ANDREW LO: Actually, at the end of class last time, we were talking about what happened with the stock prices of those four companies that were engaged in manufacturing parts for the space shuttle. And I didn't realize this, but apparently, in some of your other classes, I've been told that you actually did a case on Morton Thiokol, and the fact that there were some interesting discussions between the Morton Thiokol and NASA engineers about whether to launch. And that, in fact, when you just look at it from the perspective of the data, it would not have made sense to go ahead with the launch.

Well, the point about efficient markets is that, while it may not be immediately apparent as to what all of the inputs are for coming up with a bottom line price for an asset, the fact is that enormous, enormous amounts of information are collected, collated, analyzed, and ultimately reflected in the price, to the point where, after a six month investigation, it was determined that Morton Thiokol was at fault for the explosion. But, in fact, within hours after the crash and literally minutes we see that the Morton Thiokol stock price was the one hit hardest. And even when you control for other factors like size and industry effects, you still have a pretty significant finger pointed at Morton Thiokol purely from the stock market.

In a nutshell, this is what efficient markets is about. And for the longest time that is really what academic finance taught, and what was the basis for virtually everything that we do. So, in fact, all the material that we've covered in this course really assumes and requires that markets work well. That markets reflect all available information. Because obviously if it didn't, then when I tell you, go look at the market, I'm telling you to waste your time, right? Because why would you consult something that really didn't contain some significant informational advantages?

That's the good news. That's the positive side of efficient markets. Over the last 15, 20 years, there have been more and more criticism leveled against this hypothesis of efficient markets. And the most easy, the most obvious and easiest way to make that point, is with a joke that you might have heard about economists. Two economists walking down the street. One of them sees a $100 bill lying on the ground and starts to pick it up when the other economist says, "Oh, don't bother picking it up." And then the first economist says, "Well, why not?" The second economist says, "Well, if that were a real, genuine $100 bill, someone would have

already taken it, so it must be a counterfeit."

Now you laugh at that. But that's exactly what efficient market says. It says that you can't make any money in markets because, if you could, someone would have already done it. Markets are so competitive that, in fact, you can't make any money. And after awhile, people started asking questions about this hypothesis. In particular, they would ask the question, well, if nobody can make any money, then why does anybody bother going into financial markets? If nobody makes any money, then who's the folks out there that is gathering information to make markets efficient? So first of all, there's a bit of a Zen paradox. And we'll talk about that Zen paradox a little bit later on.

But the more substantial criticisms have to do with the fact that this presumption of efficiency requires rationality. In particular, it requires that market participants behave the way that economists would argue that they behave. So all of you are very gracious in not arguing with me that you would all want to hold the tangency portfolio.

Now, you could have asked me at that time, well, why would I want to hold the tangency portfolio? I may happen to enjoy holding a small subset of stocks that I know, and love, and have a particular emotional attachment to. But you probably recognize that that wasn't where the class was going, so you were very gracious in not raising that as an issue, even though, in your heart of hearts, you might really prefer that. You might simply want to hold a few stocks that you know, and enjoy, and believe in, and so on and so forth. Well, that's an example of an irrationality from the point of view of the economist. And in a minute, I'm going to actually call into question what we mean by rationality altogether.

So by the end of this lecture, I'm going to make a fairly strong prediction. I'm going to predict that what I'm going to tell you in the next hour and 15 minutes will change your lives permanently. That's a tall order. But you'll let me know. In five or 10 years, I want you to write me back and tell me whether or not I'm right. I think I am right, because I'm going to change the way all of you look at rationality completely. And actually we're going to do this in the context of your own behavior. All right?

So let me tell you where we're going with this. Behavioral finance, the alternative to market efficiency, says that market participants are simply irrational. They don't make decisions the way that economists would presuppose that they do. In particular, they suffer from all sorts of biases, and they're listed here. Loss aversion, anchoring, framing. Overconfidence.

Overreaction. Herding. Mental accounting. And so on.

And some of you, I think, may have come across these in some of the other courses that you've taken. If you ever take an experimental psychology course, you would actually see these kinds of examples in pretty intimate detail. When you look down this list, and you take seriously what the psychologists are telling us, you would conclude that the human animal is among the stupidest creatures on earth because we engage in all of these kinds of biases. And I want to go through a few examples. Some of you may have already seen this because I actually gave these examples in my introductory talk on finance. And if you have, we're going to go through it pretty quickly. But if you haven't, I think you'll be kind of surprised by some of the outcomes.

So the loss aversion example is one that I did give in my introductory lecture. How many people have seen this or remember this? OK. So I'm going to go through this pretty quickly. This is an example where clearly most people, when they're confronted with a choice of a certain gain versus a riskier alternative that might have even bigger gains but might also entail gaining nothing, that most everybody would pick choice A over B, as most of you did when we ran this example at the beginning of the semester. So even though B has a higher expected value, more risk, more expected return, like the CAPM says you should have, nevertheless, most of you as a personal preference would pick the less risky alternative, A.

Now, when you're confronted with losses, as you recall from the example, most of you picked not the sure loss but rather the gamble that actually might cause you to lose even more but might also allow you to get back to even. So the reason that these two choices are so interesting is that, in the first case of A versus B, you picked the less risky alternative because you are being confronted with gains. But in this case, when you're being confronted with two losses, instead of being consistent and picking the less risky alternative-- which, by the way, is the sure loss C-- virtually all of you picked the gamble. You're willing to take more risk when it comes to losses than you are when it comes to gains. That's an asymmetry that frankly doesn't jibe with modern financial theory, with utility maximization, with efficient markets.

So the reason that these two sets of choices are so interesting when juxtaposed together is that the choices that most of you did pick, A and D, was actually strictly dominated by the choices that most of you did not pick, which is C and B. When you combine these two, you can show that B and C is exactly equal to the most popular choices, A and D, plus $10,000 cash. So you guys left $10,000 lying on the sidewalk. And that's clearly not efficient.

Well, it turns out that there is a reason for this kind of bias, and it's hardwired into all of you. And I'm going to tell you what that is in a few minutes, after I go through just a couple of other examples to make sure that we all understand the limitations of what we consider to be rational, economic decision-making.

Any questions about this example? This is called loss aversion. This is an example that was first proposed by two psychologists, Kahneman and Tversky, and for which Kahneman won the Nobel Prize in economics a couple of years ago. Tversky would have won it as well, had he been alive, but he died a few years before. And what's interesting about the fact that Kahneman won the Nobel Prize is that he's not an economist, he's a psychologist. And so, in a way, maybe the Nobel Memorial Prize in Economics was trying to signal to the economics profession that they ought to take these kind of things more seriously.

OK. This is the second example that I gave in that introductory lecture on drawing balls out of an urn. How many people still remember this example? No? OK, so let me go through this in a little bit more detail because this is directly relevant to the current financial crisis that we're facing.

Those of you who've ever taken an undergraduate statistics course, you'll remember the bane of your existence during that semester. It was the prototypical urn example, right? Drawing balls out of an urn. I hated those examples. They're a real pain in the neck. So I'm going to give you one now. But this one is not as bad as the others that you might have come across.

