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DO WE UNDERSTAND THE FALLIBILITY OF MEMORY?

John Gabrieli and Barbara Tversky compared notes at a Wonderfest panel at the University of California, San Francisco, 16, August, 1998

Barbara Tversky

I want you to think for a moment of what it would be like if you suddenly lost your memory and what implications that would have on your self, on your activities, and so on. My students' first response is always, "Oh, then I would really fail the exam". You don't get an exam on this but maybe you would have difficulty finding your way home; maybe you would forget how to walk, how to talk; maybe you would lose your identity. Think of how much of your identity is imbedded in the memories that you have - of who you are, who you know, how they behaved toward you, how you behave, and so forth. What this little mental exercise shows is that memory consists of many different kinds of things: knowing how to walk, how to talk, to knowing facts about the world, to things impinged on. "Impinged on" are varied identities and varied conceptions of ourselves, mainly the accumulated memories that we have of ourselves.

There's a famous psychologist named George Miller who said, "Memory is like a junk box". He meant it in jest but the more he got talking, the more seriously this metaphor seems to be a theory of memory. The idea of it is that you have a junk box in your attic that you throw in old clothes, old books, and all kinds of old things. Then you go and you say, "Ah, I know it's in there somewhere" and you go looking around to see if you can find it. You've got two major problems on whether you're going to find it or not. One problem is getting the stuff in and one problem is getting the stuff out. If you want to get stuff out eventually, it depends on how you put it in. So things that you never put into the junk box in the first place, there's no way that you can get it out, and the things that you thought that you put in, you didn't. Then, how you put it in - whether you put it in haphazard order or you're putting all the shoes in one spot and the shirts in another spot and all your old books and photographs in another spot - that's going to affect whether you can find it. If you throw everything in one drawer and it's all a mess, then it's probably much harder to find it. So how you put it in affects whether you get it out and also how you search. You can search in a way that you're just throwing everything around and that might make it harder to find. If you search only at the top because it's harder to get to the bottom, then that might make it harder to find.

This makes for a lot of similarities of that to our memory, only psychologists think in technical terms; we can't talk about junk boxes, only in jest, so we call the "putting it in" encoding and we call the "taking it out" retrieval. Things may happen at either encoding or retrieval that make our memories vulnerable to either forgetting or to distortion. So I want to talk about each of those things in turn, first encoding and second, retrieval, and I want to emphasize certain processes that affect both correct memory and incorrect memory in each of these.

Our encoding is selective; we don't encode everything that happens to us, only certain things. What's more, our encoding is interpretive. We don't just put in raw sensory

events, we make sense out of them in some way and we link them together. Our retrieval is stimulated by something; we call that something a cue. We don't just randomly retrieve memories; something happens to us in the world that reminds us of something - somebody asks us a question - and we have to go get that memory. Those cues are going to affect what we're going get out, so that retrieval is cue dependent.

Let me talk about encoding, since that seems to happen first. We have to get things into memory before we get them out. One of the first things that happens to us is that we ignore most of what is happening to us. We know this now if I said to you, "What's happening with your right foot?" Maybe you walked a little too much yesterday, maybe you got a little callous on one foot, maybe you don't like me talking about it because I'm suddenly reminding you of something that's slightly uncomfortable that you didn't want to think about. But the point of it is that we're overwhelmed with information that's coming in through our senses and most of it we just plain ignore. So things that are ignored can't be retrieved and, in a way, we need to ignore all of that information. Suppose that we were paying attention to our feet and they're a little restless sitting around in the chair, they really want to move around, and our arms feel like doing something else, and so forth. The only way that we can focus on what we're doing is by ignoring a lot of that other information that's coming in through our senses, and focusing on what we're doing.

The selection is actually a good thing but selection can also affect memory. I have two ways that it does up there and this gets us into the realm of the more practical. There's a phenomena called weapon focus, and it's likely most of us won't ever experience this phenomena directly but we can read about it in experiments. The idea is that if you are in this horrible situation where there is a weapon pointed at you, that draws your attention in some sort of chilling way and makes you ignore everything else but that weapon. In fact, sometimes people in that situation are not good at identifying the perpetrator because their full fixation is on this dangerous thing that's pointed at them. The general point behind this is that strong emotion can narrow our focus of attention to certain things even more than it would normally be. When we're under a highly emotional state, we might find ourselves being more selective than otherwise and not noticing things were we perfectly calm and open minded that we would normally notice. But the emotions are focusing all of our body's resources on whatever it is that's causing this strong emotion and leading us to ignore lots of other things. So one way that we can forget things is by not noticing them in the first place and emotion is particularly powerful in narrowing our focus.

The other way that encoding is important in what we remember and what we don't is its interpretive function. When we think about what's happening to us now, you describe what you're doing now by saying that you're sitting in a chair and you're listening to a talk on memory. You don't say that you're sitting on something that's cushioned, your back is on something else that's vertical, and you have your legs in certain positions, you have your face in certain positions, and so forth. This would be the wrong level of analysis in which to encode events. This is a very sensory level of analysis. Similarly, you don't encode the voice that you're hearing, in terms of qualities of the voice or "Does she have a funny accent or not?" or "Is the voice high-pitched?" Instead, you're encoding whatever it is that I'm saying, making some gist out of it. You're

not even paying attention to the particular words that I'm using; instead you're trying to extract the meaning from it and to remember it in that way. In fact, that's how we go about life and it's a quite sensible way to go about life in trying to extract the meaning. But in extracting the meaning we sometimes misinterpret; we don't always get the right meaning or we rearrange the meaning and can err in that way. Psychologists do very simple experiments to get at that.

This is a simple experiment that psychologists do: they'll give people a list of words - table, apple, violin, shirt, chair, peach, flute, pants, couch, grapes, plum, jacket - and ask other people to remember it. What people notice, and what you probably noticed right away, is that there are certain groups of things here. There's some furniture, some fruits, some musical instruments, and some clothing. If you give people this list of items and ask them to remember them, they don't give the list back to you in that way, as table, apple, violin, etc. Instead, they'll say, "table, chair, couch, apple, peach, grapes"; in other words, they categorize things. They impose an interpretation on this, they see the categories, and then they remember in terms of the categories.

