The Neural Mechanisms of Risky Decision Making

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I want to start off with the big picture: Why is my research important? Why is it important that we invest time and energy into these topics? Often, as scientists, we tend to be researching something quite specific, sometimes pretty esoteric, and quite difficult to understand. It is the case that, at the end of the day, maybe eight people in the world will understand this and maybe five people actually find it interesting. This Bookend is in January—the month of New Year's resolutions. Some of you may be able to relate to this, either from this year or previous years. Maybe you started out 2018 by saying, "I am going to get fit this year. It is going to be a good year of exercise. I am going to the gym often. I am going to get stronger, or faster," or whatever your fitness goals may be.

Let us say that one afternoon you are sitting watching an episode of your favorite television show on Netflix. You have plans to go to the gym after this episode ends. However, you are soon faced with a difficult decision. Once the show ends, Netflix encourages you to continue watching by auto-playing the next episode after a brief countdown. It seems so easy! You love this show, and you really want to know what happens next in terms of the plot.

Now you are faced with a pretty difficult choice. When it comes to these choices, which one looks more fun, which one looks more rewarding? I think we can all agree, probably the Netflix option. Now you have to choose between something that would provide immediate gratification versus something that would probably provide a reward—getting in better shape—but you may not see the payoff for weeks or months down the road. A lot of my research focuses on these choices that people are making every single day.

The same occurs with food choices. Some of you may have New Year's resolutions that relate to eating more healthily. We all know that we should be eating fruits or vegetables, but in reality we really just want to eat foods like burgers or cookies.

Figure 1: Humans are making choices about what kinds of food to eat every single day. Sources: "What Is a Candida Diet2." Digital Image. Nutrition Grid December 11, 2016. https://www.nutritiongrid.com/candida-diet/ Erbs55. "Fruit Bowl." Digital Image. Pixabay. February 24, 2015. https://pixabay.com/en/fruit-bowl-fruit-bowl-fruits-food-657491/. Stu Spivack. "Cheeseburger at Reddstone." Digital Image. Free Stock Photos.biz May 1,2008. http://www.freestockphotos.biz/stockphoto/17820. Kimberly Vardeman. "Chocolate Chip Cookies." Digital Image. Wikimedia Commons. May 26, 2010. https://commons.wikimedia.org/wiki/File:Chocolate_Chip_Cookies_-_kimberlykv.jpg

It is important that we research these choices to try to understand what makes someone choose one of these options. We are constantly making choices between something that gives us the immediate gratification versus something that may have a more delayed reward, like getting in shape or eating more healthily, which may not give us results for weeks or months.

This research has important implications for health behaviors like exercise and food choices. It also has important implications for the obesity epidemic and for addiction. Some of you may have friends or family members who suffer from addiction. Maybe you are addicted to smoking cigarettes. You really want a cigarette, but your long-term goal is quitting smoking. However, it is difficult for an addict to refrain from smoking a cigarette "now," in the immediate future, since that cigarette would bring immediate satisfaction.

One of the reasons that I think that human decision-making is so fascinating is because, if I surveyed the audience right now, we would probably all be in agreement about the kinds of decisions we should be making. There is a lot of evidence out there in the medical and scientific literature that it is important to eat well and exercise, to not drink a lot of alcohol, to not smoke cigarettes, and to not do

drugs. But in reality, we know that as humans, we often make decisions that are not optimal for our health.

My research focuses on understanding the variables that can contribute to a risky choice. We know that there are a multitude of variables that contribute to each one of our decisions. My research also focuses on the brain. I am interested in the underlying neural mechanisms, in understanding what is going on in the brain when someone is making a risky decision. Ultimately, the goal of this research is to improve decision-making. If we could actually improve people's decisions, and in turn improve health outcomes, that would be pretty awesome!

I have two lines of research. The first focuses on studies that I did at Cornell University prior to coming to Juniata, looking at what is happening in the brain when someone is making a risky decision.[1] The second is research that I have done here at Juniata with some students, and it focuses on cross-cultural differences in decision-making.[2] Essentially, it asks the question, "Can we change preference for an immediate versus a delayed reward?" In light of the real-world implications of this research, it would be pretty cool if we could show that we can change someone's preference for something in the immediate future versus pursuing a long-term goal—that is, if we could actually shift preferences towards the long-term goals.

