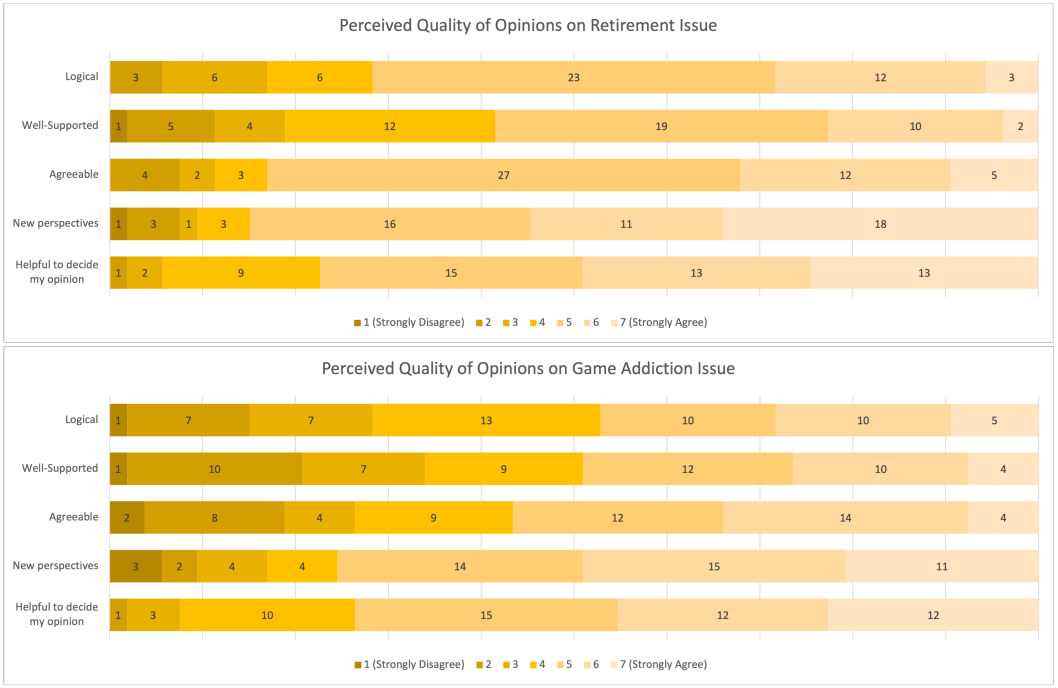

Fig. 7. Distribution of participants' rating on the quality of the opinions used for the study. While participants were favorable to the opinions in general, participants felt opinions on Game Addiction issues were less agreeable and less novel.

on the Game Addiction issue from opposing to neutral, saying "I saw an opinion from a person suffered from game addiction, and they mentioned that external help was essential. Also, I agreed with the opinion that mentioned classifying game addiction as a disorder would help the actual game addicts to get good care."

6.3 Effect of StarryThoughts on evaluation of other's opinions

To answer **RQ3**, we analyzed how the participants valued the opinions in terms of respect and the perceived quality of the opinions.

6.3.1 Respect towards different opinions. The survey results show that the experience of using the system did not significantly affect the level of respect towards other opinions. On the Retirement issue, the Respectfulness Composite index increased from 5.60 / 7 to 5.70 / 7 (Wilcoxon signed-rank test, $p = 0.055$). On the Game Addiction issue, the Respectfulness Composite index increased from 5.47 / 7 to 5.58 / 7 (Wilcoxon signed-rank test, $p = 0.133$). There were no significant differences for each of the component ratings of the composite index as well.

6.3.2 Quality of other opinions. Figure 7 shows the score distribution of the participants' quality evaluation of the opinions they saw. We statistically analyzed the difference among five questions with the Friedman test and conducted post-hoc analyses using Dunn test with Holm correction.

While the participants felt generally positive for the opinion quality, the results showed that participants less agreed that the opinions were logical or well-supported. For the Retirement issue, Logical vs. New perspectives ($p \leq 0.01$), Well-supported vs. New perspectives ($p \leq 0.001$), and

Well-supported vs. Helpful for my opinion ($p \leq 0.01$) showed significant differences. For the Game Addiction issue, Logical vs. Helpful ($p \leq 0.05$) and Well-supported vs. Helpful for my opinion ($p \leq 0.05$) showed significant differences.

Participants commonly mentioned that there were a lot of arguments based on personal experiences. This had varying effects on the persuasiveness of an argument, mostly based on whether the participants did or did not have conflicting experiences themselves. In the case of the Retirement issue, participants mostly reported that they did not know of the experiences mentioned in the opinions, which had a positive effect on the perception of these opinions. However, in the case of the Game Addiction issue, participants were more skeptical towards opinions based on personal experiences because they were "different from what I have experienced." (Q5) Such difference is also visible from the difference in ratings between the two issues. The participants rated opinions on the Game Addiction issue as significantly less agreeable (Wilcoxon signed-rank test, $p = 0.037$) and less new (Wilcoxon signed-rank test, $p = 0.011$).

