An Intelligent Tutoring System for Cognitive Debiasing

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Abstract. Intelligent tutoring systems allow students to progress through course content at their own pace. Cognitive biases are systematic patterns of deviation from rationality in judgments. This paper introduces an intelligent tutoring system developed using the Oppia platform to teach the basics of metacognitive theory. Its primary purpose is to help individuals identify and reduce their own cognitive biases so that they may make decisions in a more critically-minded fashion.

Keywords: Intelligent Tutoring Systems, Metacognition, Cognitive Biases, Debiasing, Oppia.

1 Introduction

In the traditional education model, an expert on a particular subject will stand in front of rows of students who are not experts, and that person will explain that subject to them. The pace of the lesson, inevitably, ends up being too slow for the students who grasp the material quickly, and too fast for the students who need extra explanation; so, half of the class ends up bored, and the other half gets left behind.

Bloom [1] has shown that students who are tutored one-on-one by an expert capable of adapting to the student's learning pace perform two standard deviations better than students who learn via the conventional lectured approach. Unfortunately, there aren't enough human resources to give every student such an expert tutor.

The field of Intelligent Tutoring Systems has begun to address this problem by providing digital tutors that can adapt to students' learning behaviors in real time. Separately, teaching self-regulated learning skills provides students with the tools necessary to tackle this problem on their own. Metacognitive tutoring systems attempt to combine the benefits of both of these strategies into a single comprehensive approach.

This paper introduces an adaptive digital tutor to help students learn concepts in metacognition and to help them self-identify common cognitive biases. It is adaptive in the sense that students are able to move forward through the material faster if they grasp the concepts quickly, and provides extra help if they don't. In addition, the debiasing skills that it teaches provides students with a way to approach new material within any domain in a more critically-minded manner.

2 Related Work

Most of today's work on improving metacognitive function in students using intelligent tutoring systems comes from Carnegie Mellon's Carnegie Learning Group. Aleven and Koedinger [2], have performed studies on the benefits of having students explain their reasoning while solving problems, Mathan and Koedinger [3] have looked at ways to involve students in self-correction when they make errors, Baker et al. [4] have experimented with ways to teach students to not "game" the instruction system, and Roll et al. [5] have researched how to improve students' help-seeking behaviors.

In all of these studies, however, the metacognitive lessons were made secondary to the those of some other primary subject, such as geometry or algebra. None of these previous studies have attempted to teach metacognition as a first-class citizen.

Additionally, none of these studies have touched on any of the many other foundational concepts in the study of metacognition, such as cognitive biases, like confirmation bias, relying on anecdotal evidence, or believing that prior random events affect the outcomes of future random events. To the author's knowledge, there currently exists no intelligent tutoring system that both provides an essential overview of basic metacognitive theory and lays the groundwork for teaching more advanced debiasing concepts in future work.

3 Proposed Solution

The proposed solution is a metacognitive tutoring system with three objectives. The first is to provide students with an essential overview of basic metacognitive theory in a way that adapts to their real-time understanding. The second is to systematically debias students so that they can approach content in any domain with a more critically-minded perspective. The third is to create an extensible platform that lays the groundwork for teaching more advanced metacognitive and debiasing concepts in future work.

4 Implementation

The tutor is built using Oppia (https://www.oppia.org). Oppia is a free and open-source online learning platform founded in 2014 whose mission is "to help anyone learn anything they want in an effective and enjoyable way". Oppia allows individuals to create and learn through "explorations", which emulate one-on-one tutoring sessions.

4.1 Course Content

The course exploration begins by presenting the concept of metacognition (thinking about thinking) and the motivation for studying it. It claims that we are susceptible to a number of cognitive biases that cause us to make suboptimal decisions every day, and that by being able to identify and understand them, we can mitigate their effects, and approach the world in a more critically-minded manner.

The tutor explains what cognitive biases are, and that they stem from some combination of attribute substitution and other information-processing heuristics, mental noise, limited mental information-processing capacity, social influences, our desire to avoid cognitive dissonance, and conflicting emotional and moral motivations.