There's a very famous case of somebody who was known as a man who couldn't forget who was written about by a Russian psychologist. This is a fun book called "The Mind of the Nominiss". This man took pictures of the world essentially, and he remembered everything literally. If you gave him a list of categorized items like that, he would remember them verbatim; he couldn't help it. He never even saw the generality for the grouping that were there. So while his memory was perfect in some sense, it imperfect in another sense: he didn't reorganize or interpret what was happening to him. In fact, he found faces really hard to remember because with faces, they keep changing all the time; one minute they're one expression, one minute they have another expression, and he found them really difficult to remember. We're excellent at remembering faces because we form conglomerates of faces. He didn't impose any interpretation, but we do.

Here's another sort of list on that: bishop, cardinal, priest, envelope, folder, file, bat, ball, base, cigarette, pipe, cigar. Here, I put the categories in, and of course, people remember even better. But suppose that I asked you, was there a bird in the list? Tell me the bird that was in the list.

Cardinal

Good. Now, how about the plumber's instrument?

Pipe

Good. But those were hard, and most of you didn't get them. The reason is that I put cardinal in there with members of the clergy, so you thought of it in one particular way and not thought of it in its other meaning. I put pipe in there with things that you smoke, and again, you thought of it, interpreted it in one particular way, and went after the meaning and not after the actual characters that were up there, so it becomes harder to get it.

Let me give you some other examples from the spatial domain. Suppose that I put these two maps of the world up and ask you which is the correct map of the world. I've done this many times and I find that the significant majority of people pick the map at the bottom, which is the incorrect map, so if you picked that one, then I'm glad. What we've

done with the map at the bottom is organize things the way that people organize them. So we've moved the United States to be more in alignment with Europe and we've moved South America to be more aligned with Africa. The way people organize things in the real world is that they organize big land masses together and then they remember them as more together; this is something that's done in encoding, and it's how you remember these things. Another phenomena in encoding is that you remember things with respect to a frame of reference. If I ask people to put South America into a frame, in the way that it actually is, most people put South America more upright than it actually is. Again, the reason is that South America seems to have its own organization, and you want it to be organized with respect to the organization that's imposed on it from the outside, and so you remember it as more organized whether it's more southeast-west, than it actually is.

This sort of thing works for the Bay Area too. If I ask people, and these are Stanford students that I would be asking, "What's the direction from Berkeley to Stanford?" most people will say, "Well, Berkeley's north of Stanford". I say, "Okay, well what about east-west?" and they say, "Well, Berkeley's east of Stanford." But it turns out that Berkeley is not east of Stanford; Santa Cruz is actually east of Stanford too and the reason is that the Bay Area is tilted. It goes at a forty-five degree angle; we code it as going north-south-east-west. Again, we think the Bay Area has its own natural direction; we want it to go in the same direction as the overall north-south-east-west, so we end up encoding it incorrectly and making errors.

That's about all I want to say about encoding. Let me talk about retrieval. Here again, we said that retrieval is usually stimulated by something. There's a reason that we start looking for certain memories and we call those cues. The problem with cues is that any given cue can be associated with lots of different memories. So if I asked you, "What happened on your ninth birthday party?" you might confuse that as a cue. Since it's a birthday party, and you go back thinking about birthday parties, you may easily confuse it with what happened on your tenth birthday party, or your eighth, or some other birthday party.

An even more mundane example is phone numbers. If I asked you for the phone numbers of some of your friends, and the friends have just moved, sometimes the old phone number comes to mind and sometimes the new one does. Parking places - if you go to the same place many times to work, and you're parking in the same lot, you don't always go to the right parking place, because you've parked in many different places in this same area, so that you mix up the parking places. The problem is that cues are associated with many memories, and while you're looking for a particular one - where did I park today, what happened on my ninth birthday party - it's easily confused with things that have a similar cue, or the same cue, but happened at other times. Psychologists call this phenomena interference. They say that all of these different responses that are associated to the same cue interfere with each other and they can lead to forgetting or to the wrong answer.

This can happen in more real life events that might have dramatic consequences. One of these is eye-witness testimony, and this is a slide taken from some experiments that Elizabeth Loftoff, who is instrumental and famous in this field. She showed a series of slides of a car, her car, going through the streets, and then there was an accident. Prior to that particular slide was a slide showing this car parked at a stop sign; it had turned

right, and then there was the accident. What that says is that it stimulates what happens when there is an accident and she asks questions about what happened to the people and some of the questions contain leading information. Some of the questions are deliberately planted information that contradicted what had actually happened. So these people saw a set of slides in which the MG stopped at a stop sign, turned right and then was involved in an accident, and one of the leading questions is, "Did the MG make a right turn at the yield sign?" So, as she's planted this incorrect information, when you think of it, this is exactly the sort of situation of Where did I park today? Where did I park yesterday? I've had this accident, I'm supposed to tell about it and now I have one memory that's associated with the stop sign, one memory that's associated with the yield sign. Sure enough, when she went back to those people at the end of all these questions and time passed, she showed them these two slides and said, "Which one is the correct one?" The significant majority of the people now picked the yield sign, instead of the stop sign, which they actually saw because they got the information from this leading question confused with the information that they had actually seen.

That's a more insidious problem that happens with cues, but another thing that happens is our memories do not quite fit into the encoding and retrieval but fit in with, say, repeated retrievals. Probably a number of you were living here in the 1989 earthquake. All your friends from across the country would call and you would start telling your stories of what happened to you when you were in the earthquake. I don't know if this happened to you but it certainly happened to me; my stories got better. They got more dramatic, sometimes I said things that happened to other people that I had heard, really embellished. You want to tell a good story. Now, this is true whenever we tell about our life's events. We don't want to just list the facts, right? That would bore even the most doting of parents. They don't want to hear the facts; they want a good story. So we're constantly telling these stories, for ourselves, or for our listeners. Sometimes it's not just to amuse them; sometimes it's to draw up sympathy, sometimes it's to amaze them, and so forth. But we restructure things and maybe add some things in order to tell a good story.

