

Using Exploratory Learning Methods to Challenge Sociopolitical Beliefs

Sarah French (sarah.french@louisville.edu)

Department of Psychological and Brain Sciences, University of Louisville
Louisville, KY 40292 USA

Marci S. DeCaro (marci.decaro@louisville.edu)

Department of Psychological and Brain Sciences, University of Louisville
Louisville, KY 40292 USA

Daniel A. DeCaro (daniel.decaro@louisville.edu)

Departments of Psychological & Brain Sciences and Urban & Public Affairs, University of Louisville
Louisville, KY 40292 USA

Abstract

Exploratory learning before instruction has been effectively employed in STEM education to promote deeper conceptual understanding. However, its application to sociopolitical reasoning is underexplored. This research investigated whether exploratory learning can mitigate biased information processing, fostering more reflective evaluation of counter-attitudinal sociopolitical information. We examined how the order in which participants engaged with exploratory (data table) versus directly persuasive (verbal message) stimuli influenced the strength and confidence in sociopolitical beliefs. Participants reported increased support for positions they had initially opposed, and to large effect, regardless of stimuli order. However, an interaction of time and order on confidence levels hinted at potential metacognitive benefits for participants who explored first. Exploratory learning may be less beneficial in the context of sociopolitical decision making—at least when individuals are likely to update their beliefs anyway. However, exploratory learning might impact individuals' metacognition when the messenger contradicts their political position.

Keywords: exploratory learning; productive failure; belief updating; judgment and decision making

Introduction

In a sociopolitical landscape characterized by polarization and entrenched beliefs, traditional persuasion techniques often trigger defensive processing. When individuals encounter counter-attitudinal information, they tend to engage in motivated reasoning, selectively processing evidence that confirms their pre-existing views while dismissing or counterarguing contradictory evidence (Petty & Cacioppo, 1986; Petty et al., 2009). This challenge is particularly acute in sociopolitical domains where issues such as climate change policy, economic reforms, and social justice are intertwined with personal and group identities. Motivated, biased processing of sociopolitical information reduces the effectiveness of fact-based arguments when people's beliefs are strongly tied to their political identity (Hornsey & Fielding, 2017).

This paper examines whether *exploratory learning* before instruction, a pedagogical method often applied in STEM education, might impact reasoning about sociopolitical

issues. Exploratory learning invites learners to engage with materials and attempt to solve problems before receiving direct instruction (DeCaro & Rittle-Johnson, 2012; Weaver et al., 2018). In STEM, such methods have been shown to help learners identify gaps in their understanding and integrate new knowledge, leading to deeper conceptual understanding (Loibl et al., 2017). Given the potential of exploratory learning to foster elaborative processing and reduce cognitive rigidity, this paper examines its utility in the novel context of political belief updating (see also Bush et al., 2023; DeCaro et al., 2024).

Sociopolitical Beliefs

Sociopolitical beliefs are often deeply held and resistant to change. The Elaboration Likelihood Model (ELM; Petty & Cacioppo, 1986) has long been used to explain why individuals process persuasive messages differently depending on factors such as motivation and cognitive capacity. When individuals are highly motivated and able to process information, they tend to use the central route, engaging in thoughtful, elaborative processing. However, when motivation or ability is low, individuals are more likely to use the peripheral route, leading to less durable attitude change. A critical barrier to effective persuasion in sociopolitical contexts is that messages often trigger defensive processing. Individuals tend to disregard or counterargue information that conflicts with their pre-existing beliefs—a phenomenon known as motivated reasoning.

This effect is compounded by the fact that many sociopolitical issues are intertwined with group identity, causing messages from outgroup sources to be dismissed or viewed with skepticism (Fielding et al., 2020). Consequently, interventions that reduce defensive processing and encourage deeper, more reflective engagement with counter-attitudinal information are urgently needed.

Exploratory Learning before Instruction

In STEM education, exploratory learning methods have been deployed to improve conceptual understanding. By allowing students to work through problems and interact with

materials before being given a canonical explanation, exploratory learning helps learners activate prior knowledge, identify knowledge gaps, and ultimately construct a more robust understanding of the material (Loibl et al., 2017). This process, sometimes referred to as “productive failure,” has been associated with improved long-term retention and greater transfer of knowledge (Kapur, 2016).

