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Putting 'filter bubble' effects to the test: evidence on the polarizing impact of ideology-based news recommendation from two experiments in Germany and the U.S.

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ABSTRACT

Algorithmic news recommender systems (NRS) are present in many digital platforms. A decade after Eli Pariser introduced the infamous 'filter bubble' hypothesis, empirical evidence challenges the assumption that recommendation algorithms predominantly create homogeneous opinion environments. Studies indicate that algorithmic platform use may amplify users' political polarization. Whether the link between platform use and polarization can be causally explained by ideological news filtering, however, is still an unanswered question as rigid causal designs to test the notion of 'filter bubble' effects are still largely lacking. To fill this gap, we conducted two experimental studies in Germany ($n = 1{,}786$) and the U.S. ($n = 1{,}306$) with running NRS selecting news items based on the political orientation and political interest of its users. For both national contexts, results indicate that an NRS with a bias towards users' political preferences increases ideological polarization among politically moderate individuals, supporting the notion of 'filter bubble' effects for this group. No such pattern could be found for affective polarization. Yet, in the German data, affective polarization among moderate users was reduced by a politically balanced NRS (as compared to a randomized news diet), while the same NRS increased affective polarization of politically extreme participants. We discuss the democratic implications of these findings against the backdrop of increasing digital news consumption.

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Introduction

Polarization is seen as a key driving force behind numerous societal and political (mal)developments in recent years (e.g., Baldassarri & Gelman, 2008; Fiorina & Abrams, 2008). The emergence of digital media, particularly algorithmically tailored or individually customizable environments such as social media platforms, news aggregators, and search

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engines, is often cited as a development that has fueled polarization (for an overview, see, Barberá, 2020). Particularly, the alleged formation of 'filter bubbles' through algorithmic content selection on the Internet is typically regarded as a major cause for polarization (Pariser, 2011). The 'filter bubble' hypothesis proposes that personalized news recommender systems (NRS) prioritize articles that align with users' pre-existing political beliefs. This process is thought to establish enclosed information environments that strengthen users' existing viewpoints, potentially contributing to the overall polarization of society.

Empirical evidence on the emergence of 'filter bubble' like information environments as a result of algorithmic news filtering is mixed, at best. While several studies suggest that the use of algorithmic news feeds does not necessarily decrease news content heterogeneity (Hüllmann & Sensmeier, 2022; Jürgens & Stark, 2022; Kitchens et al., 2020; Michiels et al., 2023), others found evidence supporting this assumption, particularly so with regards to the Facebook algorithm (Guess et al., 2023; Levy, 2021). Moreover, there is a plethora of research indicating a correlation between the use of algorithmically curated platforms and both ideological (e.g., Ohme, 2021) as well as affective polarization (e.g., Lee et al., 2022).

Thus, while the extent to which NRS produce 'filter bubbles' is unclear, there still seems room to assume 'filter bubble' effects on political polarization. At the same time, rigid causal designs to test the notion of 'filter bubble' effects are still largely lacking (Ludwig & Müller, 2022; Mitova et al., 2023). To fill this gap, the present article presents the results of two experimental studies in Germany and the U.S. with running NRS selecting news items based on the political orientation and political interest of its users.

'Filter bubble' effects on political polarization

Political polarization is not a one-dimensional phenomenon but can occur in different forms. The most prominent distinction is made between affective and ideological polarization (Iyengar et al., 2012). Both entail the segregation of individuals from divergent political factions, typically rooted in the ideological left and right, due to disparities in policy perspectives (Webster & Abramowitz, 2017). In the case of affective polarization, this is manifested through a strong affinity for and a strong attachment to one's partisan party, accompanied by the simultaneous dislike of the opposing party and a desire for distance from it and its members (Iyengar et al., 2012). Ideological polarization resembles affective polarization but revolves around the degree of divergence and endorsement of stances on issues or attitudes toward political topics. Consequently, ideological polarization is often, but not necessarily always, linked to partisan identification. Particularly in nations with multi-party systems, as is the case with our study context Germany, ideological polarization might be an indicator of societal fragmentation that is easier to assess compared to affective polarization, as the political coalitions and rivalries are oftentimes manifold and less straightforward than in bipolar two-party systems, such as the U.S.

The notion of 'filter bubble' effects on political polarization suggests that NRS could be held accountable for promoting polarization by creating homogeneous opinion environments online (Pariser, 2011). This allegedly occurs through a hybrid combination of content-based (CB) and demographic filtering (DF) that is typically used in real-world NRS (Pazzani, 1999). CB calculates similarities between items based on their feature vectors. For a news article, this vector could e.g., contain the topics of the article, the news outlet,

or the words included in the article text. DF operates under the premise that users with similar demographics share common interests, and, therefore, are also interested in similar news items. User similarity is determined by analyzing profile information such as age, gender, political affiliation, or the location of the user to recommend items that are popular among users with similar characteristics. Sorting news based on age or location might not be seen as very problematic (although this might also lead to biased information environments creating bigger divides among societal groups), but when it comes to custom-tailored news based on political orientation, homogeneous information environments might, in fact, occur.

The influence of NRS considering users' political orientation, nevertheless, is still disputed and only little research has been conducted so far. In particular, there is an urgent need for causal research designs (Ludwig & Müller, 2022). Most studies establishing links between social media use and political polarization within the electorate rely exclusively on survey data (e.g., Lee et al., 2022; Ohme, 2021). Typically, this research uses the extent of social media use as a predictor for polarization. However, this does not allow us to claim a causal trajectory between algorithmic content selection and polarization. Social media platforms have other features (such as popularity cues or commenting functions) that might explain why their users are more polarized than non-users. Nonetheless, evidence on algorithm effects from a field experiment indicates that exposure to pro-attitudinal news exposure on social media increases affective polarization (Levy, 2021). The same study found that social media algorithms limit exposure to counter-attitudinal news, consequently increasing the probability of affective polarization, without however causally testing the link between algorithmic selection and polarization (Levy, 2021).