I want you to imagine an urn that I have where I've got 100 balls. And 50 of those balls are colored red, the other 50 are colored black. They're otherwise identical. And you and I, we're going to play a game. And here's the game.

You pick a color, red or black. Don't tell me what it is. Write it down on a piece of paper. And then I'm going to draw a ball out of this urn. And if the ball that I draw is your color, I'm going to pay you $10,000. And if it's not, I'm going to pay you nothing. OK? That's the game.

And we're going to do this exactly once. Play this game once. I wish we could do this in reality. But the prize is a little bit higher than what our dean is willing to let me gamble with. But let's imagine we're going to do this for real. OK?

So I want you to tell me, first of all, how many people would be willing to play this game with me for $1? In other words, you pay me $1 and we'll play this-- Yeah, OK. Good. How about

$1,000? $2,000? $3,000? $4,000? $4,500? $4,999? $5,010? OK.

So I still had a few hands up at $4,999. Nobody wants to play this with me for $5,010, presumably because? Louis?

AUDIENCE: So if you asked the question, how many people would sit down at a blackjack table--

ANDREW LO: Yeah.

AUDIENCE: Or a roulette wheel--

ANDREW LO: Yeah.

AUDIENCE: I think people would raise their hand.

ANDREW LO: Mm-hmm.

AUDIENCE: But they won't pay $5,010 to play this game of red black?

ANDREW LO: Well, that's a different question though, right?

AUDIENCE: This is a roulette wheel.

ANDREW LO: Well, but it's--

AUDIENCE: [INAUDIBLE] house money.

ANDREW LO: --not a roulette wheel though. It's a different game. It's an urn with 50 balls red and 50 black.

AUDIENCE: [LAUGHTER]

ANDREW LO: I mean, you know, I have to tell you that a roulette wheel happens to be more entertaining. You know, you see the little ball rolling around, and it's a different game. All right, I want to come back to this in a minute.

But let's get back to the price. I established the price of $5,000. And, not surprisingly, all of you extremely numerate MIT students, you figured out that the expected value is $5,000, right? And so that's what you bid. OK.

Now before I go on, let me ask you one other question. Do you have a preference for which color you'd pick? No preference? You sure? Why not? No preference?

AUDIENCE: It's 50%.

ANDREW LO: It's 50/50, that's right. So there's no reason that you have a preference one or the other. However, I should just let you know that in populations where they do this kind of survey, there is a slight preference for the color red in the population. It's kind of interesting. But, you know, all right, fine, 50/50. You understand the game. There's no preference.

OK, now, we're going to play the exact same game except with urn B. Urn B is identical to urn A in every respect except that, in this case, I'm not going to tell you the proportion. There could be 50/50 red and black, but it could be 40/60, or 70/30, or 85/15, or 100/0. I will promise you that there are exactly 100 balls and there are, at most, two colors, red and/or black, but beyond that, I will not tell you anything. And now we're going to play the exact same game. OK?

So the question is, first of all, what color would you prefer? Any of you have any particular preference here? Why not?

AUDIENCE: Red.

ANDREW LO: Red. You'd prefer red? OK, yeah.

AUDIENCE: Go for black because you know that most people prefer red.

ANDREW LO: Well, no, I didn't say most people prefer red. I said there was a slight preference for red, and, Ingrid, you seem to fall into that category. And so you'd prefer black instead. All right. Well, we're going to come back to the color later on. But now let me ask you, how much would you pay to play this game with me? Everything else is the same. $10,000 prize if you get the color that I pick. All right?

AUDIENCE: Do we trust you?

ANDREW LO: What's that?

AUDIENCE: Can we trust you?

ANDREW LO: I don't know. Do you?

AUDIENCE: [LAUGHTER]

ANDREW LO: Well, first of all, what is there to trust?

AUDIENCE: Is there really a hundred?

ANDREW LO: I, yes, that I will guarantee. So after the fact, that we will verify that there is exactly 100 balls and it will be, at most, two colors, red and/or black, and that's it. No other elements will be introduced. OK? So that's perfectly verifiable, and we will verify that after the fact, that all prices are contingent upon that verification. But that's the extent to which you need to trust me.

If you're asking whether or not I'm the one that's picking the distribution, then, yes, I am. I'm picking the distribution. But I don't communicate with you, and you don't communicate with me ahead of time, other than what I know about you in this class and over the last semester. OK?

So now, let's figure out how much this will draw in terms of the price. How many people will be willing to play this game with me once for $1? $1,000? $2,000? $3,000? $4,000? $4,999? $5,010? OK. So it's about the-- You'd pay more? You'd pay more to play this game than the one before? I'm going to come back to that in a minute. That's worth exploring. But before I get back to Davide, Justin, you were willing to pay the same for both. Why?

AUDIENCE: Well, because the proportion doesn't matter because you pick your color, so it's kind of out of your hands. You know it's either one color or the other color. You know the proportion's already been decided upon so it should be the same as the previous game.

ANDREW LO: OK, so you think that the odds are the same in this case as before? Even though I'm the one that picks the odds?

AUDIENCE: When you pick it beforehand and, I guess if it was random--

ANDREW LO: Well, no, no, no. It's exactly what I just told you. I get to pick the odds so, unless you consider me random--

AUDIENCE: Yeah, but we still get to pick the ball--

ANDREW LO: You get to pick the ball. You have to pick the color, I pick the ball.

AUDIENCE: Yeah, I still think it's about 50/50.

ANDREW LO: 50/50. OK. Mike?

AUDIENCE: Do you pick the odds after we tell you our thoughts?

ANDREW LO: No, it's clearly not. Yeah. No, no. That's a good point. And, no, we won't cheat, in the sense that I will not pick the distribution after you tell me what your color is. OK. Dannon?

AUDIENCE: [INAUDIBLE] I mean, you really don't know the probability, so--

ANDREW LO: Yeah.

AUDIENCE: You really need to have one black ball? Since you're drawing, you know, one more person who has to match the color. Then you have another 99 that are left. So your probability's are really high at that point. Unless you're very unlucky, with that very first ball as being black, then-- So, but it could go either way.

ANDREW LO: OK. So I'm-- So what's the bottom line? Do you think it's the same as before, or it's different? Would you bid the same amount to play this game with me?

AUDIENCE: I ended up bidding the same amount.

ANDREW LO: You did? OK. Anybody disagree with that? Anybody that would not pay the same? A lot of you didn't pay the same. Yeah, Jen?

AUDIENCE: Well, I would just calculate that the worst outcome here is worse. It's like $100.

ANDREW LO: Yeah, that's right.

AUDIENCE: I would pay $100.

ANDREW LO: That is the worst outcome. I mean, if you pick red, I could have 100 black balls in there, and then you're going to lose, no matter what.

AUDIENCE: But that's also the best. Yeah. Pick black. Because it's-- [INAUDIBLE]

ANDREW LO: That's true, yes. If you look at it the other way, it's the best case if you did the opposite. Hmm. So what do we make of that? Yeah?

AUDIENCE: I think basically it's, the laws of standard probability are the same.

ANDREW LO: Yeah.