Exploratory learning is thought to benefit conceptual knowledge change through three primary mechanisms. First, engaging with a problem allows learners to activate relevant prior knowledge, which they can then integrate within their existing knowledge schemas (Loibl et al., 2017; Schwartz et al., 2007). Second, struggling with the problem helps learners identify where their understanding is incomplete, or their knowledge gaps (Glogger-Frey et al., 2015; Newman & DeCaro, 2019). Third, by navigating a new problem space, learners begin to identify what problem features appear to be relevant or not, helping them to build a deeper conceptual structure (Kapur & Bielaczyc, 2012; Schwartz et al., 2007).

Current Research

In the current work, we examined whether exploratory learning, as with STEM learning, might aid in conceptual change with sociopolitical reasoning. Specifically, we hypothesized that exploratory learning might help individuals process counter-attitudinal information more openly. When individuals view a persuasive, counter-attitudinal message, they are more likely to use more superficial, peripheral processing. If, instead, people engage with empirical data on the issue, without significant messaging, they may be less likely to rely solely on their pre-existing, potentially biased, beliefs. Instead, the exploratory phase could promote central processing—a more nuanced evaluation of the evidence. This approach may allow for adjustments in both the content of beliefs and the confidence with which those beliefs are held. Then, individuals may be more aware of gaps in their knowledge, curious to fill those gaps, and attentive to the counter-attitudinal message.

One potential indicator of these metacognitive processes is the confidence individuals report in their beliefs. Confidence is not merely a measure of certainty—it also reflects the extent to which individuals feel their beliefs are well-founded and resistant to counterevidence. In this research, we investigated the effects of the order of materials (exploring data first or receiving a persuasive message first) and time (pre- and post-intervention) on beliefs about sociopolitical policies to which participants initially indicated opposition. We measured beliefs in the form of support for policies and confidence in beliefs. We hypothesized that, compared to a more traditional message-first condition, exploring first would lead to greater (1) belief change and (2) confidence in their (updated) beliefs. If exploration leads to decreased confidence in a belief that appears otherwise unchanged, it could suggest a decrease in cognitive rigidity about the issue.

In Experiment 1, the persuasive message was not attributed to any particular source. In Experiment 2, the message was attributed to a partisan source in a political party opposite that

of the participant. We reasoned that this peripheral cue (messenger) might be more likely to lead to automatic rejection and/or counterarguing. It may be that exploratory learning is only beneficial when a message would otherwise strongly activate biased processing.

Experiment 1

Method

Participants

Participants were 112 undergraduate students (age $M=19.70$, $SD=4.73$, 83% female, 62% Democrat, 21% Republican, 17% Independent) from a Midwestern U.S. university, who participated for psychology course credit. Twelve additional participants were excluded for exceeding or failing to meet the minimum acceptable duration, calculated using the interquartile-range method of identifying outliers.

Additional participants were initially screened based on their reported attitudes toward carbon taxes and electric vehicle incentives. Only those who expressed opposition to the experimental issue were allowed to continue the experiment past the screening. This screening ensured that all participants were exposed to information that challenged their existing beliefs.

Design

We used a mixed-factorial design with a between-subjects factor: Order of presentation (Explore-First vs. Message-First) and a within-subjects factor: Time (Pre-intervention vs. Post-intervention).

Materials

Initial Beliefs Participants were first asked to report their beliefs about four randomly presented sociopolitical issues: carbon taxes and electric vehicles (experimental positions designed to be polarizing to Republicans and Democrats, respectively) and gun control and illegal immigration (fillers). Beliefs included general support (e.g., *How strongly do you support or oppose this position?*), responded to on a 5-point scale from *strongly oppose* to *strongly support*. Participants were then asked other, similar questions about these issues that were not analyzed for the current study. Finally, participants were asked about confidence in beliefs (*How confident are you in your beliefs about this position?*), responded to on a 5-point scale from *completely unsure* to *completely confident*.