Contradictory, a field experiment by Guess et al. (2023) found that neither ideological polarization nor affective polarization were affected by removing the algorithmic filtering function from consenting users' Facebook and Instagram feeds during the 2020 U.S. election. However, while this study may provide evidence of the absence of causal effects of algorithm use in general, it is still unable to isolate specific algorithm effects, such as the 'filter bubble' assumption. For instance, the study also found that in the no-algorithm condition, the content diversity of participants' news feeds increased, which also meant an increase in hate speech and untrustworthy news content. Thus, negativity in the news feed might have counteracted the potential impact of turning off filtering along ideological lines in the no-algorithm condition (see, e.g., Wu & Shen, 2020), ultimately leading to the observed net null effect of removing algorithmic filtering altogether. This could then not be read as evidence against 'filter bubble' effects.

Taken together, these previous field experiments, even though offering links between polarization and algorithm use, are not unambiguously able to tell whether ideology-based filtering or some other systematically varying patterns can be held accountable for the observed (null) effects on polarization. Only designs that compare the polarizing effects of content selected by an NRS (or different versions thereof, see Ludwig et al., 2023) would be able to establish such a causal trajectory. Yet, there are but a few studies using such designs within the realms of 'filter bubble' research. Two experiments from Germany (Kelm et al., 2023; Neumann et al., 2021) indicate little difference between the effects of exposure to algorithmically and randomly selected political messages on both ideological and affective polarization. Contrary to that, Cho et al. (2020) found that exposing participants to videos selected by the YouTube algorithm based on their

personal preferences increased affective polarization. Beyond this, evidence is scarce. In light of these somewhat limited findings, we stick with the original 'filter bubble' hypothesis for the present study:

> H1: Engagement with an NRS suggesting ideologically homogeneous news content will heighten a) ideological and b) affective polarization (compared to engagement with random news suggestions).

Countering polarization with content diversity?

Extant research, in turn, also suggests that more diverse content recommendations might have depolarizing effects. From a theoretical, deliberative standpoint, the significance of being exposed to diverse viewpoints lies in its ability to assist citizens in forming well-informed perspectives and fostering attitudes that are less polarized and more tolerant towards individuals holding differing opinions (Garrett & Stroud, 2014). Consequently, in deliberation theory, it is regarded as a prerequisite for the functioning of democracy that individuals with diverse political orientations cultivate mutual understanding and engage in compromise. This could be strengthened by NRS promoting diverse political viewpoints instead of creating homogeneous opinion environments (Helberger et al., 2018). In line with this argument, Heitz et al. (2022) discovered a relationship between diverse news recommendations and increased tolerance for opposing views, particularly among politically conservative users. Furthermore, it was found that exposure to counter-attitudinal news decreases negative attitudes toward the opposing political party, thus reducing affective polarization (Levy, 2021). Based on this prior research, we thus propose the second hypothesis:

> H2: Engagement with an NRS suggesting ideologically balanced news content will reduce a) ideological and b) affective polarization (compared to engagement with random news suggestions).

The moderating influence of political extremity

Research into political polarization suggests that the polarizing impact of news exposure varies as a function of political extremity (e.g., Brown & Hohman, 2022; Karlsen et al., 2017). While politically more moderate individuals might not be as strong in their issue positions and their party affiliation, and therefore also not so easy to polarize, the opposite can be assumed for politically more extreme individuals. The latter are more attached to 'their' party, which is often also defining their sense of self (Ajzen, 2001), and are, therefore, more motivated to hold on to their attitudes (Dylko et al., 2017), which makes them more likely to be polarized (Brown & Hohman, 2022). In line with this, Karlsen et al. (2017) found in an experimental study that politically extreme people were more affected by one-sided information than people with moderate opinions. Hence, it can be assumed that content that reinforces preexisting positions has different effects on politically extreme and politically moderate individuals. However, there might also be 'ceiling effects' that limit additional polarization. Evidence pointing in this direction was found by Dylko et al. (2017): When customization technology was provided to ideologically extreme individuals it only modestly decreased their exposure to counter-attitudinal content, while for politically moderate individuals counter-

attitudinal exposure decreased substantially. This is explained by the fact that counter-attitudinal exposure was already very low for politically extreme individuals.

More diverse news recommendations, on the other hand, might reduce polarized attitudes by providing new perspectives and opening up thoughts for diverging viewpoints. This should rather be the case for people who do not have very strong prior issue stances and affiliations with political parties, thus for politically more moderate individuals. At the same time, politically more moderate individuals might already be more commonly exposed to a diverse information environment less shaped along the lines of partisan selective exposure. Therefore, counter-attitudinal content could also have weaker depolarization effects in this group. Among politically extreme individuals, any divergence from their 'true' viewpoint might be seen as a nuisance and in turn rather create a backfire effect, leading to an even stronger attachment to prior viewpoints (e.g., Bail et al., 2018). But also, the opposite might be true: individuals with strong political attitudes might not be exposed to counter-attitudinal viewpoints very often, wherefore more diverse news content might open up new avenues of thinking and lead to depolarization, as shown in an experimental study by Fishkin et al. (2021) analyzing group discussions about political issues. In light of this heterogeneity of potential interaction patterns, we ask:

RQ1: Does the level of political extremity moderate the effects postulated in H1 and H2?

Influences of political and media systems

The potential impact of NRS algorithms on polarization, of course, is embedded in societal contexts. Different (a) political and (b) media systems might lead to deviating algorithm effects. It has been argued that media systems that feature high journalistic professionalism, state support, and low political parallelism will result in a less polarized mediated discourse (Hallin & Mancini, 2004; Humprecht et al., 2022). In such 'democratic-corporatist' systems, therefore, NRS' impact on political polarization might be 'naturally' limited by a lower amount of potentially polarizing content that can be selected from the pool of media content that is available overall.

Media system features are intertwined with features of the political system in the respective countries (Hallin & Mancini, 2004). The concept of political polarization has been developed predominantly with the majority-oriented U.S. two-party system in mind (Wagner, 2021), in which clear frontiers between political camps can be drawn. In a multipolar, consensus-oriented party system, on the contrary, multiple positive identifications with several parties are possible (e.g., Garry, 2007). Consequently, frontiers between party camps are more ambiguous which might create less opportunity structures for polarization to occur. Consequently, again NRS algorithms might have less potentially polarizing content to be selected from the overall pool of available news content.