So it turns out, when we do that, it actually does distort our memory. We've done some studies in the laboratory and these re-tellings - where you embellish, elaborate, and so on - for an end, actually later, you're not so sure of what really happened; what you said or what really happened. You do make errors in that direction. I think that we're all vulnerable to this; we do it all the time, and this is part of a function of memories - they serve us to amuse friends and to interest them and we use these sorts of schemas, or knowledge structures, to guide our reinterpretations. Now we're not just interpreting what happens, we're reinterpreting. We use these schemas to do that and those can distort our memory. Memory isn't like a file cabinet (this is one sort of metaphor that has been used for memory) where you can just take things out that come from a particular folder in the file cabinet, and then put them back in a particular folder, with everything being as it was. Memory is much more like this junk box that we throw things in; sometimes ordered, sometimes not ordered; when we go to look for it, we're going to look for it for a different reason than we put it in, so how we look for it is going to change. Then when we take things out and then put them back in again, it's going to change, yet again. So memory is more like this fluid thing that keeps changing, interpreted and reinterpreted, unlike something that is written on a piece of paper and is inserted in the same place.

We've talked about ways that our memory can get distorted and there are two key concepts occurring. One is encoding, in which we use these schemas or interpretive devices. Stories that we tell ourselves have both encoding and in re-telling. The other key concept in distortions is interference, when cues have too many responses associated to them, and then we get confused about them at the end. Perhaps I've given you the feeling that memory is very fragile, and I don't want to give you that feeling. I think to summarize what's happening in memory is that we're going after the general. We're unlike this genius who couldn't forget things but who couldn't remember faces. We want to remember faces, we want the generic concepts, we want to remember how to get home from many different places, we want to remember how to do arithmetic and how to ride our bicycle. We want these general sorts of knowledge and the specifics are maybe not that important. But they become extremely important in certain situations. But the way memory functions for us in most cases is these general sorts of things, so that we know who our friends are, who our family is, and so on. So these sorts of schemas that we use to interpret are extremely useful but, on the other hand, they can get us into trouble. With that, I will let my colleague continue.

John Gabrieli

Barbara Tversky gave a very nice overview of what goes into putting experience into memory - encoding, and recovering the past from your mind and brain - retrieval. One of the models that we have of memory is, and here's another metaphor, that it's like a video camera tape. Do we go around, in our own brain, with a video camera that records everything that we experience and feel? Some stuff is not available to us at different times but if we get the right reminder, the right cue or suggestion - we've all had that experience where you think of a high school classmate from years ago and you say, "How did I ever think of that experience?" So that makes us think that maybe all of our memories are there, put into vaults, one by one, and if we get the right key to go into that room, we get that videotape from September 4, 1982.

So that's one thing and that has a lot of implications. For example, the whole debate about recovered memories, where therapy or hypnosis can let you into a locked door to get the videotape of the real memory. Is that the way that memory works? When we go and interview people about their experiences in politics or international affairs, and they tell you the story of how they did this or that - does the right key unlock the video of when they were back doing something really important historically, or interesting socially? We don't think nowadays that we store our life as a series of videotapes and if we have the right key, we can get into that room.

I will ask you the following question: How many times do you imagine in your life, different ages, different people, that you've handled a penny? Thousands of times, right? Thousands of exposures to a penny; and the point is that if you don't care too much about the visual details of a penny, you're not going to remember too much about it. So let me ask, you can probably tell who the president of a penny is. It's Lincoln. How many people would be willing to put their savings on the following question: Is Lincoln facing the right direction or the left direction? Think about it for the moment. How totally

confident are you that there is something written above his head? What is it? Below his head, what is it? Anything written to the left, or to the right? You've seen pennies thousands and thousands of times. Go find the thousands and thousands of videotapes that you could pull up and say, "That's what a penny looks like". Most people have a tremendous difficulty in answering this question. It's rare, when I teach introductory psychology, of a couple hundred students, only two or three students typically answer all of these questions correctly. Then they say, "Well, okay, that's a tricky thing, give me multiple choice". Everyone likes multiple choice. Any choices? Which of these is the real penny that you see thousands and thousands of times? The answer is A. Even I have to look that up each time in my notes before I give this demonstration.

The point is, where's the videotape of the thousands of experiences with a penny? The answer is that if you don't attend to details, you don't remember stuff; what you're thinking of when you look at something or feel something is what determines what you will ultimately remember. So we don't care about details of pennies; there's no videotape out there if you don't care about it. You only make movies when you put a lot of production money into them.

Here's another example. It helps me a little bit if I have two volunteers who can just sit in their seats and get a little memory test. What I need each of you to do is close your eyes for a moment. For the woman in the back, keep your eyes closed for a moment, for the gentleman up here, if you would open your eyes for a second and read this instruction. You're going to see a list of words in a few moments, okay? That's your instruction. Close your eyes. For the woman in the back, if you would open your eyes now, that's your instruction. Everybody's eyes open? Now, do your job. Done? Now, here comes the really bad news. What were the words on the list, as many as you can remember? No video camera to go to, you just saw this. Do you remember any of the words on the list? Now, both of you saw the same list, right? The man in the front, you were asked to look at the meanings of the words, right? Are they abstract or concrete in meaning? You wrote ten things of meaning. The woman in the back, you were asked whether they were upper or lowercase, to look at the most superficial element that you can look at in a word, not their meaning. Therefore, what you are attending to sealed the doom of memory from those words, and you were tending to meaning like it had a fighting chance. So again, it's like with the penny - if you just do superficial stuff, it's not like there is a nice videotape waiting to go back. What you're thinking of when you see something determines what actually gets into your mind and brain for the future and that's it, as far as we can tell.