6.3.3 Value of identity factors. Participants mentioned that the demographic identities helped them understand the opinions better. Out of the 50 participants from the first round of evaluation, 44 responded that the feature was helpful.

One of the common benefits was having the opportunity to observe how different social groups thought about the issue. Q1 said, "I feel like people tend to flock together with people with similar opinions in online space. With the system, I could see the collected opinions of the whole public and filter them. I could acknowledge and resolve my misunderstanding towards social groups that I don't belong to, and people do not share the same opinion with me."

Demographic identities also positively affected the perceived credibility of the opinions. Q4 valued that the demographic identities made the opinions more credible compared to comments on online news, which presents "nothing about who wrote such comments."

Participants also mentioned that they could empathize with the opinion of others when they saw their demographic profiles. Participants used the information on demographic identities to imagine what kind of interests or experiences the authors of the comments would have and how it would be related to the opinion. For example, Q4 said, "I read a supportive opinion for Game Addiction issue, and I saw that the author is a woman in her 40s. I could understand why she ended up having such an opinion. Still, it's separate from whether I agree with her or not." However, this was not always the case, as in the example of Q2, who mentioned that for more politically controversial issues, he would try to see the opinions more skeptically if he knew the author's political stance.

Some participants expressed worries that they might develop stereotypes or biases from associating opinions with individual identities. P18 said, "as I knew about the demographic identities of the author before actually reading the opinions, I realized that my prejudice was making me selectively accept the opinion." Similarly, P7 said that they "felt like I had to reflect my bias in the process" and that "if we start perceiving these individuals as stakeholders, we may garner prejudices, thinking that they only think this because it affects them. That might hinder communication." As a solution to this problem, P18 suggested that "maybe if the identities came after reading the opinion, or placed below the text, it could have helped with the issue of bias."

6.3.4 Value of expectation. Participants commonly mentioned that they would expect others' opinions to be aligned with their own interests or their experience related to the issue. It led to some common patterns in the participants' expectation on the trend of opinions. For example, on the Retirement issue, five out of six participants from the second round mentioned that people in their 20's and 30's would be the likely dissenters as they expected that the issue could shrink the job market. On the Game Addiction issue, all six participants expected that people in their 20's

and 30's would be the likely dissenters because they expected that such group would have more familiar with games.

Confirming expectations. When participants discovered that the opinion was distributed as they expected, they considered the groups were making rational decisions and respected such opinions. For example, Q4 shared his experience with the Retirement issue, "I could see what types of advantages or disadvantages each group would get from the issue so that I could understand both supporter's and dissenter's perspectives." However, with the Game Addiction issue, such experience worsened the negative stereotype of other demographic groups. For example, P2 shared their negative experience of reading opinions on the Game Addiction issues. They mentioned, "I couldn't help laughing as the supportive groups and dissenting groups were almost like what I expected. (...) I hope the supportive group could play games at least once before leaving opinions. I almost got mad at them because they were just saying 'Games are bad, it's a disease"'.

Unexpected trends encourage understanding others. On the other hand, when the participants discovered that the expected trend did not exist or even the opposite trend existed, participants were surprised and intrigued to explore why the social group actually thought differently.

From such exploration, the participants could widen their perspectives on the issue and understand other social groups better. For example, Q6 found out that the people in their 40s opposed the Retirement issue more than he expected. From their arguments, he learned that they were skeptical on the issue because of their negative personal experiences of working with older colleagues. P27 mentioned that they could widen their perspectives when they read the opinions against the initial expectation. From such opinions, they learned that people had considered multiple aspects of the issue even if they had not aligned with the group's interests.

7 DISCUSSION

In general, the evaluation results suggest that StarryThoughts could support the users to explore a wide range of opinions. In this section, we discuss some of the notable findings from the participants' behaviors and comments that would guide future research in this domain.

7.1 Role of identity

Participants' responses and activity patterns suggest that the identity factors supported exploration and interpretation of opinions in several dimensions. Demographic identities made the opinions more credible, and they helped participants understand the whole picture of the opinion landscape by demographic groups. Furthermore, participants used the demographic identities to guess the author's personal interests, experiences, and circumstances related to the issue. Based on such prediction, the participants could interpret opinions in the context of authors. When the actual opinion agreed with the expectation, participants could empathize with and respect the opinion, regardless of their stance. On the other hand, when participants discovered opinions were against their expectations, they were motivated to read the opinions and widen their perspectives on the issues and other social groups. However, participants also pointed out that their preconceptions or mental images of specific demographic groups could be a source of prejudice on other demographic groups.