Taken together, media and political system factors speak in favor of a lower probability of algorithmic polarization effects in less polarized countries due to the less polarized content available. Countering this argument, however, ceiling effects could occur in highly polarized countries. An already highly polarized population might be less likely to become even more polarized by NRS use. Against this backdrop, we chose to test our

hypotheses and the research question in two different national settings: the U.S. – a prototypical two-party political-system which has a 'hybrid' media system with medium journalistic professionalism, state support, political parallelism (Humprecht et al., 2022) and a highly polarized population that is highly polarized (Boxell et al., 2024) – and Germany – which has a prototypical 'democratic-corporatist' media system, a multi-party, consensus-oriented political system, but a less polarized population (Boxell et al., 2024).

RQ2: Are the effects postulated in H1 & H2 different between the U.S: and Germany?

Method

To test our hypotheses and research questions we conducted two experimental studies[1] with a most similar design in two different national settings, the U.S. (dual-party system, $n = 1{,}306$) and Germany (multi-party system, $n = 1{,}786$).[2] We developed a four-step empirical procedure that enabled us to use a real NRS that participants were able to engage with as experimental stimulus: First, we scraped two large corpora of real U.S. ($n = 10{,}801$) and German ($n = 5{,}157$) news articles from a broad variety of different news websites (including all major mainstream outlets as well as left- and right-wing alternative news sites), all relating to the topic of migration. Second, we conducted an online pre-study in each of the two countries in which a quota sample of their populations was asked to rate a random selection of news items from the respective national corpus and state their political interest and left-right orientation. Third, this data was used to train a demographic NRS to learn the news preferences of users of different political orientation. Fourth, two different versions of this pre-trained NRS were used as experimental stimuli (alongside a control group) in two online experiments in the U.S. and Germany.

NRS as experimental stimuli

There are three reasons why we opted to use real NRS to approximate 'filter bubble' effects in the present study: First, we deemed a text-similarity based algorithmic selection to potentially include more mis-classified articles as stimulus versions constructed by a researcher. Second, it enabled us to include a large number of texts to be selected from. Third, using a manually constructed article selection instead might have yielded in an overspecification of the experimental conditions, so that a 'filter bubble' like environment might have been presented in an exaggerated way. Taken together, using real NRS as experimental stimuli is therefore a pragmatic way of creating a naturalistic article selection for the study.

Generation of news corpora

Prior to setting up NRS for the experimental studies, we had to generate two news corpora (for the U.S, and Germany, respectively) that the NRS could draw articles from. To limit the amount of topical variance in the news corpora and, thereby, increase recommendation quality for the (cold-starting) NRS algorithms, we opted to select topically homogeneous articles. We opted for the topic of migration and flight, as we deemed it

sufficiently relevant and potentially polarizing for a largest possible group among experiments' participants in both countries.

The U.S. news corpus (compare Iana et al., 2023) comprises 10,320 English-language articles from 45 U.S. news outlets, covering the period from 1 January 2021, to 1 July 2022. It includes established national quality news outlets (e.g., *MSNBC*), tabloid newspapers (e.g., *New York Post*) as well as left-wing (e.g., *Mother Jones*) and right-wing partisan media (e.g., *Breitbart News Network*). The German news corpus (compare Iana et al., 2023) consists of 8,642 news articles which were sourced from 39 different news outlets and encompass the time span from 1 January 2019, to 20 October 2020. Again, the sample includes national quality news outlets (e.g., *Süddeutsche Zeitung*), tabloid outlets (e.g., *Bild*) as well as left- (e.g., *Junge Welt*) and right-wing partisan media (e.g., *PI-News*). Full lists of outlets for both corpora can be found on osf.

For both corpora, all articles were scraped with keyword searches referring to the topic of interest (e.g., 'refugee', 'asylum', 'immigrant'). The selected articles had to fall within a length range of 150–1500 words and were screened to exclude live tickers, video descriptions, or letters to the editor. To ensure consistency, any distracting text elements, such as ads or hyperlinks, were removed, and the texts were uniformly formatted. All identifying information, including outlet and author names, as well as images and logos, were removed as well.

Generation of training data

To generate training data for the NRS, we conducted pre-studies for each of our two experiments in the countries under study, around two weeks before the respective main study (Germany: 20 February 2022 – 27 February 2022; USA: 19 August 2022 – 26 August 2022). In an anonymous online experiment, user profiles and browsing histories are unavailable to an NRS system, as this would be the case in a typical platform setting. We thus have a cold start problem with the NRS. To compensate for this, we conducted two online vignette surveys as pre-studies, in which we measured participants' evaluations of four randomly assigned news items from the previously scraped corpora alongside their political left-right orientation and political interest. To ensure structural similarity of the data from the pre-studies to the main studies, participants for the pre-studies were recruited via the same online access panel providers as the respective main studies (for the U.S. data: Dynata; for the German data: Bilendi), both quoted for age, gender, and education of the countries' general populations aged 18–74 (U.S. sample: n = 1,499; age: M = 46.76, SD = 16.69; 51.91% female; 19.4% with college degree; German sample: n = 1,635; age: M = 50.56, SD = 15.13; 50.70% female; 29.4% with Abitur).

The evaluation of news items comprised an assessment of teasers of news articles with a star rating. This made it possible to collect information about what kind of articles individuals with a specific political orientation favor. This information was subsequently used in the main study to suggest news items tailored to the political orientation of its users. To train the NRS algorithms, we grouped users into four different groups, based on their self-reported political profile: (a) left-leaning partisans (U.S. sample: 18.21%, German sample: 25.99%), (b) partisans of the political center (U.S. sample: 25.88%, German sample: 33.70%), (c) right-leaning partisans (U.S. sample: 30.95%, German sample: 17.61%), and (d) politically disinterested individuals (U.S. sample: 22.55%, German sample: 20.31%). The latter group was constructed after a first descriptive assessment

of the pre-study data revealed that a large cluster of participants existed who identified as politically moderate but at the same time, largely uninterested in politics. Political interest was assessed on a seven-point scale (1 = not interested to 7 = very interested) and we used a value of 3 or lower as the cut-off point for this fourth group to which participants were assigned irrespective of their left-right orientation. The remaining sample was distributed across the three political partisan groups, using the left-right self-assessment on a scale from 1 (= left-wing) to 11 (= right-wing) according to the following logic: 1 to 5 = left-wing partisan, 6 = partisan of the political center, 7 to 11 = right-wing partisan. After clustering of cases, the star ratings of participants from the different groups were passed on to the NRS algorithms as training data for the article preferences in the four different groups.