Data Table Participants engaged with a data table presenting numeric evidence related to a sociopolitical issue (either carbon taxes or electric vehicle incentives). Participants viewed the materials corresponding to the issue they expressed opposition to in the Initial Beliefs questionnaire (selected *oppose* or *strongly oppose*). The data table for each experimental issue were constructed with identical numeric content but different axis labels and descriptions (adapted

from Washburn & Skitka, 2018). Figure 1 shows the table and description for the carbon tax issue. Under the data table, an open-ended question asked participants, “What conclusions (if any) do you draw from this table?” Below this question, participants were asked, How confident are you in your conclusion?” Participants responded on a 5-point scale from *completely unsure* to *completely confident*. These questions were asked to direct participants to engage in the data table; results were not analyzed for this report.

Carbon emissions are carbon compounds released into the atmosphere, and are produced from the burning of fossil fuels such as coal and gas. These emissions are thought to contribute to local and global climate change, among other things. A Carbon Tax is a fee paid by major producers and users of fossil fuels (e.g., energy companies, corporations). This tax is intended to pay for solutions to counteract potential side-effects of carbon emissions (e.g., planting trees, alternative energy sources).

The table below shows data compiled from several reports about the effects of Carbon Taxes on the economic prosperity of different cities. Here, economic prosperity refers to general economic growth, security, and wealth. Please examine the table carefully and come to your own conclusions about the data.

	Total # of Cities	Economic Prosperity			
		Improved	Decreased	Percentage Improved	Percentage Decreased
Cities with carbon tax	128	107	21	83.6%	16.4%
Cities with no carbon tax	298	223	75	74.8%	25.2%

Figure 1: Example Data Table (Debiasing Information): Carbon Taxes.

Persuasive Message Two written persuasive messages were developed, one for each of the two sociopolitical issues. Participants viewed the one that corresponded to their oppositional belief. The two messages were structured as similarly as possible given the distinct subject matter. The message for the carbon tax issue is shown in Figure 2.

People often think that carbon taxes will hurt the United States' economy and cause economic distress for the American people. However, recent research shows that carbon taxes can be implemented with little to no economic harm. In fact, some countries have seen economic benefits from carbon taxes. In one North American community, for example, more than \$1 billion generated by the carbon tax has been returned to the people's households and businesses. Low-income families and small businesses are receiving tax credits, and their tax rates have been reduced. A one-time payment was also given to every resident. Each year, human activities release more carbon dioxide into the atmosphere than natural processes can remove, causing the amount of carbon dioxide in the atmosphere to increase. Research shows that carbon taxes work to lower greenhouse gas emissions.

So, there is good evidence that it is possible to design carbon taxes that can actually contribute to a country's economic prosperity while reducing carbon emissions. Introducing a nation-wide carbon tax in the United States is a promising direction for addressing climate change without hurting the economy.

Figure 2: Example Persuasive Message (Carbon Taxes).

Final Beliefs After viewing the data table and message, participants were again asked to report their support for the four policy positions (experimental and filler) and their confidence in their beliefs, using the same items as in the initial beliefs questionnaire.

Demographics A final questionnaire asked for demographic information, such as age, gender, and political affiliation (*Which major political group do you identify with the most?*). Possible responses were Democrat, Republican, Independent – Democrat leaning, Independent – Republican leaning, and Independent – Non-partisan. For analyses, Democrat and Independent – Democrat leaning were collapsed, as were Republican and Independent – Republican leaning.

Procedure

The experiment was conducted online using an online survey software. Participants first provided informed consent. Then, they were asked to report their initial beliefs about the target (and filler) policy issues. Next, participants were presented with either the data table or persuasive message in support of one of the two experimental positions. Which set of stimuli they encountered depended on their previous responses; each participant was directed to an issue to which they had expressed opposition. Thus, all participants viewed counter-attitudinal stimuli.

The order in which participants viewed the data table and message was randomized. Participants in the *message-first condition* first viewed the persuasive message, then the data table. Participants in the *explore-first condition* viewed materials in the reverse order—the data table and then the persuasive message.

