Clear Thinking in an Uncertain World: Human Reasoning and its Foundations

Lecture 14

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Information cascades

We often rely on other people's opinions when making decisions or forming our beliefs.

For example, suppose that you are deciding whether to eat dinner at restaurant A or restaurant B. You have some information about the restaurants suggesting that A is better (e.g., you have looked at the menus of both restaurants). However, when you arrive at restaurant A, you notice that it is nearly empty while restaurant B (which happens to be next door) is almost completely full. Naturally, you take this as evidence that restaurant B is in fact better and decide to eat there.

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There is nothing particularly surprising or troubling about the diner's behavior: upon receiving new evidence that more people are eating at restaurant B, she updates her beliefs and makes her decision where to eat accordingly.

However, situations such as this, in which people form their beliefs using information obtained by observing the behavior or opinions of others, can bring about a so-called *information cascade*.

Bikhchandani, S., D. Hirshleifer, and I. Welch. *Learning from the behavior of others: Conformity, fads and informational cascades*. Journal of Economic Perspectives 12(3), 151 - 170, 1998.

D. Easley and J. Kleinberg. *Networks, Crowds and Markets*. Cambridge University Press, 2010.

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Of course, imitation may also occur due to social pressure to conform, without any underlying informational cause, and it is not always easy to tell these two phenomena apart.

Consider for example the following experiment performed by Milgram, Bickman, and Berkowitz in the 1960s:

The experimenters had groups of people ranging in size from just one person to as many as fifteen people stand on a street corner and stare up into the sky. They then observed how many passersbys stopped and also looked up at the sky. They found that with only one person looking up, very few passersbys stopped. If five people were staring up into the sky, then more passersbys stopped, but most still ignored them. Finally, with fifteen people looking up, they found that 45% of passersbys stopped and also stared up into the sky.

Direct benefit vs. informational effects

There is also a fundamentally different class of rational reasons why you might want to imitate what other people are doing. You may want to copy the behavior of others if there is a direct benefit to you from aligning your behavior with their behavior.

Eg. buying the first Mac computer.

Direct benefit vs. informational effects

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There may be trade-offs: If you have to wait in a long line to get into a popular restaurant, you are choosing to let the informational benefits of imitating others outweigh the direct inconvenience (from waiting) that this imitation causes you.

Herding Experiments

1. There is a decision to be made — for example, whether to adopt a new technology, wear a new style of clothing, eat in a new restaurant, or support a particular political position.
2. People make the decision sequentially, and each person can observe the choices made by those who acted earlier.
3. Each person has some private information that helps guide their decision.
4. A person can't directly observe the private information that other people know, but he or she can make inferences about this private information from what they do.

We imagine the experiment taking place in a classroom, with a large group of students as participants. The experimenter puts an urn at the front of the room with three marbles hidden in it; she announces that there is a 50% chance that the urn contains two red marbles and one blue marble, and a 50% chance the urn contains two blue marbles and one red marble. In the former case, we will say that it is a “majority-red” urn, and in the latter case, we will say that it is a “majority-blue” urn.

Now, one by one, each student comes to the front of the room and draws a marble from the urn; he looks at the color and then places it back in the urn without showing it to the rest of the class. The student then guesses whether the urn is majority-red or majority-blue and publicly announces this guess to the class.

The First Student

The first student should follow a simple decision rule for making a guess: if he sees a red marble, it is better to guess that the urn is majority-red; and if he sees a blue marble, it is better to guess that the urn is majority-blue. This means the first student's guess conveys perfect information about what he has seen.

The Second Student

If the second student sees the same color that the first student announced, then her choice is simple: she should guess this color as well.

Suppose she sees the opposite color—say that she sees red while the first guess was blue. Since the first guess was exactly what the first student saw, the second student can essentially reason as though she got to draw twice from the urn, seeing blue once and red once. In this case, she is indifferent about which guess to make; we will assume in this case that she breaks the tie by guessing the color she saw. Thus, whichever color the second student draws, her guess too conveys perfect information about what she has seen.

The Third Student

If the first two students have guessed opposite colors, then the third student should just guess the color he sees, since it will effectively break the tie between the first two guesses.

But suppose the first two guesses have been the same—say they've both been blue— and the third student draws red. Since we've decided that the first two guesses convey perfect information, the third student can reason in this case as though he saw three draws from the urn: two blue, and one red. Given this information, he should guess that the urn is majority-blue, ignoring his own private information (which, taken by itself, suggested that the urn is majority-red).

The Third Student

More generally, the point is that when the first two guesses are the same, the third student should guess this color as well, regardless of which color he draws from the urn. And the rest of class will only hear his guess; they don't get to see which color he's drawn. In this case, an information cascade has begun.

The Fourth Student and Beyond

Suppose that the first two guesses were the same—suppose they were both blue.

Now consider the situation faced by the fourth student, getting ready to make a guess having heard three guesses of “blue” in a row. She knows that the first two guesses conveyed perfect information about what the first two students saw. She also knows that, given this, the third student was going to guess “blue” no matter what he saw—so his guess conveys no information.