NRS design

In both experiments, we compared two different types of hybrid NRS. The first NRS ('Similar2Peer') recommended a mix of news articles that were liked by individuals with a similar political orientation as the respective participant in a pre-study (DF) as well as news articles similar to articles the user had selected previously (CB). The latter was implemented using the term frequency-inverse document frequency (tf-idf). The second NRS ('Balanced') likewise recommended news articles similar to articles the user had selected previously, combined with demographic filtering of which suggestions were 50% news articles that were liked by individuals with a similar political orientation and 50% news articles which were liked by individuals with a different political orientation in the pre-study. These two NRS[3] were compared with a control condition that featured a random article selection from the same article corpora but did not vary from the two experimental treatments with regards to any other design element (3×1 design, 'Similar2Peer' NRS vs. 'Balanced' NRS vs. no NRS/random recommendations). Pretests ensured the technical functionality of the algorithmic implementations as well as the comprehensibility of the questionnaires.

The demographic filtering component was based on the data points collected in the pre-studies. The NRS algorithms used the same survey items to group users into the same four clusters of political orientation as were used to pool the pre-study data: (a) politically interested left-leaning partisans (U.S. sample: 14.78%, German sample: 26.88%), (b) politically interested partisans of the political center (U.S. sample: 20.59%, German sample: 25.69%), (c) politically interested right-leaning partisans (U.S. sample: 22.97%, German sample: 16.46%), and (d) politically disinterested (U.S. sample: 41.65%, German sample: 30.96%).

After data collection, we ensured the correct functioning of the NRS versions by comparing the average amount of read articles with attitude-consistent endorsements in the different experimental groups. Results (see, Table 1) indicate that both the Similar2Peer NRS and the Balanced NRS lead to significantly higher exposure to such articles as compared to random suggestions. However, it is only for right-wing participants that the Similar2Peer algorithm resulted in a clearly higher selection of attitude-consistent articles than the Balanced NRS: Thus, even though the Balanced NRS recommended a more diverse set of articles than the Similar2Peer algorithm, this was seemingly counteracted by users' selection decisions in most user groups. Nonetheless, these data can still be read as supporting the internal validity of the experiment as both NRS systems were designed

Table 1. NRS validation results.

Participant group		German sample	U.S. sample
Left-wing participants	S2P NRS	2.84 (1.21)	4.46 (1.17)
	Balanced NRS	2.82 (1.22)	4.38 (1.28)
	Random	1.22 (0.97)	1.22 (0.88)
Centrist participants	S2P NRS	3.68 (0.98)	4.51 (1.11)
	Balanced NRS	3.49 (1.03)	4.57 (1.07)
	Random	1.59 (0.96)	1.50 (1.08)
Right-wing participants	S2P NRS	2.49 (1.30)	4.84 (0.68)
	Balanced NRS	1.34 (1.03)	2.04 (1.06)
	Random	1.01 (0.94)	1.72 (1.07)
Politically disinterested participants	S2P NRS	3.47 (1.13)	4.99 (0.09)
	Balanced NRS	3.55 (1.03)	5.00 (0.00)
	Random	1.59 (0.96)	1.68 (1.00)

Note: Values are mean values with standard deviations in parentheses. Values indicate the average amount of exposure to articles with attitude-consistent endorsement in the different experimental groups on a scale from 0 to 5 articles.

to emulate different versions of 'filter bubble' like information environments, which the analyses indicate they did.

Main studies: participants & procedure

The German sample of the main study consists of 1,786 participants quoted to match German citizens aged 18–74 with regard to age (M = 48.25, SD = 15.96), gender (49.44% female), and education (43.51% with Abitur). We recruited the participants through the access panel Bilendi, a German company often contracted for academic research purposes. The U.S. sample consists of 1,306 participants also quoted to match U.S. citizens aged 18–74 with regard to age (M = 47.29, SD = 17.63), gender (51.84% female), and education (94.56% finished high school). We recruited these participants through the access panel Dynata, an international panel service frequently engaged in academic research endeavors. In both experiments, participants were evenly distributed among three different experimental conditions. Randomization checks revealed no significant differences between the treatment groups. Only participants using desktop-based devices were included in the study due to the display limitations of the experimental conditions.

During the experiment, participants were randomly assigned to one of the three experimental conditions. Before being exposed to the experimental treatment, participants responded to several survey items, including the scales measuring political left-right orientation and political interest. In the two NRS conditions, these two measured variables were used to assign participants to one of the four political orientation groups (left-wing partisans, partisans of the political center, right-wing partisans, and politically disinterested) following the rationale outlined above. In the S2P condition, participants consequently received merely article recommendations that had been positively evaluated by members of the same group in the pre-study. In the Balanced condition, this made up of only 50% of recommendations, the other half of recommended articles came from the pools of news items that were positively evaluated in the other three groups.

At the initial stage of stimulus exposure, participants were displayed a selection of six article recommendations that were selected according to the respective experimental

conditions' selection routine. Participants were then asked to select one of the six displayed articles for reading. The selection interface presented the headlines and the first 50 words of each article. After selecting and reading the chosen article, participants were presented with another set of six recommendations, which were either generated randomly (control condition) or tailored by one of the two NRS versions, depending on the participant's experimental assignment. This process was repeated five times, with the recommendations gradually becoming more personalized based on the participants' selections in the two NRS conditions. The interactive stimulus was integrated into an online questionnaire. After stimulus presentation, the dependent variables, as well as sociodemographic variables were assessed.