Next, all participants were asked to report their beliefs about all the sociopolitical positions a second time. Participants completed three additional exploratory items, and individual difference scales, that were outside of the purpose of the current research and not reported here. Finally, they were debriefed, thanked, and presented with a brief message about misinformation and disinformation. All study procedures were approved by the university Institutional Review Board.

Results

Preliminary Analyses

As anticipated, Republican and Democrat participants did not show differences in initial support for the counter-attitudinal experimental position presented to them, that they had initially opposed (carbon tax or electric vehicle incentives), or in belief change, $F_s < 1$ (Figure 3). Further analyses were collapsed across political affiliation.

Support for Position

A 2 (Time: Time 1, Time 2) × 2 (Order: explore-first, message-first) mixed-factorial ANOVA was used to analyze support for the counter-attitudinal position. There was a main effect of time, indicating that support was significantly higher at Time 2 ($M=3.10, SD=.07, 95\% CI [2.97, 3.23]$) than at Time 1 ($M=2.57, SD=0.05, 95\% CI [2.47, 2.67]$), $F(1,110)=61.03, p<.001, \eta_p^2=.355$ (Figure 4). The main effect of order, $F < 1, p=.858$, and interaction, $F(1,110)=1.35, p=.247, \eta_p^2=.012$, were not significant.

Planned comparisons revealed no difference in support at Time 2 between the message-first ($M=3.16$, $SD=0.71$) and explore-first conditions ($M=3.05$, $SD=0.65$), $t(110)=.82$, $p=.207$, 95% CI [-.15, .37], $d = .16$.

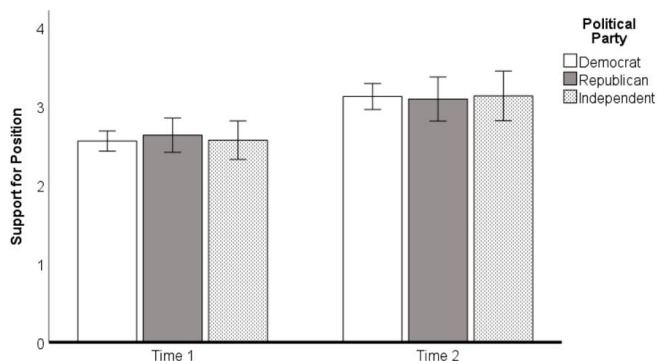


Figure 3. Exp. 1 Support for Position by Political Party. Error bars=95% CIs.

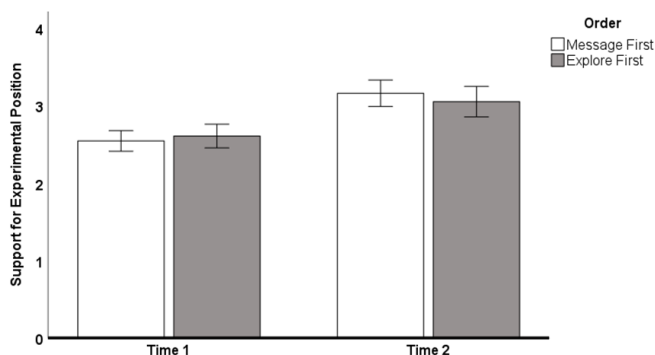


Figure 4: Support for Position at Time 1 and Time 2 by Order.

Confidence in Beliefs

Using the same ANOVA to examine confidence in beliefs, there was a main effect of time, with confidence dropping significantly from Time 1 ($M=3.51$, $SD=0.08$, 95% CI [3.35, 3.67]) to Time 2 ($M=3.23$, $SD=0.08$, 95% CI [3.07, 3.40]), $F(1, 110)=6.76$, $p=.010$, $\eta_p^2 = .057$ (Figure 5). The effect of order was not significant, $F(1,110)=2.52$, $p=.115$, $\eta_p^2 = .022$. The interaction was also not significant, $F < 1$, $p = .328$, $\eta_p^2 = .009$.