We face a multitude of decisions every day: whether or not to drink an extra cup of coffee; whether to drive to work or walk; whether to attend a Bookend Seminar; or how many times to press "snooze" in the morning. A number of those decisions come with a small level of risk. Do we save money or spend it, indulge in a second dessert, or take a medication that comes with certain benefits but also comes with some risky side effects? Some of my research focuses on adolescent risky decision-making. We know that adolescence is an interesting period of development because although adolescents are often physically healthy, the main contributors to mortality during this period of development come from decisions that adolescents have made, like risky driving, engaging in unprotected sex, or experimenting with drugs. Given that some of these risks have negative and potentially fatal consequences, like drinking and driving, it is fundamental that we understand more about behavior and more about what is going on in the brain.

How can we investigate risky decision making in the laboratory? We can do this in a few different ways. The method that I am going to talk about today is called the risky-choice framing task. Here, the audience was split into two groups and presented with this problem preamble: "There is a disease outbreak that is expected to kill 600 people. You must choose between two programs, 'A' or 'B', to fight the disease." I presented Group 1 with two options, a safe option and a risky option, and the options are presented in terms of lives saved.

- You have the options of "200 people will be saved for sure" or "There is a one-third chance that 600 people will be saved and a two-thirds chance that no one will be saved."

For Group 2, I actually gave the identical options, however they were presented in terms of lives lost.

- You have the options of "400 people will die for sure," or "there is a one-third chance that no one will die, and a two-thirds chance that everyone will die."

Notice that the options are mathematically equivalent. In the "gain" frame, we see that there are 200 people saved, and in the "loss" frame we see that 400 people will die. If we subtract 400 from the initial 600, these options are mathematically equivalent.

The interesting thing about this problem that the psychologists Amos Tversky and Daniel Kahneman discovered around the mid-1980s is that in the "gain" frame most people opt for the safe option, while most people in the "loss" frame chose the risky option.[3] This is a robust effect across many different studies, researchers have shown that people switch their risk preferences depending on how information is framed.

Why is this important? If the way that we present information changes risk preference, this has important implications for actually reducing risk taking. If we can present information in different ways and show that people can reduce their risk taking, that would be impressive. That is the idea behind the studies I participated in at Cornell.

We had people complete a number of risky-choice framing problems while they were in the Magnetic Resonance Imaging (MRI) scanner.[4] The technique that is used to look at brain activity is called functional magnetic resonance imaging (fMRI). Basically, participants lie in a scanner, which is just a big magnet, and complete problems of different sorts. There are fMRI studies that show what parts of the brain show activation when people are solving a math problem, or looking at a picture of their significant other, or viewing emotional or graphic images.

Let us say a scary stimulus is presented, like a picture of a snake (at least I think that would be scary). You would imagine that the area of our brain involved in processing scary things—fear stimuli—will show activation. It turns out that there is a primitive area of the brain, the amygdala, that responds to things like a snake. If you are hiking and see a snake in your path, your amygdala will start to go crazy and respond very quickly, in only 100 milliseconds. Your brain is comprised of cells called neurons, and when those cells in the amygdala fire, they are working really hard and they are essentially depleting oxygen in that area. So as a result, blood is sent to that area. We can measure the blood flow, and that is used as a correlate of neuronal activity to understand where in the brain is there activation for this particular stimulus.

In our study, we were not using snakes, but risky-choice framing problems. These problems were similar to the one about the outbreak of disease that I mentioned earlier, except these problems used

rewarding stimuli because we are interested in, essentially, when will people take risks or not take risks for rewards. For the two types of rewarding stimuli, we used money and candy. Participants were placed in a scanner holding a button box in their right hand, and they were just making a choice by pressing one button on the box for a safe choice, and the other for a risky choice.

Participants were presented with this situation: "You have entered a raffle and sixty dollars is at stake. Which would you choose, winning thirty dollars for sure (a safe option) or a 50% chance to win sixty dollars and a 50% chance of winning nothing (a risky option)?" Then they are asked how confident they were in their decision. Participants in the study did not complete just one problem, but about 200 of these problems.