Measures

Affective polarization was assessed in the U.S. study focusing on the two main parties, Republicans and Democrats. We applied the widely used and well-tested feeling thermometer (Stroud, 2010). This scale ranges from 0 to 100, with lower values indicating less warmth or positive sentiment towards the respective political party (Stroud, 2010). For the subsequent analyses, an index of affective polarization was computed based on the absolute difference between the scores given to the two groups (M = 50.15, SD = 39.78). For the German study, a country with a multi-party system, a similar approach was employed to measure affective polarization. *Affective polarization* was assessed separately for all six parties represented in the German national parliament at the time of the study, using feeling thermometers. To calculate an index of affective polarization, we followed Wagner's (2021) suggestion for multi-party systems to compute an index representing the average absolute like-dislike difference between a respondent's most favorably rated party and each of the other parties in parliament (M = 49.83, SD = 22.15).

To assess *ideological polarization*, participants were presented with 12 items related to the topic of immigration and their attitudes toward refugees. Each item represented a contrasting viewpoint, ranging from strong right-wing to left-wing political stances. Participants were asked to rate their level of agreement or disagreement with each item using a 7-point Likert scale. After inverse-coding negatively worded items, the reliability of this measurement was high, with a Cronbach's alpha coefficient of .95 in Germany, and .91 in the U.S. The survey items included subjects such as the acceptance of refugees in Germany, respectively the U.S., along with contrasting viewpoints on economic and cultural aspects, and criminality, as well as their positive contribution to German, respectively U.S. society (see the full list of items in Online Appendix 5 on osf). By folding the scores from the 12 items at the midpoint, signifying the lower range of the polarization spectrum, while the two extremes represent the upper range, an ideological polarization index was calculated (Germany: $M = 1.83$, $SD = 0.68$; U.S.: $M = 1.88$, $SD = 0.73$).

Subjects' *level of political extremity* was calculated based on an 11-point Likert scale inquiring about the participants' political orientation on the left-right spectrum (Kroh, 2007). This scale was folded at the mid-score, with the midpoint also corresponding to moderate partisans. This resulted in a scale from 1 = political center orientation (moderate partisans) to 6 = extreme (left/right) orientation (Germany: $M = 2.43$, $SD = 1.56$; U.S.: $M = 2.86$, $SD = 1.97$).

Political interest was assessed using five items (Germany: α = .94; U.S.: α = .93), that asked for participants' general interest in politics and political topics and the frequency of their political information intake (see the full list of items in Online Appendix 5 on osf). A mean index was computed for further analyses (Germany: $M = 4.59$, $SD = 1.59$; U.S.: $M = 4.14$, $SD = 1.81$).

Results

Linear regression analyses for the two dependent variables affective and ideological polarization were computed to test the hypotheses and research questions (see Tables 2 and 3). The models' predictor variables included dummies for the experimental conditions (with random article selection as the control condition), political extremity, interaction terms of political extremity, and experimental conditions as well as a set of control variables. Importantly, when linear regression models include interactions between a dummy and a metric variable, the main effect of the dummy variable does not indicate an average effect of the dummy contrast condition that occurs at all levels of the moderator. Instead, it indicates the effect of the dummy only for those cases in which the continuous moderator equals zero. Hence, in our example, a significant main effect of the experimental conditions only indicates a signification difference in polarization varied between experimental conditions among participants with zero political extremity. Consequently, to interpret results patterns, a visual exploration of the interactions between experimental conditions and political extremity is necessary in addition to the coefficient tables.

Regression coefficients indicate that the NRS version 'Similar2Peer' significantly heightened ideological polarization in the U.S. study as well as in the German study (see, Table 1), in comparison to random suggestions. This is in line with H1a. However, the interaction terms with political extremity are not significant in both studies. As can be seen from the interaction plots (see, Figures 1 and 2), this is because ideological polarization is only higher among politically moderate participants in the 'Similar2Peer' condition (as compared to the control condition) whereas this pattern vanishes with increasing political extremity (RQ1). H2a is unsupported. The 'Balanced' NRS version

Table 2. Linear regression results for ideological polarization.

	Germany		U.S.A.	
	β	B (SE)	*β*	B (SE)
Intercept		1.06 (0.10)		1.46 (0.09)
NRS version: Balanced	.07	0.08 (0.06)	.03	0.05 (0.08)
NRS version: Similar2Peer	.12*	0.17 (0.07)	.11*	0.17 (0.08)
Political orientation	.14***	0.04 (0.01)	−.01	0.00 (0.01)
Level of political extremity	.36***	0.15 (0.02)	.22***	0.08 (0.02)
Political interest	.04	0.02 (0.01)	0.12***	0.05 (0.01)
Age	0.06*	0.00 (0.00)	0.02	0.00 (0.00)
Gender	.05*	0.07 (0.03)	−.01	−0.01 (0.04)
High school degree (1 = no; 2 = yes)	−.06**	−0.04 (0.02)	−.06*	−.03 (0.01)
NRS version: Balanced * level of political extremity	−.09	−0.04 (0.02)	−.01	0.00 (0.02)
NRS version: Similar2Peer * level of political extremity	−.09	−0.04 (0.02)	−.06	−0.03 (0.02)
df	1,774		1,287	
Adjusted model R^2	.091		.056	

Note: Values are standardized and unstandardized linear regression coefficients. * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

Table 3. Linear regression results for affective polarization.

	Germany		U.S.A.	
	β	B (SE)	*β*	B (SE)
Intercept		24.17 (3.29)		6.82 (4.96)
NRS version: Balanced	−.15**	−7.03 (2.25)	−.05	−4.13 (4.39)
NRS version: Similar2Peer	−.08	−3.74 (2.24)	.06	5.46 (4.41)
Political orientation	.04	0.44 (0.25)	.01	0.19 (0.39)
Level of political extremity	.17***	2.36 (0.56)	.25***	5.06 (0.89)
Political interest	.14***	1.95 (0.33)	.17***	3.65 (0.63)
Age	.18***	0.25 (0.03)	.15***	0.34 (0.06)
Gender	.01	0.35 (1.01)	.00	−0.02 (2.07)
High school degree (1 = no; 2 = yes)	−.04	−0.78 (0.54)	−.07*	−1.67 (0.67)
NRS version: Balanced * level of political extremity	.11*	1.56 (0.77)	.06	1.34 (1.27)
NRS version: Similar2Peer * level of political extremity	.04	0.67 (0.79)	−.05	−1.05 (1.27)
df	1,774		1,287	
Adjusted model R^2	.112		.133	

Note: Values are standardized and unstandardized linear regression coefficients. * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

does not lead to substantially different patterns of ideological polarization as compared to a random article selection.