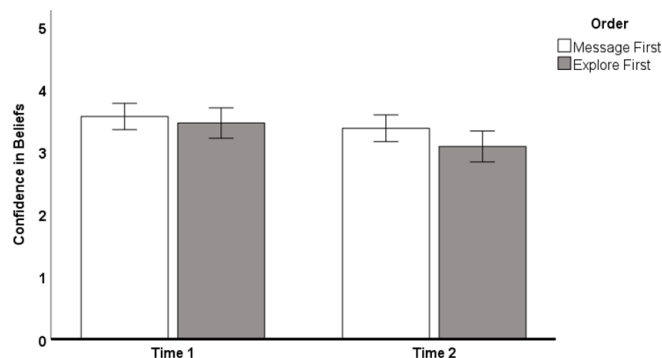


Figure 5: Exp. 1 Confidence in Beliefs.

Planned comparisons revealed significantly higher confidence at Time 2 in the message-first ($M=3.38$, $SD=0.90$) compared to the explore-first condition ($M=3.08$, $SD=0.82$), $t(110)=1.76$, $p=.040$, 95% CI [-.04, .62], $d = .34$.

Discussion

Participants significantly updated their beliefs, demonstrating increased support for the targeted policies. Contrary to hypotheses, the magnitude of change in support did not depend on whether individuals viewed a persuasive message or explored a data table first. Confidence in beliefs dropped from Time 1 to Time 2 overall. Confidence at Time 2 was significantly lower for individuals in the explore-first condition compared to the message-first condition. In short, there was no observed benefit of exploring data prior to reading a persuasive message.

Participants stated that they were opposed to the target political issue at the beginning of the study, but their support ratings were neutral-to-positive on average. This result suggests that individuals were not strongly opposed, and thus may have come into the study with a greater degree of flexibility than if the target issue was more polarizing. It may be that attempts to discover effects of exploration in the context of biased cognitive processing are rendered ineffective if the materials do not cue sufficient bias. Experiment 2 was designed to test this idea.

Experiment 2

Experiment 2 used the same measures as Experiment 1, except that the message included a peripheral cue intended to activate defensiveness about the position. Specifically, the message was attributed to a partisan research center from the political party opposite that of participants. We examined whether the persuasive message was more likely to entrench participants in their position in the message-first condition, compared to the explore-first condition.

Method

Participants

Participants were 151 undergraduate students ($M_{age}=22.02$ years, $SD_{age}=9.84$; 77.5% female; 61% Democrat, 22% Republican, 17% Independent) from the same Midwestern U.S. university as in Experiment 1. Participated completed the study for psychology course credit. Eleven additional participants were excluded for exceeding or failing to meet the minimum acceptable duration. Participants were again screened so that only those who expressed opposition to one of the target issues were included in the experiment.

Materials and Procedure

All materials and procedures were the same as in Experiment 1, except that the persuasive message was attributed to a partisan research center. Specifically, the message in Experiment 2 stated, "However, research from a [liberal,

conservative] political research group shows...” depending on the participants’ initial support ratings.

Results

Preliminary Analyses

As in Experiment 1, Democrat, Republican, and Independent participants did not show differences in initial support for experimental policies or in belief change, $F < 1$, $p = .811$, so analyses were collapsed across political party (Figure 6).

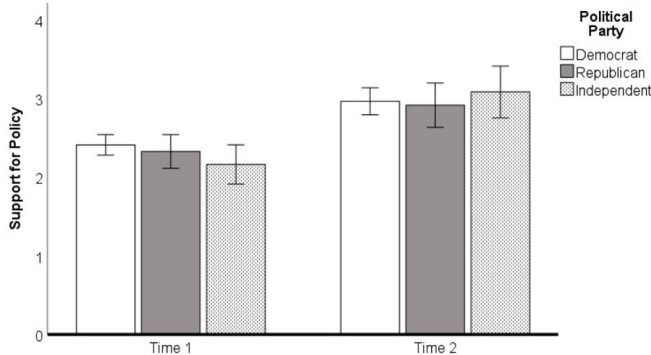


Figure 6. Exp. 2 Support for Position by Political Party.