I'm going to go inside the brain to show you the same kind of phenomena you just saw now. There's a brain inside you doing exactly those things, and we'll talk about these two different stages: encoding, as experience gets into your brain, and later on, retrieving, where you go back and time travel to the past to retrieve experience from before. In talking about brain imaging techniques, which don't show neurons working, they show what happens when blood is rushing, in a sense, to where neurons are busy. We always look at the difference between doing two things, in these brain-imaging techniques. I'm going to talk to you about the task we just saw - thinking about the meaning of words versus merely their appearance. It turns out that in this part, the brain does a lot of the work that helps you to remember the meaning of things, rather than the appearance. We

did an experiment where healthy young subjects were doing exactly the tasks that you just saw here. They're sitting in a scanner, they're seeing words appear one at a time, and their job, sometimes, is to say whether the words are abstract or concrete in meaning; other times, they say whether the words are uppercase or lowercase in appearance. As you just saw, people remember words better when they think about their meaning, than when they merely look at the word's appearance.

Here's the front of the brain, the back of the brain, and here's the brain stem rising. This is a brain cut this way, left and right, and it's a frontal lobe. What you see in this gray area is the anatomy of the brain - the white matter and the gray matter at the cortical mantel. What you see in color is activity in the brain; that's more active when people are thinking about the meaning of what they see, and look at the appearance of what they see. So that difference - Is the word abstract or concrete in meaning? Is it uppercase or lowercase in appearance? - of thinking about meaning drives this part of the brain to search for meaning. That promotes, under most circumstances, memory for the future. So what does that mean? It means that if you were looking at the case, you're never going to quite know as well those words. Later on, you can't go back and say, "Whoops, I meant to really pay attention to the meaning". Too late, because what you've put into your brain is just a superficial list of words - not a good way to remember words and their meanings.

I'm going to show you another place where it seems activity, the time you experience something, sets the destiny of memory for that experience. I'm going to look at the amegdulla, two structures in the limbic part of the brain that are related to the motion that we know, from a lot of research, specifically for manipulating how emotion makes you remember things. We know that those things that matter a lot to us, we tend to remember more easily, than things that are less interesting, emotionally.

Here's a study from Larry Kahill and Jim McGosh, where they show people very short film clips that were either emotional, very disturbing, or pretty boring. They tested their memory many weeks later and what they found is this: for emotional film clips, the people had the best memory and the most activity in the amegulla while they were watching the clips. If they had intermediate activity while they were watching the film, they had intermediate memory. Those with the least activity in the amegdulla while watching the film, memory, weeks and months later, was the worst. It doesn't apply to the neutral films. So it seems like that for memory to burn something into your brain, you really have to have that feeling at the moment when you see it. The amegdulla seems to be an instrument of the brain that says, "This really matters to me, I have a lot of feelings, I'm more likely to remember it." That doesn't mean you might misremember it; sometimes you can remember things too well over time. If you don't get motivated in the amegdulla, it seems that you're not likely to remember it very well later on.

Another brain structure that may be the single most important brain structure for memory is called the hippocampus. We know it is terribly important for memory because of one particular case, but there have been many cases since then. The patient H.M. is the most famous neurological patient, maybe of this century, whom I got to work with as a graduate student. Let me tell you a story for a moment, because then you'll appreciate what the hippocampus does. He was an epileptic who was having seizures very frequently and severely. The medications in the early 1950's were not helping him very much to control his seizures; he was having them almost constantly due to his epilepsy.

One treatment that sometimes works terrifically well in epilepsy is to go in and neurosurgically remove a small part of the brain where the seizures are starting; patients often benefit tremendously from that. They keep taking medications but for those patients where medications don't control their epileptic activity, taking out that part of the brain where seizures start often helps them a lot.

In the early 1950's they didn't understand some things very well, particularly about memory and the brain. They took out a structure called the hippocampus and some things right around it, the amegdulla as well, because that's the part of the brain where seizures most often start in epilepsy; not in everybody, but most everyone. They took out both the left and the right hippocampus, to be sure to help the patient. Well, in terms of seizure controls, it did help the patient a lot. One huge side effect, for all practical purposes, from that day forward to the very present day, he has not formed one single new memory ever again. He doesn't know what year it is; he doesn't know that his parents have passed away; he doesn't know about world wars and presidents; scandals in Washington. You can have a half an hour conversation with him, he's an intelligent man and can tell you good stories from a long time ago. Come back into the room, he has no idea he ever met you, and he will tell you the same story all over again. He doesn't remember any new facts or events since that surgery, so we know that the hippocampus is absolutely required to gain new memories. He remembers the past pretty well, before the surgery, but not one new fact, one new event, since then, for all practical purposes.

We also know that in Alzheimer's disease - here's an older, healthy person, here's the hippocampus - patients with Alzheimer's have a similar kind of problem, and additional problems. Here's the kind of shrinkage; you saw the hippocampus, and this little bit of open space here; now look at it - it's all open space because the hippocampus has shrunk so much. That's standard of what happens in Alzheimer's disease. So we know this part of the brain is terribly important for remembering facts and events.

Here is what we did: we showed subjects pictures like these while they were being brain scanned, one at a time, sometimes there were outdoor pictures, and they would judge whether they were indoor or outdoor. We looked in a particular part of the hippocampus while we were brain imaging, and then afterwards, they came out of the scanner and we gave them a memory test. We showed them the pictures that they had seen and other pictures and every time we showed them a picture, we said, "Did you see this before?" Sometimes they said, "No, I didn't" and sometimes they said, "Yes I did." If they said, "Yes, I did" we asked, "Do you really remember very well seeing it or do you feel kind of like you saw it? So, is it like a really good memory or kind of a weaker memory?" Here are the scores: on average, about half the time the people correctly remembered that they saw a picture and about half of those they were very confident about what they had seen. But then there were about half the pictures they had seen, when a picture came up that they had seen, they said, "No, I didn't see that". Those are the pictures they forgot. So they remembered some pictures very well, some pictures not so well, and some pictures they forgot altogether. That's sort of like life: you remember some things very well, some things intermediately, some things we'll never remember again. Which parts of the brain do we see activity that predicts, as you look at these pictures, what you will remember well, what you will remember intermediately, and what you will forget? Can we see the brain determining already, at the moment of seeing the

picture, what the fate of that experience will be? Does is get to have a good life in the brain and go on into the future or is it discarded, for whatever reasons it is discarded?