Concerning affective polarization, results indicate null findings in the U.S. study in which all three experimental conditions did not significantly differ, whereas significant patterns can be observed in the German sample (RQ2). In both countries, the 'Similar2-Peer' condition did not alter affective polarization. This contradicts H1b. H2b is partially supported as the 'Balanced' NRS version also significantly reduces affective polarization among more moderate individuals in the German sample. In this group, it seems to be even more effective at reducing affective polarization than the 'Similar2Peer' NRS, as judged from Figure 3.

Discussion

This study aimed to put the infamous 'filter bubble' effects hypothesis to a rigid empirical test. To achieve this goal, we conducted an experimental survey study that analyzed the polarization effects of NRS filtering along the lines of political preferences across two national settings. Our study did indeed observe results patterns that are in line with the 'filter bubble' hypothesis. However, as effect sizes are rather small, the impact of algorithmic content selection on polarization seems to be rather limited in total.

Findings revealed that, both in Germany and the U.S., algorithms suggesting ideologically congruent content slightly heightened ideological polarization, but only for politically moderate individuals. At least two reasons might account for the conditionality of the observed effect: First, as politically more moderate individuals generally consume a more balanced news diet (Guess, 2021), a set of recommendations featuring solely politically congruent news items could lead to stronger effects as it deviates stronger from users' usual news diet. Second, it might be that a ceiling effect of polarization is at play among politically more extreme individuals which does not allow for a further increase as a result of stimulus exposure (see, Dylko et al., 2017). Interestingly, no effects of our 'Similar2Peer' NRS on affective polarization could be detected in either national setting. Thus, the 'filter bubble' hypothesis is only partially supported by the data collected in this research, namely for ideological, but not affective polarization.

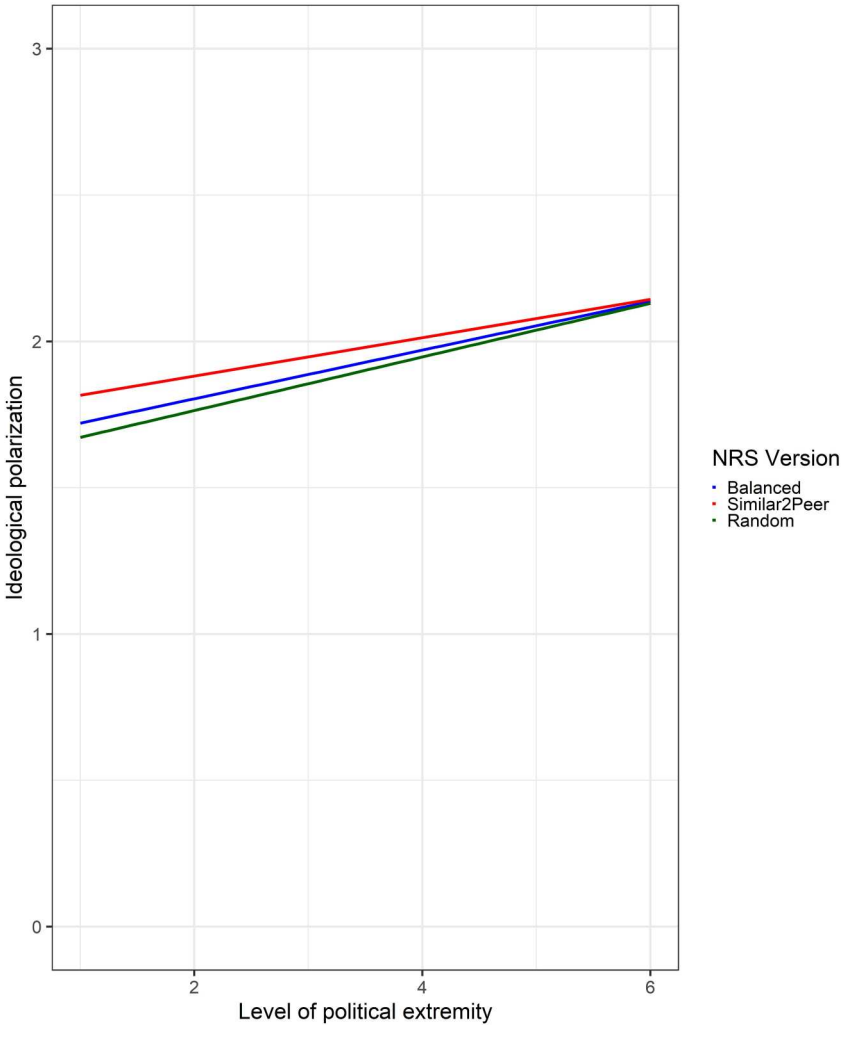

Figure 1. Plot of the interaction between NRS version and political extremity in predicting ideological polarization in the U.S. sample.