Finding the right balance of using individual identities for attenuating prejudice would be the next item for future research. To reduce stereotypes, Richards and Hewstone [51] suggest that merely presenting instances against stereotypes would not be successful. The simple presentation would lead to subtyping, where such counterexamples are perceived as an exception to the existing stereotype while not changing the stereotypical perception towards the group. To affect the stereotype, the perceiver should undergo a process of subgrouping. In subgrouping, the perceiver realizes

Table 6. Comparison between the design of StarryThoughts and existing systems.

	ConsiderIt [32]	Opinion Space [16]	StarryThoughts
Opinion visualization	Pros/cons list	Dots on a 2-D space	Dots on a 2-D space
Visualization criteria	Stance on an individual topic	Similarity of opinion profile	Stance on an individual topic
Main user interaction	Building their own pros/cons list	Freely exploring opinions	Freely exploring opinions
Exploration strategies	Pros/cons list nudging for balanced consideration of the issue	Freely exploring opinions on a 2-D space	Freely exploring opinions on a 2-D space with demographic profiles
Recommendation criteria	Opinions appealing to diverse user groups	Opinions agreeable to diverse users	Opinions distant from the one being read

that the stereotypical groups are not a single cohesive entity but composed of different subgroups with their characteristics [9, 48]. Through this process, individuals can gain subgroup salience, and in turn, their level of prejudice towards outgroups are reduced. This process could be implemented by introducing additional axes that could split the demographic groups into smaller subgroups.

7.2 Effect of visualizing opinions

Our system visualized the opinions of the users as dots on a 2-D space, similar to Opinion Space [16]. One difference between StarryThoughts and Opinion Space was how the system placed the opinions on a 2-D space (Table 6). Unlike Opinion Space, we explicitly used the stance of opinions to position them. Although we did not analyze the participants' usage patterns in a controlled experiment, the open-ended responses from participants suggested that the system was engaging and helpful to browse diverse opinions on social issues. We observed that the participants easily understood the arrangement of opinions and used it to discover the distribution of the opinions. One participant also mentioned that they could mentally prepare themselves to see opposing opinions by exploring the opinions by themselves.

Visualization of StarryThoughts allowed the participants to easily explore the opinions in a balanced manner by selecting opinions from extreme sides. This approach is based on values similar to ConsiderIt [32], which also supported the users to see more balanced aspects of the issue and discover comments that could help verify their own decision. In addition to this, StarryThoughts enables the users to discover a wider variety of arguments by not using a collaborative filtering approach in recommending the opinions. Such responses suggest that the "starry night" visualization could support people to accept diverse opinions.

When designing the system, we expected that the demographic identities of the authors and the distribution of opinions could enable the users to discover unexpected trends (or the lack thereof) of opinions for demographic groups or for them to encounter non-stereotypical opinions from a specific demographic group. By doing so, we expected that the users of StarryThoughts would be able to look at diverse opinions on social issues.

The participants' actual usage pattern showed that the participants were able to follow such flow. However, we also learned that discovering a clear trend of opinions was necessary for the participants, as discovering the opinion trend was the starting point for exploring the opinions.

We think an improved design of StarryThoughts would need to present not only the trend of the opinions in an objective scale, but the trend of the actual arguments for each demographic group. For example, topic analysis and visualization of arguments for each demographic group could be possible. For example, Baumer et al. [7] proposed "words web" visualization of text for presenting main ideas of a text while removing the framing effect from the text. Such visualization may contribute to the better delivery of the main points, so that the user could understand what ideas were used by each demographic group. It could be possible for the system to present what kind of social groups are dominant in the opposition for each user, so that the user could understand opposing opinions better.

7.3 Value of recommendation

While the recommendation feature helped the participants explore a diverse range of opinions, the evaluation result raises interesting questions about the design of algorithmic recommendations and the justification for using them.

Unlike previous work that used the appeal to diverse populations as the main criteria for recommendation [16, 32], our system used diversity as the main criteria of recommendation (Table 6). We observed that the participants were favorable to the recommendation feature and how it is visually represented. However, participants questioned how the recommendations were produced and whether they were actually representative opinions from each demographic group.

Although we implemented algorithmic recommendation as a way of facilitating exploration of diverse opinions, there were some limitations to our design. For example, our recommendation results were based on document embedding vectors computed by the weighted average of word vectors. This algorithm uses the inverse word frequency as the weight for computing the vectors. Therefore, it could be susceptible to opinions with rare words, which would cause them to be distant from all the other opinions in the vector space. The algorithm, in turn, could be biased to this specific subset of opinions. Furthermore, as diversity-oriented recommendation would treat every opinion equally regardless of how much of the population agrees with it, users might end up developing a distorted image of the opinion landscape.

To prevent users from misunderstanding the opinion distribution, the system would need to present not only the results of the recommendation but also how they were obtained, and what kind of pitfalls might exist in the results.