Here we're looking at the right and the left of the brain, and in these brain regions where you see the coloration, the more activity you have there, the more likely you were to remember the picture. All of these are in the hippocampus region, and one spot in the frontal brain cortex. Intermediate activity, not so good memory. Low activity, you forgot it. So these parts of the brain seem to be particularly important in determining the pneumonic fate of experience - what's to be remembered well, remembered moderately, and forgotten altogether.

In the spirit of popularizing science, if you sit down at a nice restaurant and see a nice sunset, in the near coming future, you will remember it to the extent that your hippocampus region and your frontal cortex get active. But I want to talk for a moment about these retrievals. Why don't you remember some things? If you're not paying attention to the right thing, if it's not grabbing your emotional interest, if it's not turning on certain parts of the brain, it's just not going to be remembered. It doesn't seem like you need to go back and do anything about it.

What about mistakes of retrieval, where you wrongly remember an experience? It's not just missing; you assert something with confidence, and you're wrong. So here's another exercise I'll do with you for a moment. I'll just read to you a list of words, not too long. Do your best as you sit there to remember these words, because I'll test your memory on them immediately afterwards. Here's the list: sour, candy, sugar, bitter, good, taste, tooth, nice, honey, soda, chocolate, heart, cake, tart, pie. Okay, here comes the memory test. You can just call out if you're willing to. How many people think the word 'sour' was on the list? Excellent, this is a really sharp audience. 'Fury'? How many people think 'fury' was on the list? Sugar? How many people heard that? All correct? Detail? No? Table? No? Sweet? Congratulations for all of you who have your hand up, you've just had a false memory. It's a trick. Here's the list you just heard, I mean, this is obviously gimmick, but here's the list you actually heard. Every single word on that list is associated in meaning, reminds you of another word, which is 'sweet'. This is a phenomena that, just like Barbara Tversky described to you, you're thinking about sweet things, so when this word came back, because the idea, the gist, the general sense of that word came to mind here, you thought you actually saw 'sweet'. When you do experiments, you ask people to judge how confident they are, and they're just as confident that they saw 'sweet' as part of the list. It's not less certain. A false memory created by your interpretation of a list, and now later on, you have a fake video, right? You say, "Yeah, I saw 'sweet', I remember it very well"; but that's not the video you have of memory, it can't have been.

Dan Shackter did exactly this experiment and looked at brain activation while people either got the lists they really saw, that would have words in it like sour, candy, sugar, bitter; or these other words like 'sweet', that you did not see, but most people think they did. Is there any lie detector in the brain that tells you "I really saw this word and I didn't really see this word"? Is there some part of the brain that knows it's different? What he found is activity in this hippocampus part of the brain, as people were remembering the words they saw, and here's the activity for the words they really saw; and here's the activity for the words like 'sweet' that they didn't see but they think they saw. As far as

you can possibly tell with this kind of technique, it looks exactly the same, right? You can't tell that these are real memories, from real experiences. These are false memories constructed from interpretations of experiences. It looks just the same. Here's the point: for memory, it is the same; there's not that word sitting there because you saw the word. 'Sour' is not sitting there with a special status because you actually saw it; you have the *idea* of something about 'sour', okay? You have the *idea* about something like 'sweet'. The brain really represents that information exactly the same, so there is no lie detector that you can look for that says, "This word I really saw, and this word I really didn't" because in the brain, the very same kind of memory is sitting there. That's the kind of memories we really have; not the word itself but the idea of the word, and that's what we remember. If you encode words about ideas and what they mean, then you remember them.

So, these are a few examples of how a combination of the kind of psychological studies that Barbara Tversky showed you some very nice examples of, many of which she has created in her own research, and brain imaging. It's kind of come together to give you roughly the same picture.

But you have nothing to worry about. It's not like you're all going around completely confused all the time, right? In teaching all these things, one thinks, "Oh my gosh, I'm not going to remember anything at all." It's a very tough thing, in terms of research and the human condition, on all kinds of levels, to say, "How can we tell when a memory is accurate or inaccurate?" We know there's lots of ways it can be wrong. We also know, from everyday experience, that there are a lot of memories that are correct. How do we tell for sure which memory is true and which memory is a little bit false? It turns out to be very hard to tell, just as in this picture they look exactly the same.

Discussion

(Inaudible question asked)

***Tversky*:** One thing that we can say is that you're going to find those individual differences where there isn't any trauma. So, there are people who have more vivid imaginations, who remember things pictorially, and there are people that remember music very well or try to put things into music, so that those sorts of individual differences are endlessly fascinating and they exist, irrespective of trauma. What happens in an individual case is probably really beyond what any of us can say, as to what happened to you and your sister specifically. There is a phenomena associated with one-time traumas, called flashbulb memories, that sometimes leads people to have very strong impressions of those particular events. The memories can be about a trauma or any dramatic event, and it turns out that those things are vulnerable, too, to distortion. You have the feeling that it's frozen in your mind, in this photographic way, but it isn't necessarily; it's also vulnerable in the same way that other memories are vulnerable.

Gabrieli: There's a limitation of what we can do. We can only do stuff in the laboratory rooms, which is so unlike real life. So some people will do things when there are famous

events that touch many people - remember the Challenger disaster some years ago? People were huddled around their TV sets for the O.J. Simpson verdict, whereas lots of people sort of know where they are at the moment, or something like that. Those kind of flashbulb memories, as Barbara Tversky said, tend to have errors, too.