That said, we were also interested in whether an ideologically balanced NRS recommending a heterogeneous set of news items was able to alleviate potential 'filter bubble' effects. In the present experiment, an ideologically balanced NRS did indeed reduce affective polarization for politically moderate individuals in Germany, compared to random suggestions. In the U.S., results suggest a similar tendency, but no significant effects. In the German context, it seems that having a higher exposure to ideologically diverse news content can milden affective polarization, yet again only for politically moderate individuals. Remarkably, the two recommendation algorithms we tested had effects on different polarization dimensions. While we found that 'filter bubble' like attitude consistent recommendations only affected ideological polarization, a balanced NRS did not vary from random

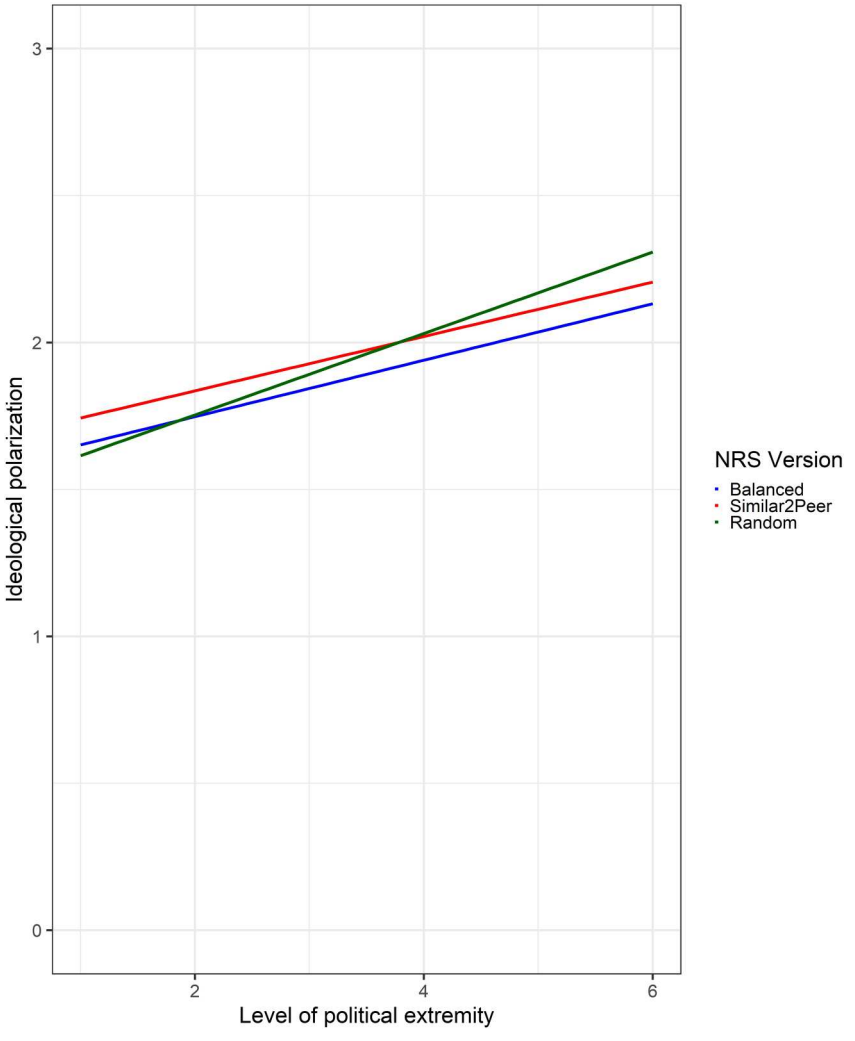

Figure 2. Plot of the interaction between NRS version and political extremity in predicting ideological polarization in the German sample.

recommendations in its effect on this dimension, but diminished affective polarization (at least in the German case).

As affective polarization is typically seen as the more severe problem of Western societies nowadays (Iyengar et al., 2012), these patterns could be seen as a spark of hope: First, in line with prior research (for an overview, see, Ludwig & Müller, 2022), our study suggests that the effects of algorithmic information selection might be limited, both in terms of the actual effect sizes, and in terms of which polarization dimension they address (only ideological, but not affective polarization). Second, the more problematic dimension of polarization (namely, affective polarization) might even be combated with recommendation algorithms, if they were designed to include a politically diverse set of articles, which, however, have been positively evaluated by other users (of various

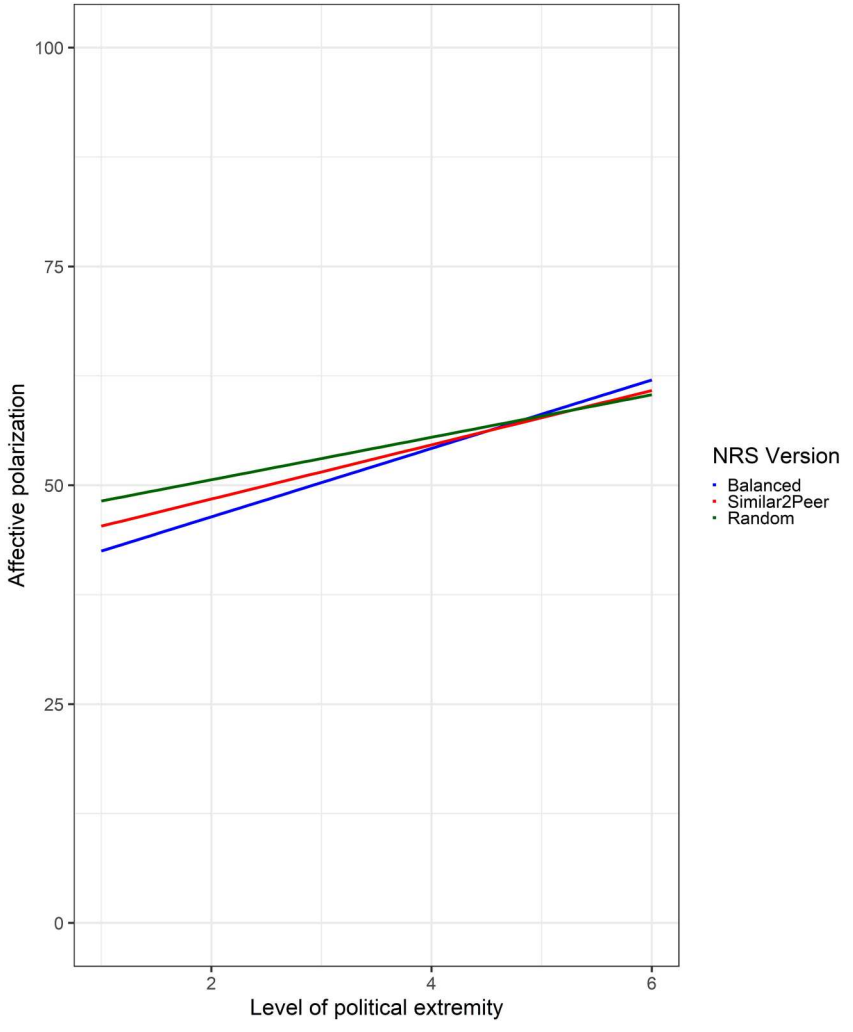

Figure 3. Plot of the interaction between NRS version and political extremity in predicting affective polarization in the German sample.

political orientations). Yet, it has to be kept in mind that, in line with previous findings (Dylko et al., 2017), these effects are only to be expected among politically moderate individuals whereas politically more extreme individuals seem to be largely immune to the influences of NRS.

