Four Biases in Interface Design Interactions

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Abstract. In a time when fake news has captured the attention of the broader public, and claims of algorithmic manipulation make us question everyday sources of information, it is essential that we unpack the ways our thinking and perception interacts with search engine results. Cognitive biases can be created from the common heuristics a person applies to process new information about a topic. These biases can contribute to difficulties in inferential thinking. In this paper, we focus on four potential sources of bias rooted in cognitive psychology that relate to information presentation in search, and unpack how they may affect the way people express their nascent understanding of a topic. Our study used a population-based experiment with 60 undergraduates at a large research university. Our findings suggest that the design of a search interface may cause a user to misapply heuristics, which can be linked to these cognitive biases. We conclude with recommendations for interface designers as well as those who mediate search practices in educational settings.

Keywords: Cognitive bias · Interface design · Information interaction · User experience · Search engines

1 Introduction

The way search algorithms present information influences our opinions (Belkin et al. 2009; Epstein and Robertson 2015). Information presentation likely affects the quality of student thinking and knowledge creation, particularly when students demonstrate and report relying heavily on the authority of search engines (Hargittai 2010; Meyers 2012). In an age of increasing science skepticism, people require both tools and critical thinking skills to evaluate the new scientific information they encounter in everyday life. According to the National Science Board, the public's primary form of science education is via the medium of search engines, but while the Internet increases the public's access to scientific information it also increases access to misinformation (2014). Therefore, it is worth questioning the level of critical thinking that people apply when selecting sources on a search engine results page (SERP) (Guo et al. 2010; Höchstötter and Lewandowski 2009). Within the SERP there are algorithmic biases that can influence user behaviour (Epstein and Robertson 2015). A search engine's algorithm presents a hierarchical list of what it deems would be the most important. However, the list may be limited by the way search engines qualify relevance over other contextual factors (Kelly 2009; Shiri and Zvyagintseva 2014). The presentation of a hierarchical list visually removes all intellectual relationships between each item in

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the list (Tufte 2006) and the algorithm behind Google's document ordering is ambiguous to even Google's search engine developers themselves (Cellan-Jones 2016). Whether the top result on Google is there because it is the most relevant, useful, popular, current, or the most hyperlinked is unknown to users. As a result, users remain unaware of the hidden biases in search engines (Gerhart 2004).

2 Background: Cognitive Biases Work

To understand the role of bias in constructing meaning from search engines, we draw on research in cognitive science, in particular theories of judgment and decision making. Cognitive biases and heuristics affect the way people perceive and process new information about a topic – particularly when the learner has to process conflicting or non-intuitive information (Tversky and Kahneman 1974). While dozens—some scholars identify as many as 53 different kinds—of cognitive biases contribute to difficulties in inferential thinking (Hilbert 2012; see also Kahneman 2013) for a survey of the literature), we look at four that we believe are directly related to Search Engine use in learning situations, namely: (1) Priming effects, (2) Anchoring, (3) Framing, and the (4) Availability Heuristic.

2.1 Priming Effects: How Our Familiarity with Google's Interface Biases Against Alternative Perspectives

Immediately after we perceive an object with our eyes a "stimulus is facilitated if it matches a prime previously seen in the same context" (Kahneman et al. 1992). A priming effect in user interfaces occurs when the repeated use of a layout automatically directs our eyes to information (Ware 2013). This creates a cognitive bias whereby we are influenced by certain cues (Kahneman et al. 1992). Scholars observed that Google's algorithm is biased towards presenting mainstream sources that users find familiar (Diaz 2008; Gillespie 2010). While efficient, users may automatically disregard unfamiliar sources that represent minority views (Braun and Gillespie 2011; Hindman et al. 2003; Rieder and Sire 2013).

2.2 Anchoring Effects: How Information at the Top of the SERP Creates Bias

Anchoring occurs when we are biased towards the first value we perceive in a set of data (Tversky and Kahneman 1974). The first result in a SERP can affect the user's impression of the importance of the next result (Lauckner and Hsieh 2013). This is problematic for SERPs because it affects the level of critical thinking that is applied to all other search results.