Support for Position

A 2 (Time) × 2 (Order) mixed-factorial ANOVA was conducted on support for political position, with time within-subjects and order between-subjects. There was a main effect of time, $F(1,149) = 86.99$, $p < .001$, $\eta_p^2 = .369$, indicating that support was significantly higher at Time 2 ($M = 2.98$, $SD = 0.07$, 95% CI [2.85, 3.12]) than Time 1 ($M = 2.35$, $SD = 0.05$, 95% CI [2.24, 2.45]; Figure 7). The effect of order, $F < 1$, $p = .407$, $\eta_p^2 = .005$, and interaction, $F(1,149) = 1.75$, $p = .188$, $\eta_p^2 = .012$, were not significant. Planned comparisons revealed no significant difference in support at Time 2 between message-first ($M = 2.90$, $SD = 0.77$) and explore-first conditions ($M = 3.07$, $SD = 0.89$), $t(149) = -1.28$, $p = .102$, 95% CI [-.44, .10], $d = -.21$.

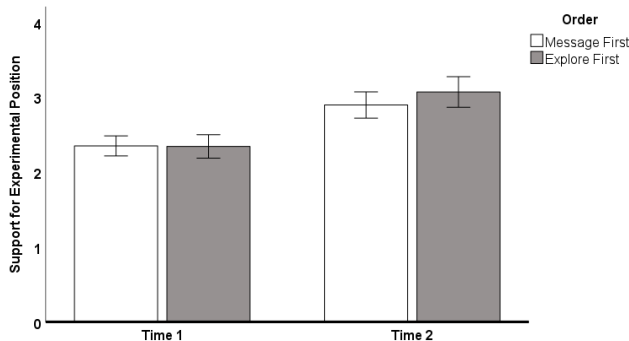


Figure 7: Exp. 2. Support for Position.

Confidence in Beliefs

The same ANOVA was conducted to examine confidence in beliefs about the experimental position. There were no main

effects of time, $F < 1$, $p = .527$, or order, $F < 1$, $p = .480$, but a significant interaction emerged, $F(1,149) = 5.62$, $p = .019$, $\eta_p^2 = .036$ (Figure 8). Planned comparisons revealed that participants in the message-first condition did not change in confidence from Time 1 to Time 2 ($M_{\text{change}} = -0.13$, $SD_{\text{change}} = 0.79$), $t(86) = -1.49$, $p = .069$, $d = -.16$). However, participants in the explore-first condition demonstrated an increase in confidence ($M_{\text{change}} = 0.22$, $SD_{\text{change}} = 1.00$, 95% CI [-.03, .47]), $t(63) = 1.75$, $p = .042$, $d = .22$).

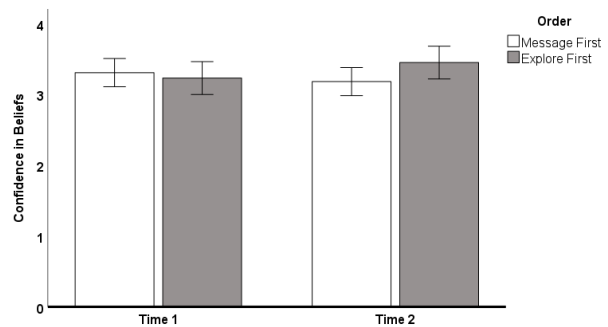


Figure 8: Exp. 2 Confidence in Beliefs.

Discussion

As in Experiment 1, participants significantly updated their beliefs, demonstrating increased support for positions to which they initially indicated opposition. However, once again, the order in which participants were exposed to the neutral data versus persuasive message had no impact on their ultimate support for the political position. However, for confidence in beliefs, there was an interaction. Participants in the explore-first condition increased confidence in their beliefs after the intervention, whereas participants in the message-first condition did not.

It may be that all participants updated their beliefs similarly, but those who explored first experienced a “now I have it” moment, resulting in not only a deeper understanding of the issue, but also a metacognitive awareness of that understanding. If so, then this experience could explain why those in the explore-first condition felt more confident afterwards than did those in the message-first condition.