The tutor further explains the structure of the rest of the class, steps through a number of biases selected because of their prevalence, and explains each one to a degree that suits the student. The content comes from a combination of Wikipedia articles, educational YouTube videos, and the author's own personal experience. The biases are:

- Dunning-Kruger effect - The tendency for unskilled individuals to overestimate their ability, and for skilled individuals to underestimate theirs.
- Confirmation bias - The tendency to search for, interpret, focus on and remember information in a way that confirms one's preconceptions.
- Availability heuristic - The tendency to overestimate the likelihood of events with greater "availability" in memory, which can be influenced by how recent the memories are or how unusual or emotionally charged they may be.
- Anchoring bias - The tendency to rely too heavily, or "anchor", on one trait or piece of information when making decisions (usually the first piece of information that we acquire on that subject).
- Framing effect - Drawing different conclusions from the same information, depending on how that information is presented.
- Gambler's fallacy - The belief that the outcomes of prior random events have an effect on future random events.
- Base rate fallacy - Judging the probability of an event without considering its Bayesian prior probability.
- Hindsight bias - The inclination to see past events as being more predictable than they actually were; also called the "I-knew-it-all-along" effect.
- Sunk cost fallacy - The inclination to justify increased investment of resources in a decision based on the cumulative prior investment ("sunk costs"), despite new evidence suggesting that the cost of continuing the decision outweighs the expected benefit.
- Mental accounting - The tendency for people to separate their money into separate accounts based on a variety of subjective criteria, like the source of the money and intent for each account.
- Self-serving bias - The tendency to attribute positive events to one's own character but attribute negative events to external factors.
- Halo effect - The tendency for a person's positive or negative traits to "spill over" from one personality area to another in others' perceptions of them.

4.2 Course Architecture

Oppia allows classes to be constructed in the form of directed graphs. At each node, the student is provided with content, and then asked to provide input that then moves them to one of some set of other connected nodes. This structure can be thought of like a "choose your own adventure" book.

The introduction of the class is the same for everyone. Then, students move one-by-one through all of the biases that the course covers. At each bias, the student is allowed to either move on if they understand the concept, or to dig deeper into the material if they need or want more thorough explanations.

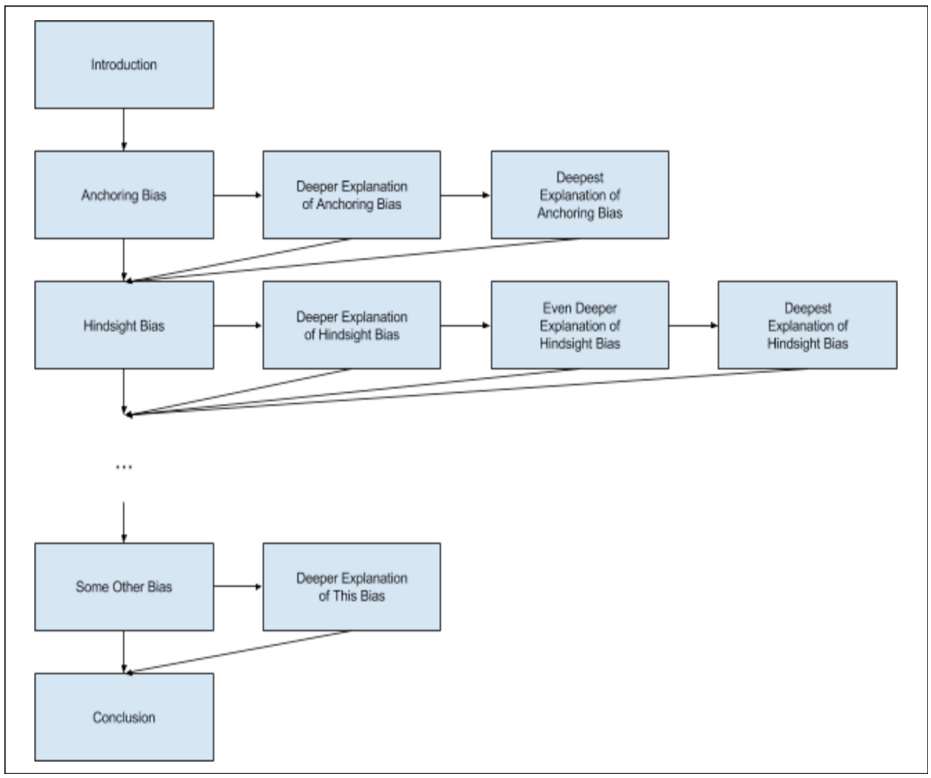

Fig. 1. The general tree structure of the class. The shown order in which the biases are presented is not actual, and is for explanatory purposes only.

There are three reasons this layout was chosen. First, it ensures that all students cover all of the concepts (no one gets out of understanding confirmation bias). Second, it only requires students to spend as much time on each concept as they need. Third, it's highly extensible; new biases and other course materials can be added easily and in a very straight-forward and intuitive manner.