2.3 Framing Effects: How the Multiple Top Results Work Together

The Framing Effect is a cognitive bias that occurs when peoples' choices are dependent on the way information is presented (Kahneman 2002). Framing is not about unavailable information, but about *whether* the presentation makes us care about competing views and *how* (Scheufele and Tewksbury 2007). For example, if a SERP represents two perspectives but the first perspective dominates the top results in a SERP, then it is seen as more valuable than the second (Epstein and Robertson 2015; Lauckner and Hsieh 2013).

2.4 Availability Heuristic: How the Availability of Sources Marginalizes Challenging Perspectives

An availability heuristic bias occurs when a person's estimate is influenced by the ease of a person's recall of immediate information (Tversky and Kahneman 1974). With SERPs, non-expert may feel satisfied with more simplistic summaries of information (Browne et al. 2007). However, this is problematic when non-experts casually browse lesser known controversies that require greater cognitive effort from the user to understand.

All of these constructs represent kinds of cognitive "short cuts", techniques that we employ, either consciously or not, to ease our cognitive load when resolving information problems. These factors contribute to judgment errors in information seeking, but can also affect the extent to which new information leads to the development or revision of conceptual structures.

3 Methods

We explored a common science controversy on the subject of biofuels and *advanced* biofuels. While biofuels are increasingly common, the general population is less familiar with the various methods by which such fuels are produced, and the scientific disagreements related to the consequences of this production. The "food vs fuel" controversy, for example, is related to the use of agricultural land to produce matter (such as corn for ethanol) that competes with cropland dedicated to staple crops for human consumption or feed crops for animals. Sixty participants were recruited from a large public research university for this study, 91% had little to no knowledge of the topic prior to their recruitment.

The sample included students ages 18–30, with roughly equal gender distribution (45% female). Participants were then asked to read and rank five search results followed by a second questionnaire on their knowledge of biofuels. The results were presented to participants in four different ways, and order balanced. Students were asked to write their own summary of Biofuels using search results with brief summaries ($\sim$25 words); they were then provided with longer summaries ($\sim$100 words). The task goal was to write a brief explanation of biofuels as though they were writing for a colleague.

Our analysis looked at the participant rankings and resulting written explanations for four different kinds of cognitive bias, specifically priming, anchoring, framing, and the availability heuristic. We using a combination of observed behaviours as well as coding of the written work to make inferences about which type of bias provided the most robust explanation for the participants' choices. We did not, however, isolate the biases as discrete variables. Given this, there are some obvious limitations to our analysis.

4 Findings

4.1 Document-Genre Effects on Scoring

When analyzing the effects of document-genre on scoring (Fig. 1), we found that participants strongly favoured Wikipedia over all other websites for its generally objective perspective. As one participant explained, it was "the perceived neutrality of Wikipedia that links as a basis" for completing the assignment. While this finding agrees with past literature, we note it here because despite its reputation Wikipedia can contain biases that misrepresent information. As we explained, earlier, Wikipedia's Biofuels article does not present information neutrally on its interface when it relegates criticisms of biofuels into a weblink at the bottom of its page.

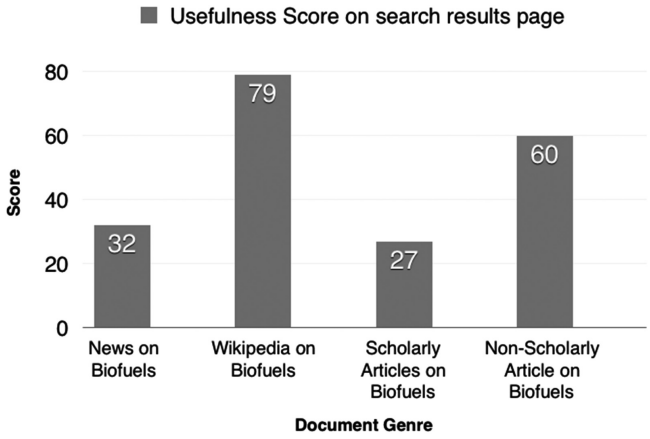

Fig. 1. Scores on usefulness of Wikipedia article on "Biofuels" in comparison to other sources (reported in percentages).