AUDIENCE: Because, in this case, the probability is you all being able to pick the right ball. And that's 50/50. The right color, right?

ANDREW LO: Is it? Is it 50/50 though? That's the question. Yeah. I'm picking the distribution, you're picking the ball, right? Yeah, Davide?

AUDIENCE: I'm not sure I understand exactly. So--

AUDIENCE: [LAUGHTER]

ANDREW LO: That would explain, certainly. Sure. Go ahead.

AUDIENCE: Say the real proportion is 50/50, I would pay you $5,000.

ANDREW LO: Sure.

AUDIENCE: If the real proportion is zero, I wouldn't pay you any more. If the real proportion is one, I wouldn't pay you any more.

ANDREW LO: Yeah, that's right. Sure. If you knew that this was-- if you had an insider's view of what the proportion is, you might pay more.

AUDIENCE: So, in other words, I would pay more than $5,000.

ANDREW LO: OK, but do you think you know something then?

AUDIENCE: No, but I would say that I would pay more than $5,000.

ANDREW LO: Why? Why? Only if you had more information. But do you? Do you think you have more information?

AUDIENCE: Even if it's less than 50/50, then I would pay more than $5,000.

ANDREW LO: But what if it's more than 50/50? What if it's more than, in other words, what if it's 60/40 against you, as opposed to 40/60 with you?

AUDIENCE: Because at 60/40-- I mean, it's like-- as if it were 100/0, then I would be winning. Sure.

ANDREW LO: That depends on your color. It depends on your color. Yeah, David?

AUDIENCE: If there's no expectation that you're biased, you can't make that expectation and the expectation of how much you could get is the same.

ANDREW LO: OK.

AUDIENCE: So if you're going just on the expectation of what your bias is--

ANDREW LO: Right. Well, so you guys have seen me over the last 12 weeks. You know what my biases are. In this case, I've already told you that I have some information. Right? That people, on average, prefer red a little bit more than black. So actually, you have that piece of information. What would you do with it? Does that tell you anything?

AUDIENCE: It tells us everything.

ANDREW LO: Well, it does tell you something. It tells you that I know that people prefer red slightly more than black. But the problem with that is that you know I know. And moreover, I know you know I know, and you know I know you know I know.

When you take it back to its infinite regression, you know what it comes up to? 50/50. It turns out that, mathematically, the odds for this game are literally identical to the odds of the previous game. But it's also the case that when you take these two urns and you auction them off to the public, there is a very, very significant discount in what people will pay for urn B. And we saw this in class. A lot fewer of you raised your hands we were going to $3,000, $4,000, and $4,999.

And you know why? When you ask people, why is it that you would pay less for this urn than the previous one, they'll tell you very plainly it's because, in this case, I don't know what the odds are. I know what the odds are in the previous case, but I don't know what kind of risks I'm dealing with. In most dictionaries and thesauruses, risk and uncertainty are considered synonyms. But in fact, we see here that, from a decision-making point of view, when there is uncertainty about your risk, you tend to shy away from that because I don't know what I'm dealing with here.

Now there is one simple mechanism by which all of you in this room could make it impossible for me to somehow strategically pick the worst distribution against you. Anybody tell me what that algorithm is? Yeah?

AUDIENCE: If you just flipped a coin to decide what color you pick?

ANDREW LO: Exactly. If Brian flips his coin, not my coin, if you take your coin and flip it and pick red or black based upon the outcome, there's no way I could possibly do anything to disadvantage you. Now, that's a real interesting conclusion, isn't it? Because what that's telling you is that by

injecting uncertainty into a system, you might actually make it more preferable, more fair, by adding randomness in there. And yet when you tell people that, they say, well, you know that sounds great, I still don't want this. Because I don't want to deal with the uncertainty. And that's hardwired. We as human beings shy away from the unknown.

OK, now, take this example and apply it to a non-financial corporation that has toxic assets as part of its balance sheet where you have no idea what the market value is, because there is no market, because it's not trading. Because you don't know how to evaluate the security because it contains too many parts that you can't figure out what the legal, never mind financial, ramifications are for those assets. And you can understand now why people say, oh, wait a minute, I don't want to play. I don't I don't care what it's worth. I don't want to know. I don't want to deal with it because I can't evaluate the risk. That's what's happening in spades today. [? Shlomi? ?]

AUDIENCE: In the second game, you said that the people preferred to pay less because they don't want to go with uncertainty.

ANDREW LO: The uncertainty about the risk.

AUDIENCE: But uncertainty about the risk is unimportant.

ANDREW LO: That's right.

AUDIENCE: They don't understand the game. This is the reason why they prefer to [INAUDIBLE].

ANDREW LO: Well, let me put it this way. All of you here, I think, are pretty sophisticated. All of you, by the way, understand the mathematics of this game, I believe. Right? There's not that many moving parts.

If we were to do an anonymous survey where I forced you to play with me-- So, in other words, I deducted $5,000 from your payroll, so you're playing with me, no matter whether you like it or not. You just paid $5,000. But I did let you choose whether you play with urn A or urn B. I bet you the result, even in as sophisticated an audience as this, is that the vast majority would pick urn A, not urn B. You don't have to raise your hands. I won't put you on the spot. But my guess is that most of you, if not all of you, would end up picking urn A simply because you then can evaluate the uncertainty, whereas with B, you can't.

So you're right that, mathematically, they're the same. But the fact is that we shy away from

anything we don't understand, and so what that suggests is that there are layers of risk. In fact, there was an economist many years ago by the name of Frank Knight who was trying to explain how it was that certain people in the economy were so much richer than others. In fact, he was trying to explain the great wealth of the big mega industrialists. These are the folks like Pierpont Morgan who was worth, at that time, $100 million, which was an extraordinary amount of wealth. The modern day version today is Bill Gates. The question is, should Bill Gates be worth $40 billion or $50 billion? Does that make sense? I mean, is he really that much more valuable in any way than any of us? Why should somebody like that be worth so much more money?

And Frank Knight struggled with this because he didn't understand how, from an economic perspective, you could justify it. And he finally came up with the following hypothesis or proposal for why these entrepreneurs make so much money. It's because they are taking on a kind of randomness that is not quantifiable. In other words, there's two kinds of randomness in Frank Knight's perspective.

One is risk. Risk is quantifiable. For example, mortality rates. I don't know how many of you have looked at life insurance policies. But if you have, as I did when I first had my first child, I decided to learn a little bit about life insurance, and read mortality tables, and looked at life expectancies, and so on. And I found it enormously depressing because it turns out that, if you tell me 15 facts about your life, with those 15 facts I can actually pinpoint your life expectancy to within plus or minus 5 years, with an enormous degree of accuracy. And, as far as I'm concerned, that's much more information than I need. I don't need to know when I'm going to die.

Think about it. Actually, as economists we always say, the more information you have, the better. Do you really believe that? Do you want to know when you're going to die? If I had that information, would you want me to tell you when you're going to die? The specific day and time? Would you like to know? Think about that.

Well, it turns out with these mortality tables, whether or not you've ever smoked, do you drink, what kind of car do you drive, have you ever had an accident? There is these 15 or 20 questions that, once you answer them, you get put into a box. And that box has a life expectancy that ends up being pretty darned accurate.