We also collected data on a number of individual difference measures. Outside of the scanner, we asked participants to fill out surveys. You can imagine all of the variables that might affect someone's decision to take a risk. One variable that is important to look at is socioeconomic status, which would certainly affect whether or not they take a risk for money. What might affect someone's decision to take a risk for something like candy? A variable like eating behavior would be important to measure. The results I will discuss focus on sensation seeking. Before their scans, participants completed a nineteen-item sensation seeking measure.[5] They indicated on a five-point scale whether they agreed or not to statements such as: "I like doing things just for the thrill of it." "I sometimes like to do things that are a little bit frightening." "I like wild uninhibited parties." Think about how you would answer, and how that might differ from how a friend would answer. Folks who disagree with these statements would be lower in sensation-seeking; people who agree would be higher in sensation-seeking. Then, we take all of our participants and look at how brain activation differs for those who have different sensation-seeking scores.

We have many results, but I am going to narrow our focus to one area of the brain that we are particularly interested in, the striatum. This area has been associated with reward processing. The striatum has a lot of dopamine input and output, given that there are a lot of dopamine pathways going to and from the striatum. The pleasure center of the brain is part of the striatum. Whenever you do something pleasurable, whether it is food, sex, or drugs, this is an area of the brain that is activated. A number of studies have shown that striatal activation has been associated with different kinds of rewards, such as monetary choices,[6] stock choices,[7] and social comparisons.[8] I am going to focus on a part of the dorsal striatum that is called the putamen.

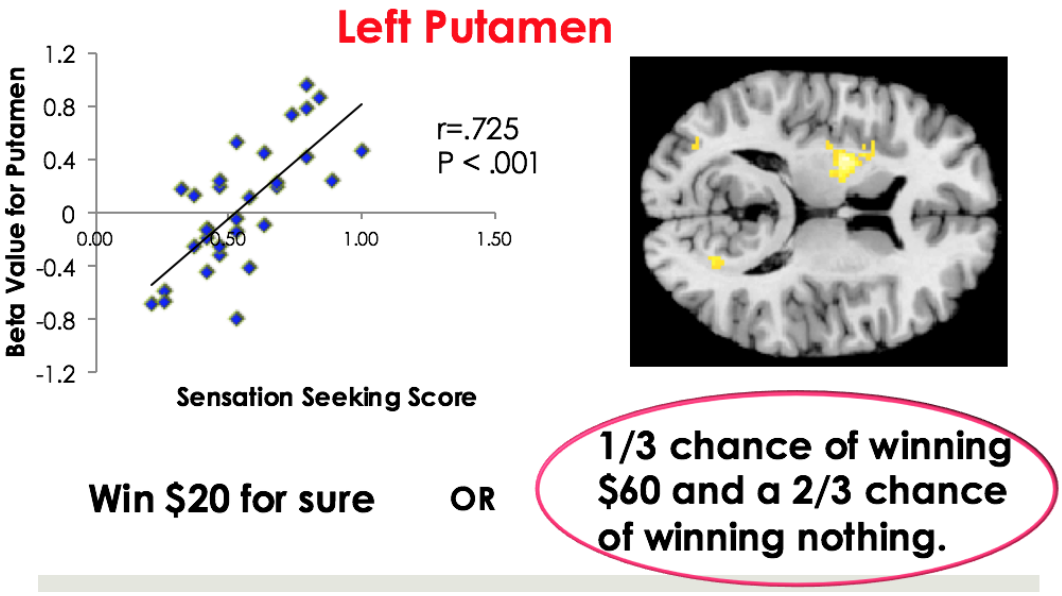

Figure 2: There is an increase in putamen activation when someone higher in sensation seeking is making a risky choice in the gain frame.