General Discussion

Sociopolitical information processing—especially about contentious issues—is influenced by many factors, and often fraught with biases. The peripheral route generally fails to deliver meaningful change, but cues in messaging (e.g., congruence with current beliefs, messenger affiliation) often trigger peripheral processes, leading to belief maintenance. Similar cues can initiate biased central-route processing, leading to counterarguing and belief entrenchment. We tested the utility of an exploratory learning paradigm as a method of bypassing problematic cues.

In two experiments, exploring data prior to receiving a persuasive message did not affect belief change, regardless of message source. Nevertheless, belief updating occurred, and to large effect. Given the multitude of biases that inhibit

flexible thinking, these results are somewhat surprising. On the other hand, participants encountered two types of compelling arguments. If they came to the study with weak or non-existent opinions about the experimental issues, it is reasonable that the stimuli would be highly persuasive. Participants were undergraduate students, who appeared to have lacked deeply held pre-existing views about carbon taxes and electric vehicle incentives. Though they reported initial opposition to these policies, their initial beliefs were between neutral and positive, on average, suggesting general, but not strong, opposition.

The null effects of exploring first on belief updating present the possibility that, although effective in STEM fields, exploratory learning may not be beneficial in the context of sociopolitical decision making. It is reasonable to suspect some differences in cognitive processing of STEM concepts versus sociopolitical arguments, particularly with regard to motivation and affect, factors crucial in the Elaboration Likelihood Model (Petty & Cacioppo, 1986).

Still, the interaction of time and order on confidence levels in Experiment 2 suggests that there could be metacognitive differences between participants who explored first and those who did not. Participants in the explore-first condition increased in confidence after the intervention, whereas participants in the message-first condition did not. These results suggest that, in addition to updating their beliefs, individuals who explored first also become more confident in these beliefs. Perhaps these individuals understood the rationales for the policy at a deeper level than individuals who started with the biasing message.

However, a different pattern of results was found in Experiment 1 for confidence ratings—individuals in the explore-first condition rated their confidence lower than those in the message-first condition. Again, individuals in both conditions updated their beliefs. Without attribution to an opposing political group, perhaps the message-first condition was sufficient to increase confidence and processing information at a deeper level. Thus, it may be only when biases are more clearly provoked that exploratory learning is useful.

Limitations and Future Research

Although the differences between explore-first and message-first conditions were largely nonsignificant, some trends were observed in the data. It is possible that any further boost to belief updating due to exploring was masked by an underpowered sample size.

Degree, rather than direction, of political affiliation might also play a role. Exploring first may have differential effects depending on how strongly identified one is with one's political party, and thus how strongly opposed to an outgroup messenger they are likely to be. A larger sample size would enable researchers to examine this possibility.

The results are limited to the specific materials selected, including exploration of a data table and a written message. Future research should test various exploration activities and persuasive messages. For example, future work could

introduce a computer simulation in which participants can interact with data or explore the effects of policy manipulations (e.g., a simulation in which they can enact different forms of a carbon tax and explore outcomes). Computer simulations are capable of modeling complex systems and processes that might otherwise be difficult or impossible to present (e.g., simulated effects of different carbon tax plans), and have demonstrated benefits in STEM education (Jimoyiannis & Komis, 2001; Sarabando et al., 2014). Issue involvement is a prime determinant of whether attitude change is induced via the central or peripheral route, with higher involvement leading to more central processing (Petty and Cacioppo, 1981). The exploratory learning paradigm used in these experiments might have failed to engage participants with issues they were not initially heavily involved in, but an interactive approach that provides dynamic feedback could be more effective in fostering debiasing elaboration of issue-relevant material.

It is also possible that a persuasive message with more salient biasing peripheral cues would lead to lower belief updating for individuals in the message-first condition. For example, a spoken message from a well-known political figure from an opposite political party, or a written message accompanied by a picture, might be more biasing than the brief written statement used in Experiment 2. Exploring before the message might be most useful when the message would otherwise lead to greater entrenchment in beliefs.

Another method of increasing engagement could be to tailor issues to the participants involved in the study. If undergraduate participants do not hold strong views on carbon taxes or electric vehicle incentives, focusing on more personally relevant issues might be more likely to show effects. For example, when sampling college students, policy positions could involve relevant issues like student loan forgiveness and free college initiatives.