Now, the point of this is that the life insurance business is not currently a growth business. I

don't think anybody here is dying to graduate from Sloan to start a life insurance company. Why is that? It's because there's not that much profit left, given that it's relatively well understood how to forecast mortality rates. And once you forecast them, you can price the insurance in such a way that you'll be slightly profitable, and that's pretty much all you're going to do.

So the profit opportunities for the kinds of randomness that you can define very precisely, like mortality tables, or property and casualty insurance, there's not a lot of profit in that anymore. Maybe for the first person who did it, yes, there was. But by that time, at that time, there wasn't a lot of data on this.

OK. So Knight said that you don't get rewarded with untold sums of wealth for taking on risk. What you get rewarded for with untold sums of wealth is for taking on uncertainty. Uncertainty is what Frank Knight called the risk that nobody can parameterize.

So, nanotechnology. Who the heck knows whether or not that's going to pay off? We don't even know what that is, or whether it's really a business. That kind of uncertainty, if you're willing to take that on, then there are those who will make literally billions of dollars.

And so the profits that economists would argue have to be in equilibrium, zero, right? Zero profit condition is typically what an economic equilibrium consists of. Zero profit only applies to the risks that can be parameterized, that can be well understood. And the point is that the human tendency is to shy away from the uncertainties of life. We don't like things we don't understand, and we will shrink from those. So if you are wired in a different way to be willing to take those kinds of risks, you're going to get paid huge sums of money for that. Ike?

AUDIENCE: In terms of the zero sum math game, what about the silence of the cemetery? That Bill Gates is offset by the thousands of entrepenuers who've failed and are worth nothing? So, on average, they're all mortal.

ANDREW LO: Well, that may be true that, on average, it all works out. But the point is that why do you have such a huge disparity for certain kinds of randomness whereas, for other kinds of randomness, you have a nice bell curve? In other words, why do you have this kind of tail risk going on? The tail risk that you're talking about? The silence of the cemeteries. The fact that, for every one Bill Gates, you've got several million failed entrepreneurs, is because people are taking on the kind of randomness that nobody knows how to quantify. That's the argument. So it's consistent with that perspective. OK?

So that's why VCs and entrepreneurs-- those of you who want to do your start-ups, I wish you great success. And in this classroom, I will bet that at least one of you will be a billionaire in 15 years. And I want to get to know you very well between now and then.

But the downside, which all of you should know, the downside is that for the rest of the entrepreneurs that don't make a billion dollars, you'll make nothing. Zero. You'll lose everything. Now, that's a reasonable trade-off if your particular psychological makeup enjoys that kind of a thrill. But it's not for everybody, and that's why people get paid what they get paid. Right? So there is some logic to this kind of puzzle.

By the way, this particular example was developed also by a psychologist by the name of Ellsberg. And it's called the Ellsberg paradox because this is a situation where, despite the fact that the odds are the same, people don't like the uncertainties. And to me, and to a lot of evolutionary biologists, and neurophysiologists, this is not surprising. Because we are hardwired to stay away from stuff we don't know because it's the stuff you don't know that can kill you. And from an evolutionary perspective, it makes a lot of sense. Question?

AUDIENCE: I feel like a big part of what got us in this whole mess is that [INAUDIBLE] came unwired-- People actually were chasing stuff they didn't know and paying more for it.

ANDREW LO: Well, I think it's not so much they were chasing what they didn't know but rather, they were chasing stuff that they thought they knew that, in fact, they didn't. So we're going to come back to that. Let me hold off on that for just 15 minutes. I want to take that head on when we actually look at the applications to finance. Zeke?

AUDIENCE: I think there's also like an [INAUDIBLE] version of this as well. It's because there's not-- there's also not doing your homework. Taking on some uncertainty whereas you could be taking risk.

ANDREW LO: Sure. Absolutely. It's possible that this kind of risk is not systematic risk. And there's nothing that says that you ought to get compensated for that, except for the fact that, if you're talking about very, very, very unusual kinds of technologies, or businesses that nobody really understands or is able to take on, that's where the multibillion dollar paydays are going to come from. It's not going to come from starting up a news stand, or setting up another restaurant, or selling coffee. Well, coffee, maybe. Let me take that back because we have some counter-examples.

But the point is that, if it's commoditized, if everybody understands how to do it, then the profits ultimately are going to get bid down to zero. OK. Yeah?

AUDIENCE: It's also brought to your attention, you know, Warren Buffet's averages of the normal conventions of, you know, [INAUDIBLE]. Then he says [INAUDIBLE] standard of [INAUDIBLE]. Right? So that's, that's a huge, that's a huge uncertainty factor. But yet he's still [INAUDIBLE].

ANDREW LO: That's right. He may have made money in other ways. Not necessarily by taking risks that nobody else understood, but rather by being early in taking advantage of opportunities that other people didn't see. So there's more than one way to make a lot of money. And we'll talk a bit about that at the end, when I talk about how evolutionary pressures ultimately allow businesses to fail and succeed. So I'll come back to that.

Any other questions about the example though? OK. So we've got two examples of irrationalities that all of us seem to possess. And the third example that I give is one that I think you have seen, which is this video clip of this gorilla. Right? This is a clear example where we are all hardwired to see certain things that we are looking to see, and when we're not looking for other things, we don't see them at all. And this final example I give because it provides, I think, incontrovertible evidence that human cognitive abilities are limited. We are not infinitely rational in the sense that we can compute, observe, analyze, forecast, and remember, an infinite amount of information.

And so, after all of these examples, this is why I said, you must think that the human animal is the stupidest creature on earth. Because we suffer from all of these behavioral biases. So the behaviorists would conclude by saying, we rest our case. People are irrational, therefore how can you rely on markets for making any kind of decisions?

Well, the official markets types have a pretty powerful retort. And the powerful retort comes in the form of what's known as the Dutch Book theorem. This is an example that I also give to try to illustrate how it could be that, even though there are crazy people some of the time, and certain people that are crazy all of the time, that nevertheless the smart money will win. So the example goes like this.

You've got an event A that we're going to bet on, OK? And the event is that the S&P 500 falls by 5% or more next Monday. This used to be considered a pretty extreme event. Now it's business as usual, right? OK. So let's suppose that you, as the irrational, behavioral, psychological creature that behavioral economists would argue you are, you have the

following probability belief. The probability of A is 1/2 and the probability of NOT A is 3/4.

Now some of you are chuckling because you would never have such beliefs, right? Because the probabilities, they don't add up to 1. Well, I guarantee each and every one of you if I got you into a darkly-lit room, and I asked you a series of questions over time, you would ultimately end up exhibiting biased probabilities just like this, because the human cognitive faculties are not designed to make correct, probabilistic inferences. This is not natural, that we know how to make probabilistic, just judgments.

So let's suppose that this is what you believe. Now, what's the problem with this irrationality? Well, the problem is that you would be willing to take both of the following two bets. Bet B1 is a bet where if A occurs, I pay you $1. If A doesn't occur, you pay me $1. OK? And the reason you're willing to take this bet is because the odds of A occurring are 1/2. 1/2 means 50/50, and so you're willing to take those 50/50 odds with bet B1.