Figure 2 shows the sensation-seeking scores for all of the individuals who participated in our study. If I surveyed all of you for your sensation-seeking scores, some of you would be on the lower end of the continuum and some of you the higher end. We wanted to look at the distribution of sensation-seeking scores and answer the question, "Is there a correlation between sensation-seeking score and activation in this area of the brain that is involved in reward processing when people are making a risky choice?" Figure 2 shows the safe and risky options in the raffle situation that I mentioned previously. These people are in the scanner choosing an option. What we are seeing is that when people are taking that risky option *and* when they have a higher sensation-seeking score, there is greater activation in the putamen, this part of the brain that is involved in reward processing. This is definitely one of our more interesting and compelling findings, and it aligns with the literature nicely.

Now let us shift gears to talk about some of my research here at Juniata. I will focus on a project that looks at cross-cultural differences in decision-making. This stems from some of the research I have done with my graduate advisor at the George Washington University, where we had looked into possible cultural differences in cognitive processing. But, given my interest in decision-making when I started my lab here in the Fall of 2016, I met with a couple of students and discussed what we could do when it comes to cross-cultural differences in decision-making. We looked into what had already been done, and the answer was, "Not too much!" That can be both a good and a bad thing as a researcher, but it is great in terms of breaking ground.

Quite a bit of scholarship has looked at differences in visual and cognitive processing in Easterners versus Westerners. For example, Easterners tend to take a more holistic approach, to look at

the whole scene and take the background into consideration. Westerners will take a scene and focus on certain target objects.

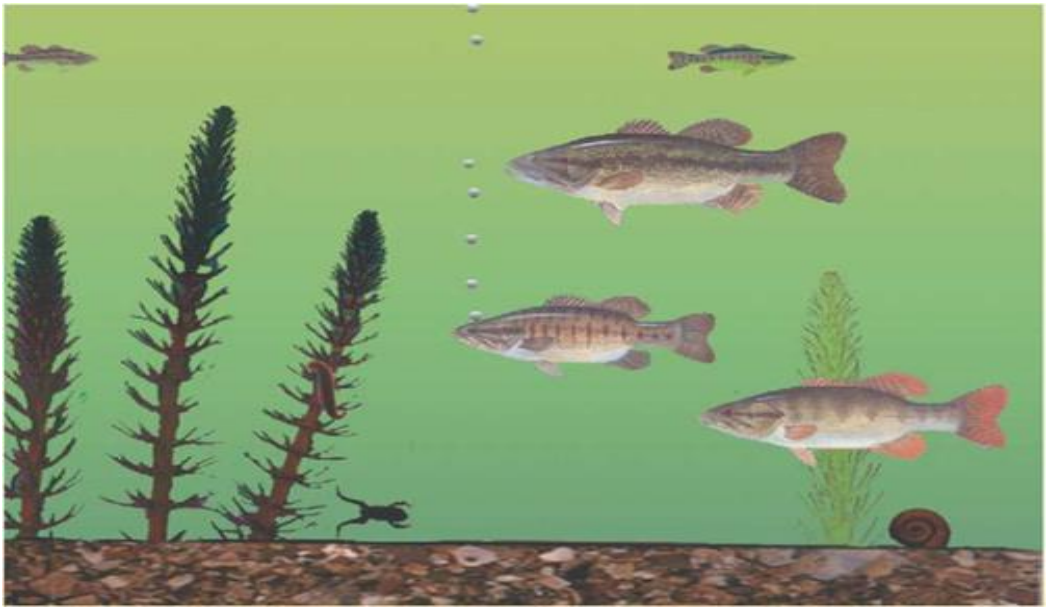

Figure 3: Evidence suggests that Westerners attend to and remember foreground objects (e.g., fish) independently of the background (e.g., fauna or color of tank), whereas Easterners attend to and remember the foreground objects in the context of the background. Source: Takahiko Masuda and Richard E. Nisbett, "Attending holistically versus analytically: comparing the context sensitivity of Japanese and Americans," *Journal of Personality and Social Psychology* 81, no. 5 (2001): 922.

There are also differences in terms of what Easterners versus Westerners remember about a scene.[9] There has been some interesting work done that shows that Easterners have a more holistic approach to life in terms of thinking about the family, while Westerners are much more likely to think about the individual.[10] Through these examples there is evidence of Westerners being more individualistic and Easterners being more collectivistic. We knew that this work had been done, but our question was about what had been done in terms of decision-making.