As a result, the fourth student is in exactly the same situation — from the point of view of making a decision — as the third student. Whatever color she draws, it will

Lessons about information cascades

The example shows how easily that information cascades can occur, given the right structural conditions. It also shows how a bizarre pattern of decisions—each of a large group of students making exactly the same guess—can take place even when all the decision-makers are being completely rational.

Lessons about information cascades

The example shows that information cascades can lead to non-optimal outcomes. Suppose for example that we have an urn that is majority-red. There is a $\frac{1}{3}$ chance that the first student draws a blue marble, and a $\frac{1}{3}$ chance that the second student draws a blue marble; since these draws are independent, there is a $\frac{1}{3} \cdot \frac{1}{3} = \frac{1}{9}$ chance that both do.

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In this case, both of the first two guesses will be "blue"; so, as we have just argued, all subsequent guesses will be "blue"—and all of these guesses will be wrong, since the urn is majority-red. This $\frac{1}{9}$ chance of a population-wide error is not ameliorated by having many people participate, since under rational decision-making, everyone will guess blue if the first two guesses are blue, no matter how large the group is.

Lessons about information cascades

This experiment illustrates that cascades—despite their potential to produce long runs of conformity—can be fundamentally very fragile. Suppose, for example, that in a class of 100 students, the first two guesses are "blue," and all subsequent guesses are proceeding—as predicted— to be "blue" as well.

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This experiment illustrates that cascades—despite their potential to produce long runs of conformity—can be fundamentally very fragile. Suppose, for example, that in a class of 100 students, the first two guesses are "blue," and all subsequent guesses are proceeding—as predicted— to be "blue" as well.

Now, suppose that students 50 and 51 both draw red marbles, and they each "cheat" by showing their marbles directly to the rest of the class. In this case, the cascade has been broken: when student 52 gets up to make a guess, she has four pieces of genuine information to go on: the colors observed by students 1, 2, 50, and 51. Since two of these are blue and two are red, she should guess based on her own draw, which will break the tie.

Each student is trying to estimate the conditional probability that the urn is majority-blue or majority-red, given what she has seen and heard. To maximize her chance of winning the monetary reward for guessing correctly, she should guess majority-blue if

$$Pr[\textit{majority-blue} \mid \textit{what she has seen and heard}] > \frac{1}{2}$$

and guess majority-red otherwise.

- $Pr[\textit{majority-blue}] = Pr[\textit{majority-red}] = \frac{1}{2}$
- $Pr[\textit{blue} \mid \textit{majority-blue}] = Pr[\textit{red} \mid \textit{majority-red}] = \frac{2}{3}$

- $Pr[majority\text{-}blue] = Pr[majority\text{-}red] = \frac{1}{2}$
- $Pr[blue \mid majority\text{-}blue] = Pr[red \mid majority\text{-}red] = \frac{2}{3}$

First student draws a blue marble:

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$$Pr[majority\text{-}blue \mid blue] = \frac{Pr[majority\text{-}blue] \cdot Pr[blue \mid majority\text{-}blue]}{Pr[blue]}$$

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$$Pr[\textit{blue}] = Pr[\textit{majority-blue}] \times Pr[\textit{blue} \mid \textit{majority-blue}]$$
$$+ Pr[\textit{majority-red}] \times Pr[\textit{blue} \mid \textit{majority-red}]$$

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$$= \frac{\frac{1}{2} \cdot \frac{2}{3}}{\frac{1}{2}} = \frac{2}{3}$$

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$$= \frac{1}{2} \times \frac{2}{3} + \frac{1}{2} \times \frac{1}{3} = \frac{1}{2}$$

So, the first student should guess "blue".

The calculation is very similar for the second student (assuming the second student draws a blue marble).

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$$Pr[\textit{blue, blue, red} \;\mid \textit{majority-blue}\,] = \frac{2}{3} \times \frac{2}{3} \times \frac{1}{3} = \frac{4}{27}$$

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$Pr[\mathit{majority\text{-}red}\,] \times Pr[\mathit{blue},\ \mathit{blue},\ \mathit{red}\ \mid \mathit{majority\text{-}red}\,]$

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$$= \tfrac{1}{2} \times \tfrac{2}{3} \times \tfrac{2}{3} \times \tfrac{1}{3} + \tfrac{1}{2} \times \tfrac{1}{3} \times \tfrac{1}{3} \times \tfrac{2}{3} = \tfrac{6}{54} = \tfrac{1}{9}$$

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$$\frac{\frac{1}{2} \times \frac{4}{27}}{\frac{1}{9}} = \frac{2}{3}$$

$Pr[\textit{blue, blue, red} \mid \textit{majority-blue}\,] = \frac{4}{27}$

$Pr[\textit{blue, blue, red}\,] = \frac{1}{9}$

So, the third student should guess “blue”, as should all subsequent students.