However, because you also believe that the probability of not A is 3/4, which is one to three odds, right? 1/4 to 3/4. One to three odds. Because of that fact, you're also willing to take bet B2. Bet B2 is a bet where I pay you $1 if A doesn't occur, but you pay me $3 if A does occur. And again, the reason you are willing to do that is because you believe that the probability of A not occurring is 3/4.

Now, if that's the case, you're willing to take bet B1 and B2, here's what we're going to do. I'm going to place $50 on B1 and $25 on B2. That's the wager that I want to engage in with you. If we do that, then let's see what happens.

If A occurs, I lose my $50 on B1 but I win three to one odds on my $25 on B2, so I win $75 on B2, so I make $25 profit if A occurs. If A doesn't occur, what happens? Well, if A doesn't occur, I lose my $25 on B2, but I make $50 on B1. I make $25 again. Heads I win, tails you lose. No matter what happens, I make $25, so I'm going to like this a lot. And I'm going to keep doing it, and doing it, and doing it, until one of two things happens. Either you run out of money, or you change your probability beliefs.

And it turns out that there is only one set of probability beliefs for which I cannot construct this free lunch. You know that is? It's when the probabilities sum to one. So the point is that there is a limit to how irrational you can get. Because as long as I'm there to take advantage of you, I'm simply going to pump money out of you until you cry, uncle. Until you change your beliefs. Yeah?

AUDIENCE: Are there any examples of where this has actually been exploited?

ANDREW LO: Absolutely. There are tons of examples. There are tons of examples of mispricing. In fact, the example that I gave you when we were doing fixed income arbitrage, when we had these different treasury securities that had different yields for the very, very same maturities, and you could solve using simultaneous linear equations for the arbitrage. That is exactly this example. So there are many, many examples where this occurs. And it doesn't last, typically, because people get tired of losing money, and ultimately either they run out of that money, or they get wise.

So the idea behind this argument that efficient markets folks make is that, sure, people may be irrational from time to time, and there may be some people that are always irrational, but as long as there are smart people out there, as long as there's smart money out there, then it doesn't matter. Because the probabilities will sum to one through market forces.

And so then the question is, how strong are those market forces? And I would point to the current crisis to tell you that those market forces, while if they sound good on paper and, at a place like MIT, I promise you that what John Maynard Keynes said decades ago is still true. Which is, the market can stay irrational much, much longer than you can stay solvent. In other words, if you are the only sane person in an irrational world, you are the one with the problem. Because you can't take advantage of these opportunities before ultimately the forces of irrationality overwhelm you. At least that's what John Maynard Keynes thought.

Now, it seems to suggest then that it's a question about magnitudes. In other words, you've got smart people here, you've got irrational people here-- They're going to interact and may the bigger pocketbook win. Question is, who's got the bigger pocketbook? Who's got the stronger set of forces? The irrational guys or the efficient markets guys?

And before I answer that question, or at least propose an answer to that question, I need to now beg your indulgence for the next 15 or 20 minutes because we're going to take a little bit of a detour. I want to bring in some evidence from the cognitive neurosciences that will speak directly to this issue of what we even mean by rationality. It turns out that what economists mean by rational is not what you and I take to be rational from a daily, kind of, activities type of perspective.

So I want to tell you about some research in the cognitive neurosciences that really changes

the way we think about rationality and decision-making. To do that, I'm going to tell you about a particular case study that was described in a book written by a neuroscientist by the name of Antonio Damasio. Damasio is a clinical neurologist, meaning that he sees patients as well as does research. And about 15 years ago, he wrote a book titled *Descartes' Error,* and in a few minutes I'll explain to you where that title comes from.

But in this book, he describes his experience in dealing with one of his patients, codenamed "Elliot," who developed a brain tumor that had to be surgically removed. And, as you may know, with these kinds of surgeries, you've got to remove a healthy portion of the brain as well as the tumor to make sure that you've got all of the tumor, and you don't leave anything remaining. So after they took out this tumor, and after Eliot recovered from the surgery, they gave him a battery of tests to see whether or not any of his cognitive abilities were impaired because of this surgery. They gave him a perception test, memory test, IQ test, learning ability, language ability, arithmetic. With every single test, Eliot passed with flying colors, either average or well above-average.

And yet, within weeks after the recovery of his surgery, he was fired from his job, his wife left him, and, for all intents and purposes, he had to be institutionalized. He couldn't live on his own because his behavior became so irrational. Now let me describe to you what kind of irrationality we're talking about. Damasio describes what Elliot did when he was engaged in a task at his job. He was an accountant at the time.

And so Damasio writes, "When the job called for interrupting an activity and turning to another, he might persist nonetheless, seemingly losing sight of his main goal. Or he might interrupt the activity he had engaged, to turn to something he found more captivating at that particular moment. The flow of work was stopped. One might say that the particular step of the task at which Elliot balked was actually being carried out too well, and at the expense of the overall purpose. One might say that Eliot had become irrational concerning the larger frame of behavior."

Now, what Damasio was telling you is a very simple example that he gave in the book, where Eliot was asked to write a letter to one of his clients. He'd fire up the word processor and, before he started typing that letter, he had to pick just the right font. And it took him three hours to pick that font. Three hours, literally.

Now, those of you who use Microsoft Word, I know that when you first got it, you did the same

thing I did. You pulled down that font menu, and you went through Arial, Sans Serif, Times New Roman. You checked out all those fonts, but it probably didn't take you three hours. Moreover, it didn't take you three hours every time you had to write a letter. Well, it did for Eliot after the surgery. Every letter he wrote took three hours at the start because he had to pick just the right font. And it didn't dawn on Damasio until he gave Elliot one test that he finally failed as to what was going on. And let me tell you what the test was.

Psychologists often use something called eye-blink response rate to measure emotional reaction. It turns out that for normal human beings, when you have a strong emotional response, you blink your eyes a little bit more quickly than usual. All right? Those of you who've ever seen the Betty Boop cartoons where they have a female character trying to flirt with somebody else, that the way they'll indicate flirtation is blinking their eyes a little bit more quickly or batting her eyelashes. Right?

Those of you who are serious poker players, you'll know that there's a poker tell, meaning a physical characteristic that will signal a strong, emotional reaction on the part of your opponent. And that is, when they look at their hand, they blink their eyes a little bit more rapidly. Either it's a really strong hand or a really weak hand. That's, by the way, why many poker players-- they wear sunglasses when they play. Not to look cool but to hide their reactions.

What they do is they take a subject and put them in front of a computer screen. Attach electrodes to their eyelids to measure how quickly they're blinking their eyes, and they show the subject strong, emotionally-charged images. Things like pornography or scenes from Nazi concentration camps. And when we have strong emotional reactions, you can measure the increase in the rate at which we blink our eyes.