That brings us to what is often called the "delay discounting paradigm;" we will call it the "delayed gratification paradigm" for the purposes of this talk. The marshmallow test is a well-known example, initially introduced by Walter Mischel in 1989.[11] The instructions are simple. The researcher typically has a child sit at a desk and places a marshmallow in front of the child. The instruction is just, "I am going to go out of the room. If you wait until I return, you can have two marshmallows. If you eat the marshmallow while I am gone, you do not get the second marshmallow."

Waiting is difficult for some kids, and probably some adults as well. You can imagine some children are better than others at waiting for the second marshmallow. You can also imagine that adults

are not quite as motivated by marshmallows, but researchers can instead ask adults about different amounts of money. For example, "Would you like ten dollars today or fifty dollars in one week?" This is one example of what you could do in terms of the delayed gratification paradigm in the laboratory with adults.

As for the cross-cultural component, we found a study conducted by Bokyung Kim and colleagues in 2012 that suggests that Westerners show significantly greater preference for the immediate reward.[12] This study was conducted with Americans and South Koreans. We were intrigued by this and wanted to take what we know about individualistic and collectivistic processing and combine that with this study on gratification. We were interested in the question, "Can we actually prime a certain type of thinking, such as a collectivistic thinking strategy, that will change preferences for an immediate versus a delayed reward?"

Based on the Kim study, our hypothesis was that individualistic priming would result in a greater number of choices for an immediate option, and that collectivistic priming would result in a greater number of choices for a delayed option. We used a pronoun circling task that had been used in prior studies of individualistic and collectivistic thinking strategies.[13] We presented this to Juniata undergraduates, and one-half of our participants were randomly assigned to a collectivistic thinking paragraph and one-half to an individualistic thinking paragraph. This was to prime different types of thinking. Here is an example of the collectivistic prime: "We go to the city often. Our anticipation fills us as we see the skyscrapers come into view." You see that as you are reading this paragraph, you are picturing going to the city with at least one other person. The individualistic prime was identical except that instead of "We go to the city often," it was "I go to the city often. My anticipation fills me as I see the skyscrapers come into view." So, now you can see that as you are reading this paragraph you have a different type of processing, a different type of thinking going on. Participants were instructed to read the paragraph and click on all of the pronouns. You are either thinking about "me" and "my trip to the city," or you are thinking about "us" and "our trip to the city."

Participants received one of two primes and then completed a delay-discounting task; for example, I presented questions that asked participants whether they would prefer a smaller amount of money sooner or a larger amount later. The amounts varied, but one example of a delay-discounting problem is: "Would you prefer $31 today or $85 in seven days?" Again, participants had to choose between this smaller amount in the immediate future versus a larger amount after a delay.

Our results actually were the opposite of what we hypothesized; this is the way science goes sometimes. We found that people assigned to the individualistic prime actually made a greater number of choices for the delayed option. I credit my undergrads for the thorough work that they did on this. We had a lot of conversations about this result, and one interpretation is that individualistic thinking may actually

prime a tendency to take a later option, because in many ways a later option is riskier because it is uncertain. If we return to that example I just gave, and the delayed option is $85 seven days from now, but who knows where we will be in seven days? There is some uncertainty, and often when we talk about risk we talk about uncertainty, which is risky in itself.

We are still collecting data and are currently conducting a second experiment that is using a different prime to understand whether this trend holds. We are excited about this work. I should also say that we do plan to look at the brain as well, using electroencephalograph (EEG), which is helpful in terms of recording electrical activity from the brain. It has very good temporal precision in terms of determining when activity is happening in the brain.

To wrap up, I hope that you are walking away with the idea that human reasoning and decision-making are malleable. There are different ways in which we can actually change risk preferences and change preferences for an immediate versus a delayed option. This is fundamentally important in terms of the ultimate goal of improving human decision-making and health outcomes.

NOTES

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13. Wendi L. Gardner, Shira Gabriel, and Angela Y. Lee, "'I' value freedom, but "we" value relationships: Self-construal priming mirrors cultural differences in judgment," *Psychological Science*, 10 (1999): 321-326; Oyserman and Lee, "Does culture influence what and how we think?", p. 311.