Another interesting design consideration regards how to present the recommended opinions. StarryThoughts purposefully utilized simple visual cues - adding a 'glow' to each dot - as an indirect mode of suggestion, keeping the level of intervention to a minimum and allowing the user to acknowledge or ignore the suggested opinions freely. At the same time, the participants needed to select the recommended opinions by themselves, which may incur an additional mental and physical load for the participants. So, there were several participants demanding a feature that shows all recommendations at once. We also provided three different modes of recommendation that were all simultaneously provided to the user at the same level. Other methods of recommendation could include using more direct indicators, reducing the number of recommended options, limiting the types of recommendation modes being provided, or even introducing new modes of recommendation.

7.4 Generalization to other issues and cultures

In this paper, we selected two controversial social issues in South Korea to evaluate the system. As participants' prior knowledge and perceived importance of the issue differed in the two cases, the reactions were different as well. For the Retirement issue, participants had less prior knowledge on the issue, which might have caused the participants to be more open to others' opinions. On the other hand, the participants had more knowledge of the Game Addiction issue, so they might have been more critical.

One important remaining question is how people's perception of others' opinions and use of the system would change for the issues with different characteristics.

While we selected controversial issues at the time of evaluation, the issues did not have a strong association with people's political beliefs or identities. This may have caused the participants to take a more rational stance and be more expectant towards others' responses. However, user reactions might differ if the issues were more sensitive and divisive by political beliefs or identity factors, such as gender conflicts or affirmative action.

In such cases, it might cause users to reinforce prior stereotypes or even develop new stereotypes from observing a polarized opinion distribution. One possible mitigation approach would be to cluster and subgroup the opinions by their argument similarities in addition to demographic identities. By doing so, users could discover arguments they could agree with and possibly break the stereotypes towards other groups. Issues related to minority groups could be an interesting domain to use demographic identities for opinion exploration since presenting explicit identity cues could help users discover opinions from such groups.

Another possible exploration would be to generalize the system to different cultural contexts. First, the list of critical identities may change according to the cultural background. Our system is built based on the social issues and demographic identities in South Korea, which is widely considered as a predominantly monoethnic country. We expected that users would not be as interested in exploring opinions by ethnicity as they would be with age, gender, or political alignment. On the other hand, if the system would be applied in a polyethnic culture such as the United States, the system would need to be modified to encompass ethnicity as an important identity factor of the authors. Second, cultural contexts may affect the users' expectation of opinion distribution by demographic factors. These trends may differ depending on the cultural and historical context of each society. It is also possible that the same issue could be framed differently according to the diverse value systems of each society.

7.5 Limitations

The design features of StarryThoughts enable users to notice the variety of opinions of people regardless of the demographic identities. However, the benefit of using StarryThoughts was not fully explored in our study because the study participants were mostly young college students, as they were mainly recruited from university communities. Therefore, we could only understand the experience of exploring and evaluating others' opinions from the perspectives of the younger generation. Further studies with more diverse populations would help us understand how other demographic groups perceive the opinions through the system. Another limitation of our study is in the demographic distribution of the opinions in the system, which was skewed towards younger people in terms of age and towards more progressive people in terms of political stances. As a result, the experience of using our system might have been limited for the participants, as they might not see enough perspectives that are not from their own demographic group.

7.6 Future Work

A possible future research direction would be to investigate the effects of the spiral of silence [46]. From the current evaluation, we did not find any evidence that participants with minority opinions experienced threats from expressing minority opinions. Participants with minority opinions could learn more about the issues by exploring opposing opinions or even gain more confidence in their opinions by learning that more people had shared opinions than expected. However, we think the threat of the spiral of silence could remain as the users are able to see the opinion distribution at a glance, both at a higher societal level and a lower social group level. We think a deployment study without pre-populated opinions targeting the general public, who are likely less interested and less open to diverse opinions compared to voluntary participants, could be the next step in investigating the issue.

One of the remaining challenges is to scale up the system to encompass the opinions of more users. With the current visualization, adding more opinions causes a denser display of dots, which could reduce usability when selecting and exploring the opinions. Interactive visualizations for presenting overviews and detailed pictures such as Overview+Detail [11], as well as clustering opinions could be a possible solution to expand StarryThoughts into a larger scale.

8 CONCLUSION

This paper explored the idea of using the identity of individuals for discovering diverse opinions around social issues and encouraging respectful attitudes for them. We built StarryThoughts, an online system for presenting the diversity of opinions and supporting exploration of them with identity-based filtering and content-based recommendation of opinions. Findings from the user study suggest that demographic identities could be a meaningful cue for exploring diverse opinions around social issues and gaining more respectful attitudes toward others' opinions. With StarryThoughts, we envision an online space where people can exchange opinions on social issues with respect and openness for those with different perspectives.

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