4.2 Document Order Effects on Write-up

The authors of the study were interested in how the document order affected how information was used by the students in their writing. When document-genre was controlled for, we found that the higher an article that mentions the biofuels controversy was presented on a search engine's results page, the more likely the controversy

is mentioned in their write up. When the top result on a SERP was a source that explicitly mentioned the biofuel controversy, 73% of the participants mentioned the controversy in their write-ups. However, if it was place elsewhere on the SERP then the number would fall to 41%. For example, a participant who had the controversy mentioned at the top of the SERP wrote: "Biofuels are basically fuels that comes from starch based plants such as corn or soy. However, because of this it takes up farmland which raises food prices. This can be really devastating to poor countries/those in poverty because they cannot afford the food." In contrast, most participants who did not have the controversy mentioned at the top of the SERP did not mention the controversy. Instead, they would focus on what corn biofuels were.

A Pearson chi-square test was performed to analyze whether a topic's position on the results list was related to students mentioning the topic in their explanations. A relationship was found between whether a group had a controversial topic anchored at the top of a SERP and the number of participants that mention the controversy in their write up, $X2\ (1, N = 42) = 4.1067$, $p = 0.043$. The association between rows (groups) and columns (outcomes) is statistically significant (Table 1).

Table 1. Chi square comparison of write-ups between group with anchored results vs. groups without.

	Number of participants that mention controversy in their write-up	Number of participants that do not mention controversy in their write-up	Total
Group with controversy anchored at top	11	4	15
Groups without controversy anchored at top	11	16	27
Total	22	20	42

When the controversial source appeared at the top of the search results, students were more likely to incorporate this information in their written responses, as opposed to the controversial information appearing lower in the search results page. As we will explain in the Discussions section the differences between the two groups may indicate anchoring effects are causing cognitive bias.

4.3 Document-Genre Effects on Write-up

This study was also interested in how information was used by students and whether there were any document-genre effects on the writing. To examine this, we compared the write-ups of participants that received the conflicting source on the topic of advanced biofuels in different document-genres; we compared the group who was provided the academic document-genre of the conflict against the group who had the non-academic document-genre of the conflict. The automated textual analysis for word

frequency revealed that three key terms "food price", "production", and "land" were mentioned frequently in the write-up for the group with the academic document-genre of the advanced biofuel conflicting source. However, for the group that was provided the non-academic version of the conflicting source the key terms were "new", "generation", "focus", and the perspective of "scientists". The words in this latter group related directly to the conflicting source on advanced biofuels (i.e., a "new" "generation" of biofuels and the current "focus" of many "scientists"). For example, one participant from the group provided the non-academic genre of advanced biofuels wrote: "Scientists are becoming aware of the food issues and have come up with other ways to obtain biofuels. There are 4 'generations' of biofuels each with different types of materials used. Algae seems to be a promising source of biofuels." However, the type of sentences that focused on advanced biofuels appeared less frequently in the write-ups of participants who received the academic document-genre of advanced biofuels. Instead, the frequent words of the participants who were provided an academic document-genre) were more focused on the old generation of biofuels (i.e., its "land" "production" and raising of "food price").

Furthermore, participants who were provided a non-academic document-genre of advanced biofuels created more comprehensive arguments. This likely occurred because for someone to explain why a biofuel is "advanced" they must first contextualize the topic by (1) first explaining what biofuels are, then (2) explaining the controversy of biofuels that are derived from corn, and then (3) explain that advanced biofuels address the controversy by focusing on biofuels that do not use land (4) and provide an example of a non-corn biofuel, such as algae. The group that received the academic document-genre sources never mentioned this fourth point about algae. In our post-hoc analysis we suggest the fact that these two groups focused their write-ups towards two different types of biofuels can be explained by framing effects causing cognitive biases.

4.4 Document Order Effects on Scoring

We presented participants with a source with an academic document-genre that was challenging because it was scientific in language and low-ranking on the SERP. When users were presented with the source on the SERP the users did not view the information as useful and gave it a very low score (Fig. 2). However, when participants were asked to read a large excerpt of the same result, its usefulness received a much higher score (Fig. 2). As we will explain in the Discussions section this increase in score may be due to a participant's initial reluctance to apply cognitive effort on a scholarly source at the bottom of a SERP and the availability-heuristic may be causing a cognitive bias.