The relatively small effect sizes of the present experiment are in line with other studies using real NRS as stimuli (Cho et al., 2020; Kelm et al., 2023) and may not be directly comparable to those of classical experiments. When using real NRS as stimuli, there is a lot of between-subject variance in the presented stimuli within the same experimental condition. Coupled with the brief exposure time it is quite remarkable that we find such clear results patterns and it is, therefore, not unlikely that long-term effects of daily news NRS usage could have more pronounced effects in similar directions.

Finally, we also found differences between the two countries under study: While the effects of NRS seem to hardly vary between different political and media systems for ideological polarization, at least concerning the topic of immigration and refugees, we found differences in the effects on affective polarization. In the German study, it was reduced by the ideologically balanced recommender version whereas no significant effects could be found in the U.S. This could potentially point to a ceiling effect being at work: While the deep-ingrained attachments and hostilities between U.S. Republicans and Democrats might already be somewhat hardened (Boxell et al., 2024) and therefore less likely to be affected by our study's short experimental stimulus interaction, the more fluent affiliations and perceptions towards parties in a multi-party system could be more easily moldable in a one-shot experimental set-up.

Limitations and future research

Naturally, this study does not come without limitations. As already mentioned above, we have a rather short experimental stimulus period, which is not comparable to real-world media use. While Internet users are usually exposed to news content on numerous occasions throughout the day and in many different contexts and thereby tend to use the same recommendation algorithms repeatedly over longer periods, in this study participants were only asked to use an NRS once and to read four news articles consecutively. Moreover, we used a very puristic stimulus design with no distracting graphical elements, source information, popularity cues, user comments, or topically diverse content that is typically given in a social media newsfeed. The construction of the NRS versions used in this study followed the goal of emulating algorithmic selection as envisioned in the 'filter bubble' hypothesis. How far this NRS design approximates the real-type selection algorithms used on actual online platforms is an open question. Consequently, the present study has limited external validity. We deliberately put up with this limitation to allow for a rigid causal design which was lacking from the research landscape thus far. Nonetheless, future research will have to test the insights gathered here in settings with higher external validity.

Another factor limiting external validity is that participants were only exposed to one news topic, that of immigration and refugees. Consequently, also ideological polarization as a core dependent variable of this study was only assessed for this topic, not in general, which would span across a multitude of topics. Being exposed to only one news topic is rather unlikely in a naturalistic news reading setting. While some media outlets might focus on a somewhat narrow set of topics (yet, these are already very specific cases), NRS are typically employed by news aggregator platforms that bundle up a topically heterogeneous overview of current affairs. To meet these limitations, long-term influences of algorithmic news filtering should be explored with longitudinal observational designs that capture participants' real-life news consumption and selection habits and assess their impact on polarization over time.

Additionally, we find rather small effect sizes, which might question the stability of the results. However, given the brief exposure to the stimulus and the heterogeneity of the articles viewed within the experimental conditions, the patterns were surprisingly clear. Therefore, it can be assumed that the long-term effects of daily news recommender system usage could probably be even more pronounced. Nevertheless,

future research should test this assumption with, for example, a longitudinal web-tracking experiment.

Another open question that remains is how to reach the politically extreme. While our results show multiple effects of news recommender systems on the political polarization of politically moderate individuals, only one change in extreme individuals' polarization could be found. While moderate participants were affectively depolarized by the balanced news recommender system, politically extreme participants were affectively polarized. This indicates opposing mechanisms for politically moderate and extreme individuals, which should be explored in more detail, as especially politically extreme individuals pose a challenge to a functioning deliberative democracy.

Conclusion

Overall, the present study did find partial confirmation of the 'filter bubble' hypothesis, showing that algorithmic news filtering considering the political orientation and the political interest of its users heightens ideological polarization among politically moderate individuals. We also found that ideologically balanced news recommendations have the potential to affectively depolarize their users – at least politically more moderate individuals. This opens up avenues for building more diverse and responsible news recommender systems that can help corroborate democracy instead of undermining it. Yet, the results also indicate that this may not be possible for all individuals throughout the political spectrum, and also not in all national settings.

Nonetheless, despite its small effect sizes, the present results underscore that algorithmic news recommendation does indeed have the potential to mold political polarization among the citizenry for better or for worse, depending on specific design decisions. This counters recent research suggesting null effects of algorithmic systems on political polarization and, thus, suggesting to discard the 'filter bubble' hypothesis (e.g., Guess et al., 2023). Importantly, however, a 'filter bubble' like information environment was tailored for the purpose of the present study. Whether and which real-world algorithms actually create 'filter bubbles' is a totally different question that cannot be answered with the present research design. What our results indicate is mainly that different NRS designs can potentially impact political polarization in different directions, particularly among its politically moderate users. Communication researchers, media regulators, and tech companies, therefore, should read the present results as a prompt not to discard the 'filter bubble' notion all too quickly, and instead continue to think about ways how recommendation algorithms can be designed in ways that are supportive of democratic culture.

Notes

1. According to the statute of University of Mannheim's research ethics committee these studies were waived from an ethics approval as they did not collect de-anonymized data, were not designed to evoke strong emotions within participants, and did not involve or touch upon security risks, traumatizing events, participants' self-image, health burdens, deception, or the participation of minors.
2. Materials and appendices related to this study can be obtained from osf: https://osf.io/zjvek/
3. The python code on which both NRS were built can be obtained from osf.

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