The current research was limited to immediate belief updating, rather than examining change over time. Prior research suggests that when persuasion occurs primarily through the peripheral route, updated beliefs are less stable and more likely to revert over time. A study design that includes a follow-up session might reveal longer-term effects of exploration.

Conclusion

Learning in the classroom and updating political beliefs both involve conceptual change. By applying methods used in the classroom to study belief updating, we can inform both literatures. Our intervention impacted belief updating regardless of whether the message or data-focused activity came first. Exploring the data table first did impact confidence in these beliefs. The slight changes in confidence achieved here provide limited evidence that experience with actual data might impact how individuals perceive a counter-attitudinal message. More work is needed to determine if such metacognitive changes, and belief updating, extend across other political beliefs, especially when biases are more entrenched.

References

- Bush, J., DeCaro, M. S., & DeCaro, D. A. (2023). Playing a social dilemma game as an exploratory learning activity before instruction improves conceptual understanding. *Journal of Experimental Psychology: Applied*.
- DeCaro, M. S., & Rittle-Johnson, B. (2012). Exploring mathematics problems prepares children to learn from instruction. *Journal of Experimental Child Psychology*, 113(4), 552-568.
- DeCaro, D. A., DeCaro, M. S., Janssen, M., Lee, A. Graci, A. A., & Flener, D. (2024). Learning from regulatory failure: How Ostrom's restorative justice design principle helps naïve groups create wiser enforcement systems to overcome the tragedy of the commons. *PLOS ONE*, 19(8): e0307832.
- Glogger-Frey, I., Fleischer, C., Grüny, L., Kappich, J., & Renkl, A. (2015). Inventing a solution and studying a worked solution prepare differently for learning from direct instruction. *Learning and Instruction*, 39, 72-87.
- Fielding, K. S., Hornsey, M. J., Thai, H. A., & Toh, L. L. (2020). Using ingroup messengers and ingroup values to promote climate change policy. *Climatic Change*, 158(2), 181-199.
- Hornsey, M. J., & Fielding, K. S. (2017). Attitude roots and Jiu Jitsu persuasion: Understanding and overcoming the motivated rejection of science. *American Psychologist*, 72(5), 459.
- Kapur, M. (2016). Examining productive failure, productive success, unproductive failure, and unproductive success in learning. *Educational Psychologist*, 51(2), 289-299.
- Kapur, M., & Bielaczyc, K. (2012). Designing for productive failure. *Journal of the Learning Sciences*, 21(1), 45-83.
- Loibl, K., Roll, I., & Rummel, N. (2017). Towards a theory of when and how problem solving followed by instruction supports learning. *Educational Psychology Review*, 29(4), 693-715.
- Newman, P. M., & DeCaro, M. S. (2019). Learning by exploring: How much guidance is optimal?. *Learning and Instruction*, 62, 49-63.
- Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In *Communication and persuasion* (pp. 1-24). Springer, New York, NY.
- Petty, R. E., Barden, J., & Wheeler, S. C. (2009). The elaboration likelihood model of persuasion: Developing health promotions for sustained behavioral change. In R. J. DiClemente, R. A. Crosby, & M. Kegler (Eds.), *Emerging theories in health promotion practice and research* (2nd ed.). San Francisco: Jossey-Bass.
- Schwartz, D. L., Sears, D., & Chang, J. (2007). Reconsidering prior knowledge. In M. C. Lovett & P. Shah (Eds.), *Thinking with data* (pp. 319-344). New York: Routledge.
- Washburn, A. N., & Skitka, L. J. (2018). Science denial across the political divide: Liberals and conservatives are similarly motivated to deny attitude-inconsistent science. *Social Psychological and Personality Science*, 9(8), 972-980.
- Weaver, J. P., Chastain, R. J., DeCaro, D. A., & DeCaro, M. S. (2018). Reverse the routine: Problem solving before instruction improves conceptual knowledge in undergraduate physics. *Contemporary Educational Psychology*, 52, 36-47.