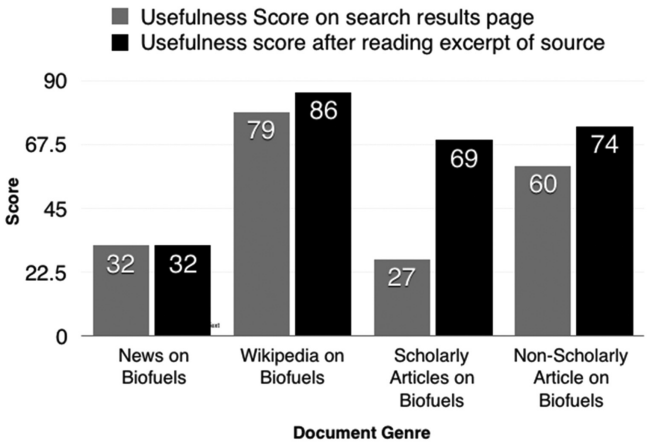

Fig. 2. Comparison between score of SERP results before and after reading excerpts of the sources.

5 Discussion

The current president of the United States, Donald J. Trump, has accused a few mainstream news outlets of distributing fake news, the outlets include *New York Times, CNN*, and "any negative polls are fake news, just like the CNN, ABC, NBC polls in the election" (Trump 2017). Trump's ongoing remarks on the issue are creating public discourse on the topic. The public, including scholars, are interested in the effect of "fake news" online and how web-services and algorithms can fact-check against them. There is no question that certain facts are more valid than others, that certain information sources are more careless with the validity of the facts, and that people are capable of critically-thinking and weighing the validity of certain arguments based on those facts against others. However, there are several assumptions in the argument "fake news affects people's judgement and should be fact-checked" that ought to be clarified: What counts as "fake"? What counts as "news"? Which web-services are to be trusted with "fact-checking"? Most importantly, do people assume that *they themselves* are on the side of the fact-checkers and its *other* people that are susceptible to "fake news"?

Even if all these prior concepts were clarified, at its core the concept of "news fact-checker" websites on its own is paradoxical because information cannot be both "new" and an "established fact" that can be checked. Because new information and established facts are distinct, new information must always have *some* degree of disagreement from prior information. Therefore, when "news fact-checkers" compare these two distinct pieces of information they will never find complete agreement (unless the information is not actually new). Fact-checker websites have and do check old facts, which can be a useful service. However, it is also the case that "new" information is generally useful when it updates, challenges, or changes what was once thought as established fact.

Instead of blaming a person's poor judgement on the lack of fact-checking websites, the authors take a different approach and argue that the average person is at risk of misinforming themselves even when the new information is "non-fake" scientific sources of information. They found that the design of a search interface causes competent post-secondary students to apply heuristics in an order that leads to four cognitive biases that are explained below. Figure 3 demonstrates the relationship between a user's eye-attentiveness to the space on a page and the stages of their interaction. For each of these sections, we also suggest four possible ways designers can assist users with countering these biases.

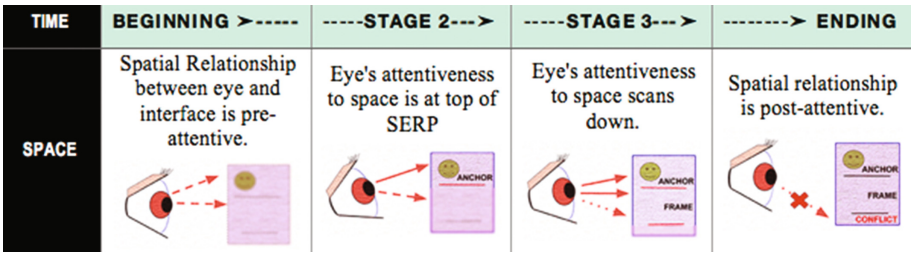

Fig. 3. Relationship between a user's eye-attentiveness to space on a page and interaction time