We have a very modest laboratory understanding of memory in individual lives and how those things work. We're not really far enough along yet to understand it.

Tversky: Let me add one more thing. There's an exhibit now at the Exploratorium on memory, a very fine exhibit, and John was instrumental in putting it up and a lot professionals got into the act. It's a lovely exhibit that's fascinating. A man who grew up in Italy, he's a local man, came to San Francisco many, many years ago, and, after an illness, became obsessed with a town in which he lived and started painting it. This is a town that he had left 30-40 years earlier, and someone went back and photographed the town. There were interesting similarities and differences in his paintings and in the photograph. So that's part of the exhibit but there's a lot of fascinating stuff there and I recommend it to any of you to go there.

(Inaudible question asked)

Tversky: Another phenomena of memory is that we remember the most recent things. The simple answer is that the cue wasn't there. The cue for stimulating the question was, presuming what I was saying about the picture of the stop sign and the car and so forth, and the cue is no longer there, what you've cued it as is, "There's a question I have". Now that is a specific enough a cue. So if you really want to remember something, the tying the string around the finger won't work, because it's a non-specific cue. You have to pry yourself with a really specific cue that will read back into what you want to remember. That takes a lot of planning, right? It's sort of thinking about, "Well, what situation am I going to be in and how can I get this cue in that situation that will promote the memory that I need to do?" So, it's like shopping at the grocery store and thinking, "Well, when I come by the canned soups, I should remember to buy _____" and try to get a vivid image of that. But the problem is that retrieval cue was inadequate.

We always did these time demonstrations but it's amazing how quickly you forget things.

Gabrieli: Just seconds. If your mind keeps going just seconds after you heard something, everything's at risk for all of you.

Does the authority for you have a different impact on a verbal versus a pictorial cue?

Tversky: Is there some primacy to the verbal information over the pictorial? That's a really good question and I think that it's one of those things that's very hard to answer, because how do we compare the verbal and the pictorial anyway? Maybe you have a strong verbal message and a weak pictorial. Those pictures were a little blurry, right?

There was shading over the pictures, so you couldn't really see the shape of the sign, and so forth. It's apples and oranges and a really hard question to answer. It works both ways.

There are studies showing you can get your interference either way. In general, our memory for pictures is better than words. So, if I show you a whole set of pictures like chair, table, and so forth, or I show you the names, and then I ask you to free recall, you're going to do a little better with the pictures. One reason might be because pictures have always just more rich detail. Retrieval cues back to them because you can get all kinds of rich detail out of them. And the authority figure - I don't know if anyone has directly looked at that. There's some old work that's been done on influence where people read a description, a plea for prison reform, and it's either written by a prisoner or by a judge, and initially, that makes a difference into how they evaluate the arguments for prison reform. Later, they forget the authority, and they just remember the argument. So that's an indirect.

Gabrieli: Normally I would repeat the question but I think the subject matter lends itself to a rather complex question, so I'll leave it to you (Tversky) to reiterate the question in your answer. And if you would like me to repeat it I would be glad to.

(Inaudible question asked)

Gabrieli: Nobody really knows because it varies but we do know that the hippocampus, the parts of the brain that are so critical for memory, are bony structures near the base of the skull. When they have a trauma, like in a car accident, they will often be, in some ways, shaken up against the skull, become temporarily dysfunctional, and then recover slowly over time. It's not well understood, but just like you're describing, it seems to happen all the time, in sports as well. It seems like, for some period of time, the hippocampus in particular is just not working. So it's not saving the memories that it's just in the process of depositing into your long-term knowledge. Sometimes now we see patients who have larger lesions in the area who seem to lose ten years of memories, for example, as far as you can measure it. It seems like there might really be a kind of a relay of several structures there that work over different time periods. So it's very hard, given the variance of how people get their entries, to sort that out.

There's lots of evidence of protein synthesis occurring at different time scales, at different parts of the brain, sort of forming these long-term memories. There's this much more complicated stuff of the storage of the memory, called consolidation of the memory. There's a lot of things going on with no grasp of humans, I think.

(Inaudible question asked)

Gabrieli: On average, as people get older, their ability to remember new events seems to decrease under most circumstances. There are different ways to interpret this. One is that our brain is getting a little tired over forty or fifty years and then changes go on in the brain. There are other interesting interpretations; for example, we know more, as the years go along, right? We've seen more faces and more names. And like the parking lot,

where you park here and here and here on different days and now you go back, that can be an issue too. It could be that the more you know, the more everything you see reminds you of ten different things; it's sort of the cost of knowing too much. So, it's not just the brain deteriorating over time; it could be just the consequence of wisdom, so to speak. There's a little bit of an inability to be precise in detail and it's hard to tell which of these things are most important. But for most people, as they get into their sixties and seventies, if you just do standard tests of word lists or everyday events, the memory is slightly decreasing over the years.

(Inaudible question asked)

Tversky: Hypnosis by testimony is generally not allowed in courts and some of the reasons are due to the sorts of things that you've been saying. What hypnosis seems to do is lower the threshold. So you're more willing to say things, and some of those things are correct and some of those things are incorrect. There's been a review article written, summarizing a number of studies that have been done in laboratories with hypnosis as an attempt to get more memories out, and that's exactly what happens. You get more memories out, some of them are fallacious, and for that reason, hypnosis is not recognized in most courts as a way of getting memory out.

Gabrieli: It's a good way to get some information that might help you with your case, right? So if you saw the license plate speeding away, and you can't remember the letters and digits, and under hypnosis you come up with some, that could really help somebody solve the case. At the same time, there is a good risk that you'll come up with the license plate of your neighbor. But for the criminal investigator, that license plate could help hugely. So it seems like they have it exactly right. Use it to help yourself move along when a case is stuck, but be very careful about how much you believe that all by itself because it could be corrupt.