5 Results

The tutor is available at https://www.oppia.org/explore/6dz_rWig579S.

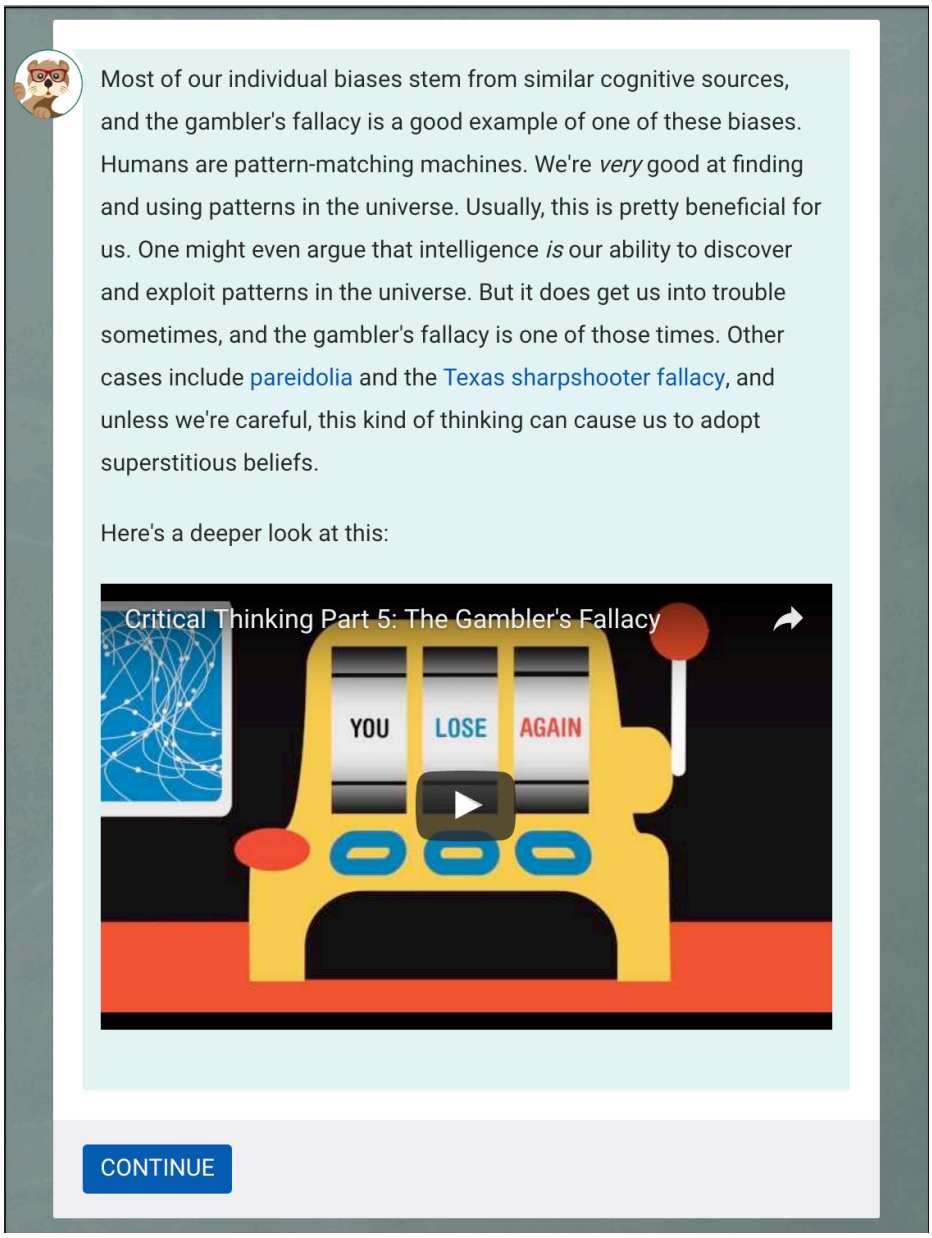

Fig. 2. A screenshot of the tutor describing the gambler's fallacy and our tendency to find patterns in randomness.

6 Conclusion

Across all domains, improving the way one thinks by the means of metacognition is one of the most effective ways of increasing learning speed and cogency. By mitigating our systematic errors in thinking, we become better decision makers. The adaptive digital tutor presented in this paper helps individuals identify and, hopefully, reduce exactly those kinds of errors.

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