Stage 1: When a user first sees a SERP, the spatial relationship between their eye and interface is *pre-attentive* (i.e., the eye subconsciously looks for patterns (Ware 2013). In this stage, the user may experience a cognitive bias known as *Priming* (i.e., the repeated use of a layout automatically directs our eyes to information that is familiar rather than relevant (Tversky and Kahneman 1974). The authors tested for the scenario where SERPs provide sources that are familiar to users, but are not comprehensive. Our study found that users preferred less comprehensive sources, but this behavior affected their work output. We suggest that designers consider how to design an interface that facilitates these user heuristics so that they can discover counter primed information. For example, an interface can visually demarcate sources that function as counter-points, falsifications, or conflicting information.

Stage 2: In the next stage, eye-tracking software reveals that a user's attentiveness focuses on the top of a SERP (Hotchkiss et al. 2010). In this stage, the user may experience a cognitive bias known as *Anchoring* (i.e. when we are biased towards the first value we perceive in a set of data (Tversky and Kahneman 1974). Users often over trust the top result in a search (Hullman and Diakopoulos 2011; Lauckner and Hsieh 2013; Meyers 2012) Our study argues that a SERP's hierarchical list over-emphasizes the top result over other results because features such as "I'm Feeling Lucky" and the Answer Box single out a dominant perspective for users when none exists. For instance, an opinion-piece might have anchoring effects on a user while they search for an academic source. Designers might counter this bias by allowing users to choose a standard for the document-genres they retrieve.

Stage 3: In the next stage, a user's eye scans down a page looking for patterns (Ware 2013). In this scenario, the user may experience a cognitive bias known as Framing (i.e., when peoples' choices are influenced by the manner information is presented (Kahneman 2002)). A SERP interface might not intentionally frame, but it might mistake conflicting results as irrelevant and rank them lower. Our study found that this process can frame a debate by narrowing the multiple perspectives that can contextualize a controversy. Interface designers might counter this bias by allowing users to "scan the landscape" of information before focusing on an area. A low-ranked website may seem out of place, but it can be a valuable resource that negates prior assumptions in a query. A quick scan by users will double-check that nothing was missed.

Stage 4: The final spatial relationship between a user's eye and the interface is post-attentive, whereby the user's attention is drawn away from the interface. In this scenario, the user may experience a cognitive bias known as the Availability Heuristic (a person's estimate is influenced by the ease of a person's access to information over subsequent information (Tversky and Kahneman 1974)). Our study found that when a SERP presents sources that contain language that is difficult to understand without context, users may skip the answer for sources that do provide familiar responses that scaffold their prior knowledge. Designers might counter this bias by allowing for multiple users to collaborate on a query with the intention of attaining multiple-perspectives on information. Scholars have expounded on the numerous benefits of collaborative searching (Dillenbourg and Baker 1996; Foster 2010; Hansen et al. 2015; Morris 2013; Twidale et al. 1997). Searching with colleagues or sharing results to discover multiple-perspectives on findings and search strategies can lead to a wider range of useful results.

6 Conclusion

The authors draw from a long scholarly debate between various information scientists and cognitive science labs to argue that the analysis of observations can determine which cognitive-biases provide the best explanatory power. For example, current public discourse is interested in the effect of "fake news" online and how web-services and algorithms can fact-check against them. However, this approach (1) assumes that we have a clear idea of how an individual's cognition works, (2) assumes that "fact-checking" removes biases and (3) removes the individual from their social context. The authors take a different approach and argue that the average intelligent student is also at risk of misinforming themselves even if the sources are "non-fake" scientific information. Instead of removing a person from context and checking for cognitive-biases on an interface, this paper addresses this issue from the opposite angle suggested by recent scholars. This paper first used a *population-based survey experiment* to work outside of the lab and within the context of a student library. Second, it created a work task that did not merely observe how students ranked the relevancy of information but how they used the information. It then altered basic interface variables for different groups of users (74 participants total) and then analyzed which cognitive-biases provided the best explanatory power for our observations. By doing

so, the paper determined that the interface design can influence the way a user interacts with a search interface. It also found the design of a search interface causes a user to misapply heuristics when they use that information. Finally, it argues that four cognitive biases can explain why the heuristics were misapplied.

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