It turns out that Elliot had no change in his eye-blink response rates. None whatsoever. And so Damasio finally asked Elliot, "Elliot, how do you feel?" And Elliot said, "You know, it's funny. After the surgery, I observed that the things that I used to enjoy before the surgery, I don't anymore. For example, I used to like steak dinners, red wine, and Mozart. And I've experienced all of those things afterwards, and I don't feel anything. I know I should be enjoying them, but I don't. I don't feel anything. I don't dislike it. I just don't really enjoy it as much as I know I should."

Now, I don't know how many of you have had that kind of reaction. I have fairly recently. My

eight-year-old son and I were at the supermarket the other day, and I was going by the candy aisle, and I noticed that there were Cracker Jacks on the shelf. I don't know how many of you know what they are? Peanut-coated popcorn candy and a prize, right?

Well, I loved Cracker Jacks when I was eight years old. I remember that very distinctly, just really enjoying it. So I decided I was going to get some for my eight-year-old. So I got some for him, and I tried some as well. And I remember thinking, gee, I know I should really be enjoying this, but I'm not. It's not-- Maybe my tastes have changed, I don't know, but it's not nearly as wonderful as I remembered it to be.

Imagine having that feeling about everything. All your fears, anxieties, your great desires, all of your emotions, gone. You don't feel anything. You sort of feel numb inside. It turns out that Damasio conjectured that what we think of as rational behavior actually requires emotion. In other words, you have to be able to feel in order to act rationally.

Now, that's really very different from the typical kind of impression where rationality is at one end of the spectrum and emotion, fear, and greed are at the other end of the spectrum. This is Descartes' perspective on the world. This is why the book is titled *Descartes' Error.* He's arguing that Descartes got it all wrong. That, in fact, emotion is the opposite side of the same coin. If you can't feel, then you can't be rational.

So this calls into question what we think of as rationality. And I'm going to beg your indulgence for another five minutes as I tell you more about the neurophysiological basis for this observation. It turns out that the part of the brain that they took out from Elliot with his tumor is the part that was responsible for emotional reaction. And there have been a number of theories that have been developed now about how the brain works. So I want to describe probably the most popular theory, at least as of about 10 years ago, and you'll get a better understanding for what's going on. And this is the part that I think will change your lives.

So it turns out that the brain, which is pictured here in cross-section, is not nearly the homogeneous organ that we often take it to be. It turns out that the brain is comprised of different components. And a neuroscientist by the name of Paul MacLean about 10 years ago came up with what's now called the triune model of the brain, which decomposes the brain into three separate components.

The first component is located at the bottom of the brain. It's also known as the brain stem. It's the part of the brain that sits on top of your spinal cord, and all of the nerves that go up

through your spinal cord attaches into that brain stem. And neuroscientists have determined that the brain stem is responsible for all of the, sort of, bodily functions that you take for granted, and typically you cannot control, unless you you're a Zen Sufi master. Things like heart rate, breathing, body temperature regulation, things that we need for basic survival. And MacLean called the brain stem the reptilian brain because this is the part of the brain that we have in common with virtually all vertebrates. Reptiles, mammals, anything with a spinal cord will have a brain stem sitting on top of that. And from an evolutionary perspective, it is the oldest part of the brain, and the part that really controls the very most primitive functions of life.

The second part of the brain that MacLean identified is the middle part, known as the mid-brain, or what MacLean called the mammalian brain. This is the part of the brain that we share only with warm blooded creatures, with mammals. So reptiles don't have this. And it's evolutionarily somewhat later in development than the reptilian brain. And this part of the brain is responsible for emotional reaction, for social behavior, for fear and greed, love, sexual attraction.

Now, you might ask, well, how do neuroscientists know this? Well, the way that they've discovered this-- and it's only been over the last couple of decades-- is they take a subject, and they put him in an MRI machine. All of you I think know what an MRI is, right? Magnetic resonance imaging.

And instead of taking a snapshot, what neuroscientists will do is to take a series of snapshots over many, many milliseconds and eventually put together a movie of your brain. Now, the reason that's interesting is because blood contains iron, and iron shows up on an MRI. So when they take a movie of your brain, they see the blood flowing in your brain. And while a subject is in there, they will impose certain kinds of stimuli on that subject and see where the blood goes.

So, for example, they ask you to lie in the magnet, and you're lying there, and they are taking a movie of your brain. And while you're lying there peacefully, they'll take a needle, and they'll stab you with it. And you go, "Ow!" And what they'll show is that blood flows to one very specific region in the brain. That region is the pain center of the brain, or at least that's how they identify it. So when you feel pain, and they'll stab you with lots of different parts of the body, and they'll show that it all leads to activation of that little pain center. So they'll say, fine, pain is identified in that particular region.

Now, the third part of the brain, the last part that MacLean identified, is actually what we think of as the brain. It's that gray matter, the curly coils. It turns out that that's not solid, but that's like a blanket that sits on top of the mid-brain. And that part of the brain is actually unique to homo sapiens and certain great apes. So this is called the hominid brain, and, from an evolutionary perspective, it is the newest part of the brain, so it's often called the neocortex, the newest part of that brain.

Using MRI techniques, neuroscientists have been able to deduce that this part of the brain is responsible for language ability, mathematical ability, and logical deliberation. What we think of as the higher thought functions of humans. It resides in that neocortex. Now, why am I telling you all this? Well, because it turns out that these three components of the brain, they end up working in different ways. In fact, they have different priorities. What do I mean by that? Well, let me give you an example.

Suppose, God forbid, you're in a car accident. You're bleeding, and your body starts to shut down. You go into shock. And, one by one, your organs begin to fail. Of the three components of the brain, which do you think will shut down last? Which of these three components will shut down last? Yeah?

AUDIENCE: The reptilian?

ANDREW LO: That's right. Why?

AUDIENCE: It's responsible for your basic functions, so--

ANDREW LO: Exactly. Once your reptilian brain shuts down, you know, that's bye-bye. That's the end. Right? So this explains why you can lose consciousness but still breathe. It's because consciousness is seated in the hominid brain and certain parts of the mammalian brain. But you don't need to be conscious in order to be breathing. Your reptilian brain controls that.

So from a priority perspective, the most important part of your three components is the reptilian brain. Now let me ask you the next question. Before that, of the remaining two, the hominid brain and the mammalian brain, which do you think has priority? Which shuts down later in the case of a car accident where you're bleeding out? Yeah?

AUDIENCE: The mammalian?

ANDREW LO: That's right. Why?

AUDIENCE: Because that's where fight or flight is?

ANDREW LO: Fight or flight is in the mammalian brain, but why would you think that that's higher priority?

AUDIENCE: 'Cause there's certain scenarios and you want to react to those [INAUDIBLE]

ANDREW LO: Right. From an evolutionary perspective, it's probably more important for you to be scared and run like hell when you're being confronted by a saber tooth tiger than for you to be able to solve differential equations. Right? Even if you're from MIT. And so as a result, from a evolutionary standpoint and, more importantly, from a physiological standpoint, the mammalian brain has priority over the hominid brain. Now, neuroscientists have documented that this kind of hardwiring is even more significant than we had thought. Let me explain why.