(Inaudible question asked)

Tversky: He just had this phenomenal memory for detail; it was almost like snapshots.

Gabrieli: Where you stand is an interesting relationship. Propohypnosia, let me say a word about this, patients with large lesions in their right peritol cortex will become like Oliver Sach's title of his book, "The Man Who Mistook His Wife For a Hat". They will be unable to recognize faces, to discriminate, for example, their own spouse's face from anybody else, and things like that. So that's different than this man, who would recognize faces. But I think your point is very good, which is that it's sort of like the two sides of memory, not specifically faces. Bad face perception is devastating, but too much good face perception is also too much. Why do you forget so much? Too many details or not enough details, both of them are bad and can end up with face problems, like you're saying.

Tversky: But there's no evidence that he had brain damage.

Do drugs impede memory?

Gabrieli: Drugs definitely impede memory. There are drugs that sometimes enhance memory a little bit, but it's not impressive. Everybody's working on that - they would like to discover those drugs for aging, for people with particular memory difficulties, or for Alzheimer's disease. There's no drug that is really powerful for improving memory.

How do people usually test short-term memory? There are lots of different senses of short-term memory but in the clinic, the typical ways, what people call "digits down", just test it, like the telephone number. When you have it on a piece of paper, they'll say, "Here are some numbers: 5, 7, 2, 1, 8, 4. What did I just say?" That's short-term memory, of a kind. It turns out, that kind of short-term memory is not at all on the road to long-term memory. So, patients with damage in certain parts of the brain will not be able to tell you the list just back right away, but in a few minutes they'll tell you them just about as well as anyone else. This is an amazing thing because there's a short-term memory path, people use the word "working memory"; we keep stuff in mind right now. And that's usually what we mean, and that's when we turn our head and it all disappears right away. That's a different active workplace than some other place that's just lurking on the long-term memory. So patients like H.M. are perfectly fine for those seven digits, but can't remember anything from the last seven years. Other patients with cortical lesions here can't tell you those digits back but they can tell you everything about their life for the last seven years pretty well.

So, there's a path - this model of short-term memory and then some people breaking through that into long-term memory. It doesn't seem to work like that; the short-term memory is a special little thing for just recent stuff and then there's another path picking what goes into long-term memory.

(Inaudible question asked)

Gabrieli: These kind of imaging techniques are new; we're kind of inching our way along. This study wasn't evident to us but there are other studies where the harder you make somebody work, the more their brain gets active. Along the lines of your question, there are some studies that show, for example, that if somebody's good at something, or not good at something, sometimes when we're not good at something, you can see the brain firing away. Imagine a tennis pro who has a good serve; they're pretty efficient in their serve, right? You take somebody who is not so good, like me; my brain is really active when I throw the ball up, hope it doesn't hit my head. So more brain activity sometimes means you're working harder, but it doesn't always mean that you're working smarter. It's a complicated story that goes case by case.

(Inaudible question asked)

Gabrieli: In humans, in animal work, and in wet labs, with things like ocleasia, people understand amazing details about their biochemical things. This goes on from getting a shock or something and one of the steps to which that becomes the long-term memory and we don't want to get shocked again. When it comes to humans, we almost always have a blank slate, so we know something like this whole big part of the brain is really important. But what's going on inside of that part of the brain, we really almost have no idea.

I've had the experience myself where certain types of physical manipulations, massage, for example, can, in a sense, release memories. Is there anything known about the connection between a physical cue, not related to the original memory, stimulating that memory?

Tversky: I don't know about physical cues. There's a famous story of Proust, where he smelled this cake that his grandmother used to prepare for him and that triggered a whole slew of memories of childhood. So, again, it's this idea of a cue, and for some reason that cue might be very distinctive and not associated with many other things and just associated with some particular memory so that it gets out this very specific memory.

I wanted to say something to the gentleman that was looking for a quick fix on how to improve his memory. Is there some drug he can take, or drinking a lot of coffee, that will do it? There's no shortcut. Some of the tools we have given you today - encoding and retrieval, encoding in anticipation of retrieval - you can use to make things more distinctive so the cues work better, at least mentally stimulating. If you can't take drugs, then maybe you can use some mental drugs that will work.

I heard about someone who was blind and could recognize shapes, for example, a triangle or a circle. Then they were able to see their sight, but then they saw a triangle and they didn't recognize it. I was wondering how you account for this difference.

Tversky: There's an enormous amount of visual learning that's going on very early in life and some of it has to do with perceiving edges and contours, and organizing shapes. It's a bit difference that we were talking about earlier between interpretations. We said that when you're listening to us, you're not encoding the qualities of our voices so much but you're encoding the meanings of what we're saying. That gets to be very habitual when you're an infant and that learning is essential to recognizing shapes later. In fact, there was a period of time when people who had been blind since birth had their sight restored and no one knew that, so they couldn't prepare people. For many people it led to depression, because they had such anticipations and the visual world was so confusing. Now I think if that sort of thing were to happen now, people would be better prepared because we know a great deal about early visual learning. It's a fascinating area.

(Inaudible question asked)

Gabrieli: Part of it is the cue. When I gave you the list of words that were all related to 'sweet', nobody thought that 'table' had been on the list, because you're in a certain mindset of words related to sugar and candy. So that's why I think you seldom see those kinds of mistakes that from another play you bring it in.

(Inaudible question asked)

Tversky: I think that you might remember a former phone number for that same person, so that you've got the cue again; it's that person, and you might confuse one phone number for that person or another phone number for that person. My father and my uncle's phone numbers are real similar and I used to get them confused.

Gabrieli: I don't know if you've had this experience, where if you try to dial a phone number upside-down, it gets kind of hard. Or, with a number you know you should know, if you start off wrong, your confidence is shaken. It's almost a mental reflex with some phone numbers, even to the extent of physically pushing, and so the cost of that is that we can't go and get that information and think about it very hard, if we don't get it in that first, automatic pass. It's not in a place where you're going to go puzzle it through very well.