They did the following experiment. Take a subject. Put him in a magnet. And they asked the subject to solve arithmetic problems while they're in the magnet. Now, you can do that because, if you're lying down, they have a mirror where they project the image of a computer screen, and your hands are free even though your head and your body are not.

And so, while you're lying down in the magnet and you're looking up at this mirror, you see a computer screen. And with your hands-- They give you a mouse, and you can move around and solve arithmetic prompts on the screen while you're in the magnet. And arithmetic is seated at this-- the hominid brain level. So they can see the blood flowing into that part of the brain as you solve these arithmetic problems.

While you're doing that, the experimenter will take a needle and stab you with it. And you go, "Ow!" And then it takes you longer to solve those arithmetic problems. Now you're saying, this is what they give grants for? I mean, anybody can tell you that when somebody's trying to stab you, it's going to take you longer to solve arithmetic problems. OK.

But here's the insight. The insight is that what they discovered was that the flow of blood was constricted to your neocortex after that pain that was implemented, but it lasted for hours. The restriction of blood flow to your neocortex lasted for hours after that pinprick. Not just seconds, not just minutes, but hours afterward, it took you longer to solve arithmetic problems. For all intents and purposes, that pain stimulus made you stupider for a period of time. You physiologically could not solve those problems as quickly as before. And this is a stunning result. Because what it says is that there are periods where, for purely physiological reasons, we are going to be inhibited from using that part of the brain.

I'm going to give you some examples of this in your own behavior, just to prove to you that this is actually going on right now in your heads. How many of you have had the following experience? You're trying to meet a very attractive individual. You want to go out on a date with them. So you think of all sorts of really clever ways of meeting them by accident. And then, when you do that, you're going to ask them out on a date. And you've got your lines prepared. You know exactly what you're going to say to make them just completely thrilled at going out with you.

And finally, it starts to unfold. It happens. You meet the person and, as soon as you open your mouth, and you start talking, you sound like a total idiot. You say all the wrong things, right? You're tongue tied, you start stuttering. And there's a reason for this. There's a physiological reason. You know what it is?

It's the fact that sexual attraction hyperstimulates your mid-brain, here. And when it does, it restricts your blood flow to the neocortex. Language ability is in the neocortex. Love makes you stupid.

Let me give you another example. This is an example that we're going to do together, OK? The example is going to go like this.

I'm going to show you a bunch of words that have different colors. And I don't want you to read anything, but I want you to say out loud with me what the colors are, from left to right. OK? So these are the words. But we're going to say out loud together, as quickly as possible, the colors. You guys ready? OK, here we go.

Red, green, blue, yellow, orange, blue, brown, red, green, purple, pink, black, blue, yellow, green. No problem, right? Very easy. We do the exact same thing now with this.

Say the colors as quickly as possible. You ready? OK, here we go. Blue, red, blue, black, orange--

[LAUGHTER]

What happened? What's going on? Couldn't do it as quickly, could you? Well, let me tell you what's going on. It turns out that language ability and color recognition are actually handled by two different parts of the brain. Language ability resides strictly in the neocortex, the hominid brain. But color recognition is actually part of the mammalian brain. Mammals can recognize

colors very well.

In fact, I don't know how many of you have redecorated your homes, or your kitchens, or dining rooms, recently. I did this a couple of years ago. And my wife talked to one of her friends who is a decorator who told her, you've got to paint your dining room in red. Because-- Why? Anybody know? Why is red the preferred color of restaurants, dining rooms? Yeah?

AUDIENCE: Makes you eat more.

ANDREW LO: Exactly. Makes you eat more. It's a more appetizing color. Anybody ever wonder why that is? Do you know why red is a more appetizing color? I hate to tell you because you may not be appetized anymore.

AUDIENCE: Because of the color?

ANDREW LO: It's the color of blood. Because it's hardwired into us. When we see blood, it's dinnertime.

[LAUGHTER]

And that is hardwired. It's true. I mean, I don't know how many of you have ever gone to The Blue Room. That's a restaurant down the street. I've actually never been there, and I have to confess the reason is that the idea of a blue room for dinner is not very appetizing to me. Blue is not a color you want to see in your food.

So color recognition is a deep-seated part of our mammalian brain. But language ability is not. Language ability is a different part of the brain. In this case, where the colors and the words don't match, it takes your brain a split second longer to adjudicate that conflict. But in this case, when they're the same, you can rattle it off like this.

[SNAPS FINGERS]

So let me bring this now all back to finance, as I told you I would. What's the point of all this? The point is that what we take to be human preferences for decision-making is not a mathematical, immutable object. But, in fact, preferences are the outcome of interactions between the mammalian brain and the hominid brain. And what we think of as basic decision-making requires the proper balance of the two.

So, in other words, rationality is not logical deliberation. The patient, Elliot, was a clear counterexample. Elliot was very logical, but he was not rational. Emotion is a critical

component of rationality. But too much emotion, and you get stupid, as the case with falling in love or in the case of overwhelming emotional stimulus cutting off blood flow to your neocortex. This, by the way, will lead to some very useful self-help kind of advice. Let me give you an example.

Those of you who've ever been involved in corporate politics, back office politics-- one of the things that you should keep in mind is that, when you are emotionally hyper-stimulated, you will not be able to think straight. How many of you've ever heard the phrase, I was so angry, I could barely speak? You've heard that, right? You've probably felt that. Well, that's not just a metaphor. That's actual physiologically true. When you are so angry, it will cut off the flow of blood to your neocortex, and you will not be able to speak. You will not be able to express yourself as articulately.

So the next time somebody goes into your office, or your cubicle, or your company, and says something to you that makes you so mad that you want to strangle them, and you can't speak, the best thing to do is not to speak. It's to say, "Thank you very much. That was very insightful. Let me get back to you in a week or so." Because if you try to talk when you are emotionally hyper-stimulated, you will undoubtedly say stupid things, things you will regret for possibly years later. And this is a direct outcome of this neurophysiological research.

Our preferences are the sum total of these interactions. Therefore, they are not stable over time, nor are they stable over circumstances. All right? You are not the same person that you were 10 years ago. And many of you who are going to be facing losses of one kind or another-- you lose a parent, you lose a spouse or child-- you will not be the same person after that event as before. It will change you because it will change the balance between your hominid brain and your mammalian brain. And unless you bring those back into balance, you're going to be making decisions differently.

So if there's any advice that I have for you about how to take this information and use it, it's to keep your eyes on the objective. In other words, decide what you want to achieve and then ask yourself at every step of the way, "Is my current actions about to help or hinder those objectives?" You know, if you're driving home from work one day, and somebody cuts you off, and you want to give them the finger and ram your car into them, ask yourself, will that help you achieve your objective of getting home without an incident or not? If it doesn't, you probably shouldn't do it, even though it'd feel really good to do that. OK?

Now, let me tell you about the adaptive markets hypothesis and how I'm going to put it all together for you. Behavioral finance and rational finance. They are both correct, and they're both incorrect. The reason that they're both correct is that they both apply to certain circumstances. What I taught you in this course up until now, what we've learned together, is the rational finance that applies most of the time when your mid-brain and your neocortex are properly balanced. But during extreme periods of distress, when you are emotionally either overwhelmed positive or overwhelmed negative, in either of those circumstances, you will not behave in ways that we would consider rational. Those are the moments when behavioral finance applies or, at least, when the anomalies arise.

Behavioral finance is not a theory, it's simply a collection of anomalies. The adaptive markets hypothesis is this theory that I've been developing for the last several years that tries to put these two together. And the way to do that is by recognizing that we are both creatures of our mammalian brain and creatures of our neocortex. Depending on market conditions, environmental conditions, and our own decision-making process, we may or may not be in the rational camp or the behaviorial camp at any point in time. And when you look at the market as a whole, an aggregate over all of these individuals, you will be able to get a sense of whether or not you can trust market prices.

At the beginning of the course, as this crisis was unfolding, I told you very clearly that finance theory is going to be taking a several week vacation. What I was getting at is that, right now, all of us are being hyper-stimulated in our mid-brain. We are all scared to death as to what we're going to read about. There was a time during this course where I was really not looking forward to the weekends because something always seemed to be going on on the weekends. And Monday I'd have to tell you, well, gee, this bank is gone, and that investment bank is no more. And it was a very stressful period. It still is.

Decision-making is going to be affected by that. So we developed heuristics, rules of thumb, to balance out our neocortex and our mammalian brain. We come up with, not theoretical optimum optimization algorithms, but we come up with rules of thumb. And the idea behind the adaptive markets hypothesis is that these rules of thumb evolve over time as they either succeed or they fail. So the economics that we learn and teach you in class is meant to be an approximation to a much more complex reality. Sometimes that approximation works, sometimes it doesn't, and the only way to really understand which it is, is to try to get a sense of how this evolutionary process works. In particular, where do these various different kinds of

rules of thumb come from?

And to do that, I want to tell you about one last thing, and then we're going to conclude, which is that evolutionary forces are really what drives the success or failure of these rules of thumb. And I want to give you an example of these kinds of rules of thumb and how adaptation works. And to do that, I'm going to tell you about a personal example that has to do with a problem that I solve every day. And it's a problem that I think you have as well. I'm going to tell you about how my heuristic developed over the years.

The problem that I'm going to talk about is the problem of getting dressed in the morning. OK? Every morning, all of us have to get dressed. And to give you a sense of the challenges that I face in my process of getting dressed, I have to tell you about my wardrobe.

So here's my wardrobe. I've got five jackets, 10 pairs of pants, 20 ties, 10 shirts, 10 pairs of socks, four pairs of shoes, and five belts. Now, you might argue that's a rather limited wardrobe. However, if you took the time to compute the combinatorics, you would see that I have two million unique outfits in my wardrobe. Now, granted, not all of them are of the same fashion content. They're not all equally compelling from the fashion perspective, so I've got an optimization problem. I've got to figure out which is the right outfit for the right occasion.

Suppose it takes me one second to evaluate the fashion content of an outfit. How long would it take me to get dressed every day? Well, you do the math. Turns out that it would take me 23.1 days to get dressed. Now, clearly, I don't take that long to get dressed, so how do I do it? Do I have some superhuman optimization algorithm up my sleeve? No. It turns out I use a heuristic, a rule of thumb. And you might say, well, where did you get that rule of thumb? I'll tell you.

When I was six years old, growing up in Queens, New York, at that time the superhero of the day was Superman. Everybody watched Superman on TV, comic books, and so on. And some clever marketing genius figured out that if you put a Superman emblem on a jacket, you could sell a lot of them to six-year-old kids. And growing up in a single parent household, we didn't have a lot of extra cash, so it took me weeks to nag my mother to get me this jacket. Weeks and weeks of daily nagging.

And finally, after weeks of nagging, she relented, and she agreed to buy me this jacket. And I remember vividly, you know, Friday afternoon after school, she got home from work. I waited for her, we went to Alexander's, bought the jacket. I spent the whole weekend wearing this

thing, day and night. It was wonderful.

And Monday morning, I got up extra early, really excited to go to school with this jacket. I looked in the mirror, did all my action poses and looked at myself. And by the time I was done with that, I was 15 minutes late for school, and I needed a note from my mother to get into class.

And I remember vividly, walking into the classroom, going up to the front of the room, giving the teacher the note, walking back to my seat, all the other kids already sitting down, reading, snickering at me. And I was completely mortified. And you know I must be mortified because, 42 years later, I still remember this exactly. And you know what? From that day on, it never took me more than five minutes to get dressed. Ever. Never.

So I solved my problem based upon very strong, negative feedback. You see how it works? I have a new heuristic for getting dressed in the morning, but that new heuristic only came about after some very strong, negative emotion. If I was like Elliot, and I never had any negative feedback, I'd go on taking hours to get dressed every morning instead of getting dressed in five minutes, like I do now.

Now, somebody else, let's say a movie star like Tom Cruise. I suspect that Tom Cruise spends a lot more than five minutes getting dressed in the morning. In fact, he probably spends more time coiffing his hair than I spend coiffing my hair. And there's a reason for that. For him, it makes sense. That heuristic for him makes sense in his context, not in my context. All of us, we engage in these heuristics that are adaptive to the particular situation at hand.

So the adaptive markets hypothesis acknowledges that people make mistakes, but they learn, and they adapt, assuming there's balance between emotion and logical deliberation. So there are a number of very practical implications for this, some of which suggest that the CAPM does not work and should not work, except during certain periods of the market.

So what we've learned together in this course describes 80% to 90% of what happens in markets. But there's another 10% or 20% of extreme and unusual market conditions that makes this field a lot more challenging than you might otherwise think. And that's the part that I want you to keep in mind. We're not going to talk about that anymore in this course, or in 402, or in 433, or in 434, or 437. We don't talk about the messy part of finance because it's still currently being developed.

In fact, as I told you at the very beginning, you're not going to find any textbook versions of the adaptive markets hypothesis. The only person you'll ever find talking about it right now is me, unfortunately. Hopefully, that will change over time, but this is still under development. But just keep in mind that the theories that you've learned apply not all of the time. Most of the time, they apply and they're useful, but they are an approximation to a much more complex reality. And that reality will incorporate lots of other phenomenon which we described here and which I'll talk a bit more about on Monday. OK.

So let me stop here since we're just about out of time. Any questions? No? Yes?

AUDIENCE: So I was wondering if you might think, for example, if I have an exam, I tend to notice that I will be way more productive at learning way before two days before. And I cannot see a conflict because I was feeling the pressure in handling my emotions. But how is it possible that I feel the emotion but, at the same time, I--

ANDREW LO: That is a fantastic question. Let me repeat the question. I'm not going to answer today, but I'm going to talk about it on Monday, because it's both a great question in the context of this theory, but it's also very apropos, so I'm going to be talking about the final exam next Monday. OK?

The question is, when you were studying for an exam, you're under pressure. You're feeling a lot of emotional stress, and yet you seem to learn better, faster, during those periods of time. It turns out that there is a physiological and psychological basis when a certain amount of pressure is actually a good thing. But the question is, what is that certain amount? Any more than that, and then you'd be a basket case. So we're going to talk about that on Monday. All right? Thanks.