Tversky: You can invent a mathematical series or something that will explain it, but some phone numbers, for me at least, are in the fingers. I don't remember the numbers. It's like typing: if you're a skilled typist, read off the letters left to right. Can you do it? I can't. If I want to do it, I have to mentally think, "Well, what letter am I typing with that finger?" It transfers in some way to the motor acts and it's bypassing completely this sort of conscious retrieval that it once had.

(Inaudible question asked)

Tversky: Here again, it depends a little bit on what you mean by "remember". Now, obviously infants who have learned about visual shapes are remembering those visual shapes. So what I think that you mean by *remember* is *recollect* experiences and a lot has to do with language. There have been studies asking people to recollect; we don't get much out before age four, before three, certainly before two. I'd be very suspicious of things that came before that; it's conceivable but hard to check. Maybe now, for this generation's children, their parents are videotaping everything. Some opportunistic psychologists will take advantage of that and use those things in memory studies. Again, some people are doing that now by creating experiences for children, two year-olds, and then going back at three and four and testing them; some things come out and some things don't come out. There's a real important role for a parent interpreting things for a child; those sorts of things are remembered better than these sorts of things that aren't interpreted by a parent. On the other hand, a parent interpreting is doing something to the memory.

My question is about evolution. I'm wondering about these various fallibilities of memories. It seems to me that they arrive in a couple of ways based on the limitations of

the physiological implementation of memory or perhaps they're artifacts of some evolutionary advantage in terms of the ability it requires that you don't remember every single thing that you see. Is there much speculation or research on why there are these fallible aspects of memory?

Tversky: There's speculation; research is hard. The time span is a little larger than what we're used to.

Gabrieli: Part of what you're saying is something about what Barbara Tversky talked about earlier, which is that we gain something by encoding meaning quickly and interpreting; we gain a lot. But we lose because we stick in the interpretation to the memory itself. The price you pay for understanding is confusing your understanding the actual event. It's a tradeoff that seems to be a gain. But that's remembering facts and events of our lives; there are other kinds of things, like our motor systems, that might be more slavish to actual experience, right? You can imagine that those evolve with different rules; if you're learning how to walk or something like that, you're not going to throw in interpretations, your guesses about the meaning of how to walk around, because you would stumble and fall. You're better off learning in a very sensory, motor way, directly what's in front of you. So there's a thought that different parts of our brain have different principles; some will risk inaccuracy to gain wisdom, so to speak; others will be slavishly detailed about every little sensation they feel on their foot to promote accurate warning. It might be that different systems evolve differently because what's good for them or bad for them is different.

(Inaudible question asked)

Gabrieli: A lot of people talk about photographic memory, and it's really rare to see it so brilliantly like in this man who, if you gave him a list of digits, he would look at them once and remember them for the rest of his life. So what happened to him is that he became a performer in shows in Russia, where he would go to an audience like this and say, "Fill out numbers". And what happened was that his personal life was miserable because while he was having conversations with his family, every word or phrase would remind him of an event from the past and they would complain that they could never get his attention for a conversation. Every time a word came on that would remind him of breakfast three years ago, the next word would, say, remind him of something five years ago. They complained that they couldn't really relate to him at all. He tried to get rid of his memories by writing them down on a piece of paper and throwing them into the fire; that didn't work, of course. So he ended up living alone as a hermit. This was a one-person, one-story and I'm not sure that would be a rule for everybody with this kind of memory but the downside seems to be you're slavishly tied to details and specific unimportant memories that flood your awareness and you're not listening to what a person means.

Why is it that we seem to forget dreams so quickly?

Tversky: That's a hard one because we don't really know what dreams are. There's some new work saying that dreams are sort of an interpretation that you're putting on to very sensory flashes all over your brain. It is kind of a lame interpretation because they aren't very coherent. Almost everything that happens in your sleep is not remembered well; you aren't attending, you're sleeping. You aren't actively doing things with it, so it's not a good candidate for memory anyway.

Gabrieli: I don't have a good answer for that, but you're right, it's impressive how they can go out of feeling. I've had that experience where you get up and say, "This dream I will remember" and a second later, it's gone.

(Inaudible question asked)

Tversky: I don't think there's any evidence that we exhaust the capacity that's in our mind. There was a former president of Stanford who was an enixiologist, so he had to know a lot of names of fish and he said, "I'm going to stop learning names of students because every time I learn the name of a student, I forget the name of a fish". I think that's probably an excuse; on the other hand, it takes effort to learn things like phone numbers because they are meaningless. You think, "What's the cost mentally of learning them as opposed to having them on my computer or in the date book where I can look them up very quickly?" I think external devices are not something that psychologists have studied much; we're beginning to study the role that they play in our own memories and they do play a role. They play a role in the way we think; you can't count change without moving the change from one side to another, right? We're constantly arranging our environment in ways that promote memory; external devices are one of those things, it doesn't have to always go on in you head. So you want to weigh the costs and benefits in that sense. Does that help?

Someone mentioned acting earlier. People learning lines and actors have to learn huge amounts of material. They get better at it and they develop techniques that help them learn it and that's an exercise sort of thing varied. They can't use external devices and they manage to develop really good techniques for learning them.

Gabrieli: One spot where I think exercise in a focused way definitely wins is expertise in different areas. You may have had this experience where people are expert in an area, law, medicine, science, technology or something, and they instantly grasp complicated things because they have all that expertise ready to go. So that's one area where the more you know definitely lets you know more stuff quickly.

Tversky: Partly because what you're doing in that case is building these abstract knowledge structures that allow you to plug things in really quickly. One of the nicest examples of expertise are chess experts. You can show them a game in progress and, in just a few seconds, they'll put all the pieces back. I wouldn't be able to do that. But they have interpreted what's been going on in the game because if you give them a random assortment of pieces, they're no better than I am. So again, that's one benefit of exercise.